QSA GLOBAL

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26 March 2018

71-9314

Branch Chief
Spent Fuel Licensing Branch
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Spent Fuel Management
Mailstop 3WFN-14A44
11555 Rockville Pike
One White Flint
Rockville, MD 20852

RE: USA/9314/B(U)-96 (Current Revision 8)

Dear Sir or Madam:

QSA Global, Inc. requests renewal of the certificate referenced above for the Model 976 Series Type B(U) containers. The current certificate expires on 31 July 2019. This renewal also incorporates updates to the package testing to allow use of an alternative drum lid closure band in addition to the band currently approved under drawing RCLM009 Rev C. An alternative is needed since the currently approved, specialized closure band is no longer available from our supplier and an alternative is needed to support continued shipments of this package.

This renewal submission also reformats the Safety Analysis Report (SAR) to match the formatting recommended in NUREG-1886 and makes other changes associated with associated drawing revisions and to incorporate testing performed under Test Plan 214 Report which was performed to justify use of the alternative drum lid closure band described on drawing RCLM011 Rev A. These changes are documented in the SAR as having no significant impact on the package performance or continued compliance for Type B transport. Also enclosed with this submission are change tables that identify the specific changes in the SAR and descriptive drawings, along with a list of affected pages updating the SAR revision.

Should you have any additional questions or wish to discuss this submission after receipt please feel free to contact me.

Sincerely,

e-Signed by Lori Podolak
on 2018-03-23 18:09:01 GMT

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e-Signed by Michael Fuller
on 2018-03-21 18:10:22 GMT

RA/QA Approval & Date

e-Signed by Steve Grenier
on 2018-03-21 15:21:19 GMT

Engineering Approval & Date

NMSS01

Enclosures:

- List of Affected Pages
- Model 976 Series SAR Changes from Revision 8 to Revision 9
- Drawing Change Table for Drawings R97600 Rev C, R97608 Rev K and RCLM011 Rev A
- Model 976 Series SAR Revision 9

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

Safety Analysis Report for the Model 976 Transport Package

List of Affected Pages	
Revision 0, 09 March 2004	Initial Submission of Safety Analysis Report
Revision 1 21 January 2005	Revision in Entirety in Response to RAI dated 04 August 2004 and to include the Model 976F.
Revision 2, 15 April 2005	Revision to Sections 2 and 3 addressing comments on thermal assessment raised during USNRC and AEA Technology QSA, Inc. meeting on 30 March 2005.
Revision 3, 04 May 2005	Revision to Section 1.4 drawings, Section 3.4.1.1 and Section 5.3.1.
Revision 4, 06 December 2005	Revision to Section 1.4 drawings and container weights for Models 976B through 976D in remainder of SAR. Affected pages are ii, 1-1, 1-3, 1-4, 2-1, 2-26, 2-28 and 3-19. Affected drawings from Section 1.4 are R976B, R976C, R976D, R976E, R3015, R3056, R3018 and R3078. The only change to these drawings involved increasing the maximum container weights.
Revision 5, 5 October 2006	Revision to modify shield placement in 976C container, to modify the dimensions for the 3018 shield pot and to add authorization for Se-75 and Yb-169 to all shield configurations. Affected pages are i-iv, 1-1, 1-2, 1-4, 1-9, 2-7, 3-1, 3-2, 3-3, 3-6, 3-7, 3-10, 3-11, 3-12, 3-18, 3-19, 3-20, 5-4, 5-6, 5-7, 5-8, 5-9, 7-1, 7-2 and 7-4 through 7-15. Affected drawings from Section 1.4 are R976C, R97615, R97615-1, R97615-2, R1911, R3018, R97623 and R97623A.
Revision 6, 21 February 2007	Revision in Response to RAI dated 7 Feb 07. Affected pages are 1-2, 1-5, 1-6, 1-10, 2-7, 2-19, 3-3, 3-7, 3-8, 3-9, 3-10, 3-11, 5-6, and 7-2.
Revision 7, 23 May 2007	Revision in Response to RAI received 22 May 07. Affected pages are i-v, 1-1, 1-2, 1-10, 2-1, 2-2, 2-4, 3-5, 4-1, 4-2, 5-1 thru 5-7, 5-11, 5-14, 7-1, 7-2, 7-4, 7-5, 7-7, 7-13, 7-14, 8-1 and 8-3.
Revision 8, 20 April 2009	Revision in Entirety to remove Models 976B, 976D and 976E and to respond to NRC RAI letter dated 8 September 2008. See SAR index pages i-v for list of affected pages.
Revision 9, March 2018	Revision to update package testing to allow for alternative clamp band and lid closure construction. SAR updated formatting to NUREG-1886 and to make other minor administrative/corrective changes.

Revision 9 to the 976 SAR includes modifications related to the updated package testing and other administrative/corrective changes as applicable. These changes are listed under the SAR Section in Revision 9 where the change occurs. These changes are made either for clarification/accuracy or detail changes pending NRC approval prior to implementation. As such they will have no impact on packages in transport until approved under an amendment Certificate of Compliance.

Section Reference	Description
Generic Format Changes	• Removed regulation/standard references in section headers. This information added unnecessary complexity to the SAR without added benefit. • Updated reference to IAEA from the 1996 edition to reflect the 2009 edition adopted under the current USA regulations. • Added reference to the Canadian Nuclear Safety Commission PTNS regulations SOR/2015-145. • SAR revision is formatted in accordance with NUREG-1886 (March 2009). • In some sections, simplified the section numbering/identification for clarity. • Updated section references where applicable due to reformatting to NUREG-1886
1.2.1	Updated the reference time frame of use for the prior inner shield containers used in the Model 976A and 976C packages. Also removed "Intended" from the identifier on the last column in the table in this section as this was a carry over from the original SAR submission and no longer applicable since the model designations are specified under the current certificate.
1.2.1.1.b	Added mm conversion for the 7 inch dimension in this section for formatting consistency.
1.2.1.1.c.ii	Corrected mm conversion for the 3.3 in dimension from 85 mm to correct conversion of 84 mm.
1.2.1.3	Section updated to reflect addition of secondary clamp band construction and the alternative lid construction using the floating nuts instead of the welded threaded blocks.
1.2.1.4	Section re-numbered (previously 1.2.2)
1.2.2	Added detail on where information related to the special form sources can be located in the SAR.
Table 1.2b	Moved Table identifier to before instead of after the table entry.
Table 1.2d	Revised Maximum content weight (grams) for 976F from 3.3 to 220. Content weight for the 976F can be similar to the 976C based on sources transported. The overall package weight for the 976F remains unchanged. This change is made for consistency and has no adverse impact on the package integrity.
1.2.3	Section reformatted per the NUREG-1886 guidance and subsequent sections re-numbered.
1.2.4	Added reference to Section 7 regarding location of assembly and securing of the packages.
2	Added reference to IAEA TS-R-1.
2.1.2	Added reference to CNSC PTNS SOR/2015-145.
2.1.3	Corrected kilogram weight reference conversion for the 300 lb weight in this section. Transport as specified on drawings in Section 1.3 is quantified on the pound weight values, so no adverse impact on package configurations results from with this weight conversion correction.
2.1.3, 2.1.4.1, 2.1.4.2, 2.2.1, 2.3.1	Updated section cross reference due to reformatting.
2.4	Moved old sections 1.3 (1.3.1, 1.3.2) to Section 2.4 (2.4.1, 2.4.2) and renumbered subsequent Section 2 sections. Added section 2.4.3 for Positive Closure. Change made to meet formatting in NUREG-1886.
SAR Rev 8 Section 2.5, 3.3.3, 4.1.2, 4.2	Removed these sections as they are not included in NUREG-1886 format.
2.6.3, 2.6.4	Added information relative to the source capsule containment ability to meet the requirements of reduced and increased external pressure during normal transport.
2.6.7	Revised section reference for description of drop test pad since testing now covers multiple test pads based on repeat testing over time. In all cases, the drop test pad complied with the requirements in 10 CFR 71.71 and 71.73.

Section Reference	Description
2.6.9	Corrected kilogram weight reference conversion for the 1,465 lb and 1,500 lb weights in this section. Transport based on pound weight values so no adverse impact on package configurations with this weight conversion correction.
2.7.6	Revised to document compliance of source capsules based on ISO 2912 performance testing.
2.6.7, 2.6.9, 2.6.10, 2.7, 2.7.1, 2.7.3, 2.7.4 & Table 2.7.8.1	Updated to reflect test results from Test Plan Report No. 214.
2.10	Section updated to reflect reference to typical special form certificates and remove previous references to capsule requirements that are no longer applicable with this SAR revision based on changes to sections 2.6.3, 2.6.4 and 2.7.6 (e.g., ISO 2912 Pressure test requirement for capsules transported in these packages).
2.12.4 through 2.12.9	Added appendices for special form certificates of typical sources transported in the Model 976 Series Packages.
2.12.10, 2.12.11, 4.3	Added references to Test Plan and Test Plan Report No. 214 covering additional package testing as applicable.
3.3.1, 3.3.2	Sections made more generic to reflect the multiple, applicable test plans.
3.4.2, 3.4.2, 3.5.2, 3.5.4, 3.5.5, 3.5.6, 3.6, Section 4	Sections ordered and titled to conform with NUREG-1886.
4.1	Added reference to additional SAR details to describe containment system.
5.1.2	Revised tables to reflect formatting from NUREG-1886. Added note for table entries to address exclusive use transport expected dose rates from tested packages in this sections tables.
7.1.1.2.d, 7.1.2.1.f	Revised sections to address lid closure band alternatives covered by drawings RCLM009 and RCLM011.
7.4.2	Updated the DOT Emergency Response Handbook from the 2004 revision to the 2016 revision.
Section 9	Updated to address Quality Assurance instead of an evaluation of IAEA TS-R-1 (1996 Edition) compliance requirements. Change made for consistency across QSA Global, Inc. package SAR formats and since the prior section is no longer applicable under this document.

Summary Tables of Changes to 976 Series Drawings Submitted with SAR Revision 9 (March 2018)

The descriptive drawings provided for the Model 976 Series packages have been revised to incorporate changes to the drum clamp band requirements and to make use of the drum clamp band optional based on additional testing documented in the SAR Revision 9. Only those drawings changed are identified in this table. Specific changes are described in the following table.

Change Location	Summary Change	Change Reported Pursuant to 71.95	Impact of Change on Units Previously or Currently in Use under the Certificate	Action Taken By QSA Regarding Affected Units
R97600 Rev C	Sheet 1, material listing revised to include RCLM011 as an alternative to the currently approved RCLM009 clamp band component.	No	No impact on units in use. Change will not be implemented until approved by revision of the Certificate of Conformance.	None. Not Applicable.
R97600 Rev C	Sheet 1, part number description for the 1911 Shield Assembly was corrected as the previous spelling referenced "1191" instead of "1911" under the part number description.	No.	No impact. Change for accuracy and to correct reference error.	None. Not applicable.
RCLM011 Rev A	Drawing added to allow alternative construction for drum lid closure band.	No	No impact on units in use. Change will not be implemented until approved by revision of the Certificate of Conformance.	None. Not Applicable.
R97608 Rev K	Drawing revised to incorporate alternate construction of the lid to replace the current welded, threaded blocks with a welded stainless steel tube housing threaded floating nut. The alternate construction achieves the same lid security as the currently approved welded, threaded block configuration based on testing performed under Test Plan 214.	No	No impact on units in use. Change will not be implemented until approved by revision of the Certificate of Conformance.	None. Not Applicable.
R97608 Rev K	Notes 4 and 5 updated to include weld and material requirements for the square tube and floating nut components in the alternate construction.	No	No impact on units in use. Change will not be implemented until approved by revision of the Certificate of Conformance.	None. Not Applicable.

Safety Analysis Report

QSA Global Inc.

Model 976 Series
Type B(U) - 96
Transport Package

March 2018

Revision 9

Contents

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Section 1 - GENERAL INFORMATION

1.1 Introduction

The Model 976 Series are designed as transport packages and storage containers for Type B quantities of special form radioactive material. They conform to the Type B(U)-96 criteria for packaging in accordance 10 CFR 71, 49 CFR 173, and the IAEA Regulations for the Safe Transport of Radioactive Material No. TS-R-1 (2009 Edition) and Canadian Nuclear Safety Commission (CNSC) PTNS Regulations SOR/2015-145. This submission is formatted in accordance with NUREG-1886 "Joint Canada – United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages" dated March 2009.

1.2 Package Description

The Model 976 Series packages are differentiated based on inner shield design, spacer configurations and activity capacities. The general design of the package is a steel jacketed lead and/or depleted uranium (DU) shield container housed within a cork lined, stainless steel drum. The containers are constructed in accordance with descriptive drawings in Section 1.3. Overall external dimensions for all 976 Series packages are 19 ¾" (502 mm) diameter and 21 ¼" (540 mm) tall. The package weights and isotope maximum capacities for the 976 Series are shown in Table 1 below:

Table 1.2a: Model 976 Series Package Information

Identification	Inner Shield(s)	Nuclide	Form	Maximum Capacity[1,2]	Maximum Weight
976A	855	Ir-192	Special Form Sources	1,000 Ci	136 kg (300 lb)
		Se-75		1,000 Ci	
		Yb-169		865 Ci	
976C	3056	Ir-192	Special Form Sources	1,250 Ci	86 kg (190 lb)
		Se-75		1,250 Ci	
		Yb-169		1,000 Ci	
976F	1911	Ir-192	Special Form Sources	1,000 Ci	119 kg (263 lb)
		Se-75		1,000 Ci	
		Yb-169		1,000 Ci	

[1]For Iridium-192, the maximum capacity is based on the output curies which are determined by measuring the source output at 1 meter and expressing its activity in curies derived from the following: 0.48 R/hr-Ci Iridium-192 at 1 meter. (Ref: American National Standard N432-1980, "Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography."). For Selenium-75 and Yb-169 the maximum capacity is based on the content curies contained in the radioactive source(s).

[2] For shipments of multiple radioisotopes in a single package, the sum of the ratios of the curie quantity of each loaded isotope to the maximum allowed curie quantity of that isotope (were that isotope the only contents of the package) must be less than or equal to unity.

1.2.1 Packaging

At the time of original package approval for the 976 Series, the shield container Model 3056 had been used in the field for over twenty (20) years without incident or problem as part of USDOT Type B endorsements of Great Britain Type B(U) approved packages. The Model 855 had been used in the field for over twenty (20) years without incident or problem as part of a USNRC and USDOT Type B approval. These containers and their associated Type B endorsement certifications are listed in Table 1.2b.

Table 1.2b – CROSS REFERENCE TABLE OF INNER SHIELD CONTAINER TRANSPORT APPROVAL HISTORY

Inner Shield Container	USNRC Type B(U) Certificate	USDOT Type B(U) Endorsed Certificate	Great Britain Type B(U) Certificate	Model 976 Package Designation
855	USA/9165/B(U)	USA/9165/B(U)	None	976A
3056	None	USA/0316/B(U)	GB/0924BZ/B(U)	976C

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

1.2.1.1 Inner Shield: The Special Form source(s) are contained in an inner shield container. The shield containers shielding is comprised of lead, tungsten, DU or combinations of these materials. The individual shield constructions are described in Sections 1.2.1.1.a through 1.2.1.1.c.

a. Model 855 Shield: The 855 shield container is comprised of a DU shield secured within a steel welded housing. The shield allows for the loading of up to eight individual sources within titanium J-tubes in the shield. The sources are attached to the end of a source wire assembly and prevented from movement during transport by means of lock assemblies which secure the radioactive sources at the bottom of the eight J-tubes. The 855 shield container housing is effectively a cylinder, 10 ¾ inches (273 mm) in diameter on top of a 11 ¼ inches (286 mm) diameter base. The Model 855 is approximately 11 ¾ inches (298 mm) tall (without the eyebolt height). Copper separators are installed around all exposed surfaces of the DU to prevent any steel-uranium interaction inside the shield container. The shield is further retained in place by the use of polyurethane foam which fills the voids between the shield and the inner surfaces of the 855 steel housing. For shipment, a steel cover is bolted to the top of the shield container. The cover design creates an interference with the J-tube lock mechanisms which further prevents source release during shipment. The 855 shield weighs a maximum of 225 lbs (102 kgs) and contains a maximum of 135 lbs (61 kgs) of DU.

b. Model 3056 Shield: The 3056 shield container is effectively a lead shield pot with steel bracing around the pot diameter and bottom. The 3056 is approximately 6 ¼ inches (159 mm) in diameter (not including the handle bosses), and 10.4 inches (264 mm) tall. The shield container (with the handle bosses) is roughly 7.7 inches (196 mm) in diameter. The shield incorporates two lifting handles 180 degrees apart on the sides. The 3056 includes a cover which protects the source tubes and caps during shipment. Primary radiation shielding is provided by a lead pot modified to use a DU inner core shield. The inner core shield provides additional, high efficiency radiation shielding in close proximity to the source positions in transport. The shielding components are clamped together by means of a steel cradle or sheath and a flange on the upper insert. Source location and retention is provided by a fabricated insert containing ten J-tubes and the use of source tube caps. Each source is secured close to the center of the shield by means of the attached flexible source holder within the J-tube and is closed by the tube cap. The 3056 shield weighs a maximum of 114 lbs (52 kgs).

c. Model 1911 Shield: The 1911 shield container is effectively a welded steel cylinder, 8 inches (203 mm) in diameter, and 8 ¾ inches (222 mm) tall (without the eyebolt or lid bolt heights). The maximum weight of the 1911 shield is 184 lbs (84 kgs). The shield lid is secured to the body by four M8 x 1.25 x 25 mm hex head austenitic stainless steel bolts and 0.75" outer diameter x 0.313" inner diameter x 0.051"-0.080" thick austenitic stainless steel washers. With the shield lid secured to the body by the bolts/washers, the 1911 is designed to be lifted by an M10 x 1.5 forged plain steel eyebolt which is threaded onto a recess in the shield lid. The eyebolt is removed after loading of the 1911 into the 976F cork lined drum and during transportation. The shield lid protects the source cavity and removable shielding during shipment.

The main shielding for the 1911 is provided by a lead shield body encased by a welded steel cylinder. The minimum thickness of the primary lead shielding pot (based on worst case tolerances) is 2 1/4 inches (57 mm). Source location and retention is provided by a shield plug and insert assembly. The shield plug, in combination with the lower shield insert, provides the inner containment for the sources inside the outer lead shield body when held in place by the shield cover lid. The design incorporates one of three insert configurations within the source cavity to allow for different source loading applications within the 1911 shield. Approval of all three shield insert configurations is for the same Ir-192 radioactive capacity of 1,000 Ci. The inner shield insert combinations are as follows:

i. Model 976F (Inner Container 1911) Shield Insert Configuration Option 1: DU Plug/Insert Configuration (P1992 and P1991)

The shield insert is approximately 6.7 lbs (3 kg) of DU encased in 1/16 inch (1.5 mm) thick carbon steel. The minimum thickness of the DU insert is 0.64 inches (16 mm). The DU insert provides a cylindrical source cavity measuring 0.92 inches (23 mm) in diameter and 1.7 inches (43 mm) deep. The design also allows for the use of an optional steel or aluminum holder within the source cavity. These holders provide negligible shielding and are intended only to consolidate and facilitate source insertion and removal from the shield cavity.

The shield plug for this configuration is approximately 5.3 lbs (2.4 kg) of DU encased in 1/16 inch (1.5 mm) thick carbon steel. The shield plug contains a minimum of 2.8 inches (71 mm) of DU directly above the shield cavity. The shield plug also incorporates a metal bail for use in lifting the plug from the container. This bail provides negligible shielding and is intended only to facilitate insertion and removal of the plug from the shield.

ii. Model 976F (Inner Container 1911) Shield Insert Configuration Option 2: Lead Plug/Insert Configuration (L1992 and L1991)

The shield insert is approximately 2 lbs (0.9 kg) of lead. The minimum thickness of the lead insert is ½ inch (13 mm). The lead insert incorporates a brass top piece and the insert is shown in greater detail in Section 1.3.

The shield plug for this configuration is approximately 5.5 lbs (2.5 kg) of lead. The shield plug contains a minimum of 3.3 inches (84 mm) of lead directly above the shield cavity. The shield plug has a recessed cylindrical area which increases the shield cavity and measures 1.42 inches (36 mm) in diameter by 0.39 inches (9.9 mm) deep. The shield plug also incorporates a metal bail for use in lifting the plug from the container. This bail provides negligible shielding and is intended only to facilitate insertion and removal of the plug from the shield.

iii. Model 976F (Inner Container 1911) Shield Insert Configuration Option 3: Tungsten Plug/Insert Configuration (T1992 and T1991)

The shield insert is approximately 4.6 lbs (2 kg) of tungsten. The minimum thickness of tungsten in the insert is 0.64 inches (16 mm). The tungsten insert provides a cylindrical source cavity measuring 0.92 inches (23.4 mm) in diameter and 2.7 inches (68 mm) deep. The design

also allows for the use of an optional steel or aluminum holder within the source cavity. These holders provide negligible shielding and are intended only to facilitate source insertion and removal from the shield cavity.

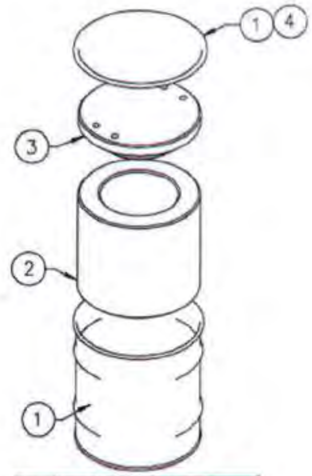
The shield plug for this configuration is approximately 7.1 lbs (3.2 kg) of tungsten. The shield plug contains a minimum of 2.1 inches (54 mm) of tungsten directly above the shield cavity. The shield plug also incorporates a metal bail for use in lifting the plug from the container. This bail provides negligible shielding and is intended only to facilitate insertion and removal of the plug from the shield.

1.2.1.2 Package Assembly Components (without shield containers): All versions of the 976 packages use a stainless steel drum with cork liner inserts to provide shield stability during transport. The drum provides structural strength to the overall package while the cork serves to limit inner shield movement during transport as well as act as a thermal insulator in case of fire. The components are described in Section 1.2.1.3.

1.2.1.3 Drum: The outer drum for this package is a 20 gallon capacity drum with 16 gauge, 0.06 inches (1.5 mm) thick 300 series austenitic stainless steel walls. The drum includes a removable lid which is secured in place using a lid closure band and four 3/8-16 x ¾ inch (19 mm) long 300 series austenitic stainless steel lid bolts. The lid bolts are inserted through four 3/8 inch (9.5 mm) diameter holes spaced equidistantly around the diameter of the drum. The holes are located 1 1/8 inches (28.6 mm) down from the top of the drum. The drum lid has four 300 series austenitic stainless steel blocks measuring 1 inch (25 mm) by 1 inch (25 mm) by ¾ inch (19 mm) tall. The steel blocks are welded on all four sides to the underside of the lid. The block welds are on the full length of the block on each side. The drum lid can alternatively be constructed to replace the welded, threaded blocks with floating nuts retained in square tubes that are welded to the lid. Both constructions (blocks/floating nuts) are drilled and tapped to accept a 3/8-16 bolt. The drum measures 19 ¾ inches (502 mm) in diameter and is 21 ¼ inches (540 mm) tall when assembled.

a. Drum Clamp Assembly: The drum uses a closure band that can be carbon steel or stainless steel and associated hardware. There are two versions of the closure band described in drawings contained in Section 1.3. The clamp bolt used to attach the closure band to the drum is torqued to 10 ft-lbs (+2, -0 ft-lbs) prior to transport. This torque is equivalent to a 0.75-1.25 inch (19-32 mm) gap between the lid closure band sides.

b. Cork Liner Inserts: All 976 Series packages use the same basic cork liners designed for transport of the Model 855 shield configuration of the 976A package. This is comprised of a combination bottom/side liner and a top liner which fits into the bottom liner after insertion of the shield container (see Figure 1.2a).



ITEM	QTY.	DESCRIPTION
4	1	CLAMP BAND
3	1	TOP CORK INSERT
2	1	BOTTOM CORK INSERT
1	1	20 GAL. BARREL

Figure 1.2a: Exploded View of Model 976A Drum and Basic Inserts

For the Model 976C through 976F style containers, additional, secondary inserts may be used to limit movement of the shield containers during transport (see descriptive assembly drawings for details).

1.2.1.4 Containment System: There are two basic methods for securing the sources in the Model 976 Series shields. The methods are described in Table 1.2c. In all cases the inner shield containers are loaded into the cork inserts within the drum, the drum lid is attached by means of a lid closure band and four drum bolts securing the drum lid to the base. The lid clamp band bolt is seal wired with a tamper indicator seal.

Table 1.2c: Shield Container Containment Descriptions

Shield Identification	Containment Description
855, 3056	Source location and retention is provided by J-tubes in the shield and the use of either a locking mechanism on the source wire or source tube caps.
1911	Source location and retention is provided by a shield plug held in place by the shield cover lid. The shield cover lid is attached to the shield base by bolts.

1.2.2 Contents

The Model 976 Series transport packages are designed to transport special form capsules containing the isotopes listed in Table 1.2a. Additional information for the contents is provided in Table 1.2d and Section 2.10 and 2.12. The maximum decay heat for Ir-192 in table 1.2d has been adjusted to account for content activity of the source. Actual content to output activity varies based on the capsule configuration as well as variations in isotope self-absorption. A factor of 2.3 was used to convert output activity to content activity as this factor reflects the worst case variation for Ir-192 sources transported in these packages. The source capsules are loaded into the transport package shield and secured according to the procedure for that shield container (see Section 7).

The maximum weight of the contents for the shield containers is also listed in Table 1.2d. The content weight values are based on either the actual source assembly weights (for the 855 and 3056 containers), or calculated based on the package capacity and the lowest specific activity of Ir-192 (200 Ci/gram) used in source production (for the 1911 container).

Note: Ir-192 of higher specific activity can be used but this would produce sources with lower total mass of the contents. Material density for Se-75 and Yb-169 are less than Ir-192, therefore the maximum content weight values listed in the Table 1.2d are the maximum content masses based on the heaviest material content which is Ir-192.

Table 1.2d: Isotope Information Permitted in the Model 976 Series Packages

Package ID	Isotope	Activity[1]	Capsule Form[2]	Chemical/ Physical Form	Maximum Content Weight (grams)	Maximum Decay Heat[3]
976A (855 Inner)	Ir-192	1,000 Ci	Special Form	Metal	176	20 Watts
	Se-75	1,000 Ci				5 Watts
	Yb-169	865 Ci				5 Watts
	Se-75	350 Ci				2 Watts
	Yb-169	350 Ci				2 Watts

Package ID	Isotope	Activity[1]	Capsule Form[2]	Chemical/ Physical Form	Maximum Content Weight (grams)	Maximum Decay Heat[3]
976C (3056 Inner)	Ir-192	1,250 Ci	Special Form	Metal	220	25 Watts
	Se-75	1,250 Ci				6.4 Watts
	Yb-169	1,000 Ci				5.4 Watts
	Se-75	500 Ci				2.5 Watts
	Yb-169	500 Ci				3 Watts
	Se-75	1,000 Ci				5 Watts
	Yb-169	1,000 Ci				5.4 Watts
976F (1911 Inner)	Ir-192	1,000 Ci	Special Form	Metal	220	20 Watts
	Se-75	1,000 Ci				5 Watts
	Yb-169	1,000 Ci				5.4 Watts

[1] For Iridium-192, the maximum capacity is based on the output curies which are determined by measuring the source output at 1 meter and expressing its activity in curies derived from the following: 0.48 R/hr-Ci Iridium-192 at 1 meter. (Ref: American National Standard N432-1980, "Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography."). For Selenium-75 and Yb-169 the maximum capacity is based on the content curies contained in the radioactive source(s).

[2] Special Form is defined in 10 CFR 71, 49 CFR 173, IAEA No. TS-R-1 (2009 Edition).

[3] Maximum decay heat for Ir-192 is calculated by correcting the output activity to content activity. A factor of 2.3 is used to account for source capsule and self-absorption in this conversion.

1.2.3 Special Requirements for Plutonium

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

1.2.4 Operational Features

These packages do not involve complex containment systems for source securement. The sources for these packages are all special form, welded capsules. The capsules may or may not be attached to flexible handling wires. Sources attached to flexible wires are held in place either by lock mechanism or source tube caps installed after the source wires are inserted into the shield J-tubes. Sources inserted into a cavity style shield container are held in place within the shield by means of a shield plug assembly and/or cover secured to the shield base. All shield containers are installed within cork liners in the 976 drum assembly and the drum lid is secured to the container by means of a bolted, seal wired lid closure band and four lid drum bolts. The 976 Series containers are assembled and secured as described in Section 7.

1.3 Appendix: Drawings of the Model 976 Series transport packages.

Section 1.3 Appendix: Drawings of the Model 976 Series transport packages.

MODEL CONFIGURATION	MAXIMUM PACKAGE WEIGHT	MAXIMUM PACKAGE CAPACITY (Ir-192)	DIMENSION "A"
976F	263 lbs	1000 CURIES	8-3/4 REF
976C	190 lbs	1250 CURIES	11 REF
976A	300 lbs	1000 CURIES	8-9/16 REF

[redacted]

PART NAME	976A	976C	976F	MATERIAL
	QTY			
LID SCREWS	4	4	4	SEE NOTE 7
CLAMP BAND	1	1	1	SEE DRAWING RCLM009 OR RCLM011
SEAL WIRE	AR	AR	AR	STEEL
RIVETS	4	4	4	STAINLESS STEEL
NAMEPLATE	1	1	1	FIREPROOF STEEL
BOTTOM INNER SPACER	0	1	0	SEE SHEET 4
TOP INNER SPACER	0	4	4	SEE SHEET 4
BOTTOM INNER INSERT	0	1	1	SEE SHEET 2
TOP OUTER INSERT	1	1	1	SEE SHEET 3
BOTTOM OUTER INSERT	1	1	1	SEE SHEET 2
SHIELD ASSEMBLY MODEL 1911	0	0	1	SEE DRAWING R1911
SHIELD ASSEMBLY MODEL 3056	0	1	0	SEE DRAWING R3056
SHIELD ASSEMBLY MODEL 855	1	0	0	SEE DRAWING R85590
DRUM ASSEMBLY	1	1	1	SEE DRAWING R97608

NOTES:

1. MODEL 976 SERIES TRANSPORT PACKAGE CONSISTS OF 3 DIFFERENT MODEL CONFIGURATIONS.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BAND BOLT TO 10$\pm$2 FT-LB (EQUIVALENT TO 0.75 TO 1.25 INCH GAP IN BAND).
4. MAXIMUM PACKAGE WEIGHT PER TABLE.
5. ALL HARDWARE MEETS ASME B18 STANDARDS.
6. "REF" OR () DENOTES A REFERENCE DIMENSION - FOR GENERAL INFORMATION ONLY. ACTUAL DIMENSION ON FINISHED ITEM MAY FALL OUTSIDE TOLERANCES SHOWN ON THIS DRAWING.
7. 3/8-16 X 3/4 LONG LID SCREWS INSTALLED BEFORE 1-AUG-2008 ARE 300 SERIES STAINLESS STEEL WHILE SCREWS INSTALLED OR REPLACED ON OR AFTER 1-AUG-2008 ARE STAINLESS STEEL PER ASTM A193 GRADE B8 (304).

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE $\pm$1/8

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE: MODEL 976 TRANSPORT PACKAGE

ERF #	APPROVALS	DATE
3742	[illegible]	3/16/18
	[illegible]	3/16/18
	[illegible]	22Mar18

SIZE	DWG. NO.	SCALE	SHEET	REV
A	R97600	NONE	1 OF 4	C

[redacted]

976 BOTTOM INSERTS

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/8

QSA GLOBAL

40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE	MODEL 976 TRANSPORT PACKAGE		
SIZE A	DWG. NO. R97600		REV C
	SCALE: NONE	SHEET 2 OF 4	

[redacted]

TOP OUTER INSERT

976C TOP OUTER INSERT 976A & 976F TOP OUTER INSERT	CORK WITH UREA FORMALDEHYDE RESIN BINDER. DENSITY: 17 ± 2 LB./CU. FT.
PART NAME	MATERIAL

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/8

QSA GLOBAL

40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 976 TRANSPORT PACKAGE

SIZE	DWG. NO. R97600		REV
A	SCALE: NONE	SHEET 3 OF 4	C

[redacted]

INNER SPACERS

PART NAME	MATERIAL
976C & 976F TOP INNER SPACER 976C BOTTOM INNER SPACER	CORK WITH UREA FORMALDEHYDE RESIN BINDER. DENSITY: 17 ± 2 LB./CU. FT.

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES, TOLERANCE ±1/8

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 976 TRANSPORT PACKAGE

SIZE	DWG. NO.		REV
A	R97600		C
	SCALE: NONE	SHEET 4 OF 4	

[redacted]

[redacted]

ERF #	APPROVALS	DATE
3742	[illegible]	21 Mar 18
	[illegible]	21 Mar 18
	[illegible]	22 Mar 18

UNLESS OTHERWISE SPECIFIED:

ALL DIMENSIONS ARE INCHES
TOLERANCES:
FRACTIONS: ±1/2
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

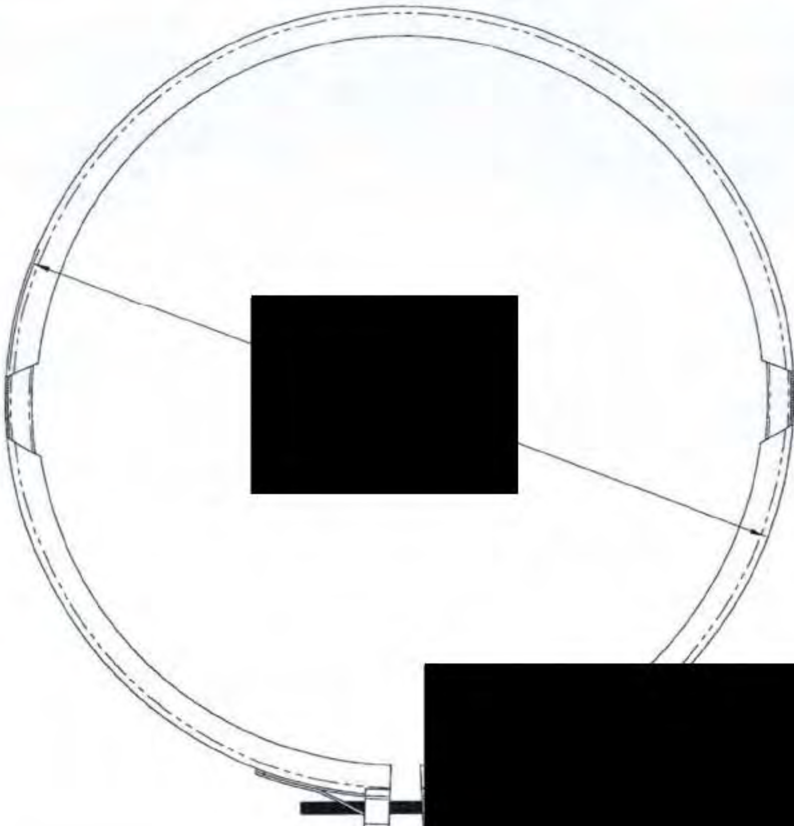
QSA GLOBAL

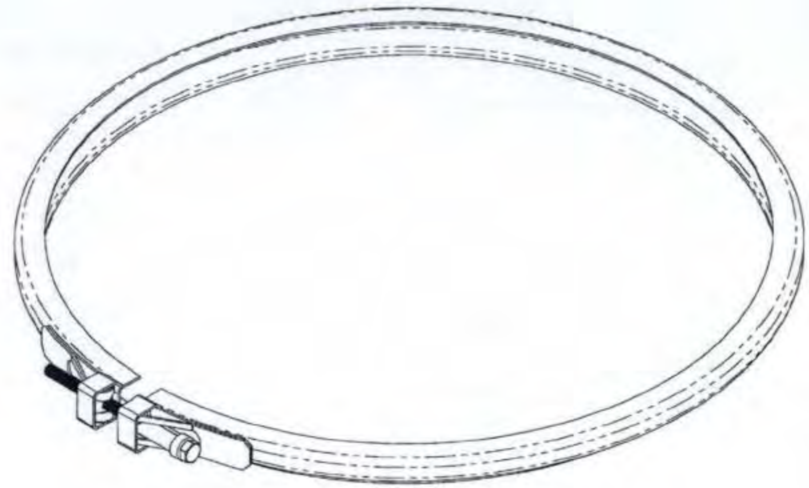
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE: 20 GALLON DRUM, MODEL 976

SIZE	DWG. NO.		REV
B	R97608		K
	SCALE: NONE	SHEET 1 OF 1	





[redacted]

DEDICATED COMMERCIAL COMPONENT

SUPPLIER: COLSTON MANUFACTURING
EATON AEROSPACE PART NUMBER 61-99-122 (ISSUE 1F)

MATERIALS:
EXCEPT BRASS NUT ALL COMPONENTS 300 SERIES AUSTENITIC STAINLESS STEEL

APPROVALS	DATE	QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING
[illegible]	6 Apr 09		
[illegible]	10 Apr 09		
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES		TITLE	CLAMP BAND
TOLERANCES: (UNLESS OTHERWISE SPECIFIED) FRACTIONS ± 1/8, X.X ± 0.12, X.XX ± 0.06, X.XXX ± 0.020, ANGULAR ± 5°		SIZE B	DWG. NO. RCLM009 — REV C
			SCALE: 1:3 — SHEET 1 OF 1

F#
03

[redacted]

1. [redacted] MINIMUM MECHANICAL PROPERTIES OF AISI C1008.
2. EACH LUG FILLET WELDED TO RING ON AT LEAST 3 SIDES PER AWS D1.3.
3. WELDS INSPECTED BY A CERTIFIED WELD INSPECTOR (CWI) MEETING REQUIREMENTS OF AWS QC1.
4. OPTIONAL PROTECTIVE FINISH: RING PAINTED. BOLT & NUT ZINC PLATED.

[redacted]

SECTION A-A
SCALE 1 : 2

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

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

ERF #	APPROVALS	DATE
3742	S. G[illegible]	3/16/18
	[illegible]	3/20/18
	[illegible]	22 Mar 18

TITLE: CLAMP BAND

SIZE	DWG. NO.		REV
A	RCLM011		A
	SCALE: NONE	SHEET 1 OF 1	

[redacted]

AWS D1.1 STRUCTURAL WELDING CODE – STEEL
AWS D1.6 STRUCTURAL WELDING CODE – STAINLESS STEEL

2. NOTES APPLY TO ALL PAGES.
3. MAXIMUM DEVICE WEIGHT – 225 LBS.
4. ALL HARDWARE TO MEET ASME B18 STANDARDS.
5. THIS ASSEMBLY IS NOT TO BE MANUFACTURED AFTER 01 JANUARY 2009 EXCEPT FOR PARTS IDENTIFIED AS SERVICE REPLACEABLE PARTS (SRP). (H)

ERF #	3288

APPROVALS	
[illegible]	24Jul15
[illegible]	24Jul15

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

QSA GLOBAL

DESCRIPTIVE DRAWING

TITLE	MODEL 855 SOURCE CHANGER		
SIZE A	DWG. NO. R85590		REV H
	SCALE: NONE	SHEET 1 OF 6	

[redacted]

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

TITLE MODEL 855 SOURCE CHANGER				
SIZE A	DWG. NO. R85590			REV H
	SCALE: NONE	SHEET 2 OF 6		

[redacted]

QSA GLOBAL

DESCRIPTIVE DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

TITLE	MODEL 855 SOURCE CHANGER		
SIZE A	DWG. NO. R85590		REV H
	SCALE: NONE	SHEET 3 OF 6	

[redacted]

SHIELD
SEE SHT 5

STANDARD
LOCK ASSEMBLY

2. SOURCE HOLD DOWN CAPS MAY INCLUDE OPTIONAL IRIDITE, CHROMATE, OR OTHER PROTECTIVE FINISH.

H

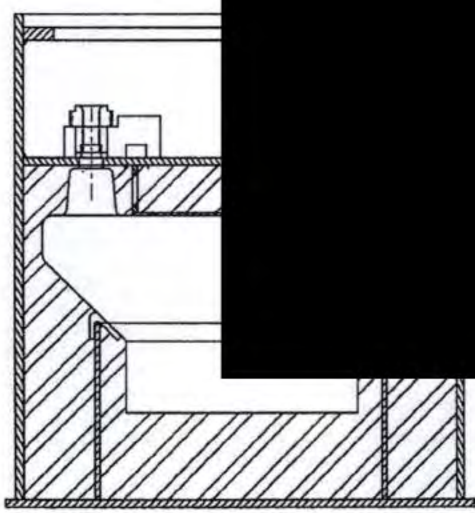
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

QSA GLOBAL

DESCRIPTIVE DRAWING

TITLE MODEL 855 SOURCE CHANGER			
SIZE A	DWG. NO. R85590		REV H
	SCALE: NONE	SHEET 4 OF 6	

[redacted]



DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

QSA GLOBAL	DESCRIPTIVE DRAWING
TITLE	MODEL 855 SOURCE CHANGER
SIZE A	DWG. NO. R85590
SCALE: NONE	SHEET 5 OF 6
REV	H

[redacted]

QSA GLOBAL

DESCRIPTIVE DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

TITLE	MODEL 855 SOURCE CHANGER		
SIZE A	DWG. NO. R85590		REV H
	SCALE: NONE	SHEET 6 OF 6	

[redacted]
CODES AT THE TIME OF FABRICATION AND INSPECTION.

2. NOTES APPLY TO ALL PAGES.

3. MAXIMUM WEIGHT = 114 LBS.

4. ALL HARDWARE TO MEET ASME B18 STANDARDS.

5. "REF" DENOTES A REFERENCE DIMENSION PROVIDED FOR GENERAL INFORMATION ONLY. ACTUAL DIMENSION ON FINISHED ITEM MAY FALL OUTSIDE TOLERANCES SHOWN ON DRAWING.

G 6. THIS ASSEMBLY IS NOT TO BE MANUFACTURED AFTER 1 JAN 2009, EXCEPT FOR PARTS IDENTIFIED AS SERVICE REPLACEABLE PARTS (SRP).

3288	[illegible]	[illegible]
	[illegible]	24 JUL 15

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE: MODEL 3056 SHIELD CONTAINER

SIZE	DWG. NO.		REV
A	R3056		G
	SCALE: NONE	SHEET 1 OF 4	

A

8 7 6 5 4 3 2 1

[redacted]

ITEM 1 - LEAD POT ASSEMBLY	UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES TOLERANCES: FRACTIONS ± 1/8 X.X ± 0.12 X.XX ± 0.06 X.XXX ± 0.020	TITLE	MODEL 3056 SHIELD CONTAINER	
		SIZE A	DWG. NO. R3056 SCALE: NONE	REV G
			SHEET 2 OF 4	

[redacted]

[redacted]

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

QSA GLOBAL

DESCRIPTIVE DRAWING

TITLE	MODEL 3056 SHIELD CONTAINER		
SIZE A	DWG. NO. R3056		REV G
	SCALE: NONE	SHEET 3 OF 4	

[redacted]

QSA GLOBAL

DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE	MODEL 3056 SHIELD CONTAINER		
SIZE	DWG. NO. R3056		REV
A	SCALE: NONE	SHEET 4 OF 4	G

8 7 6 5 4 3 2 1

D D

C C

B

[redacted]

NOTES:

1. MAXIMUM PACKAGE WEIGHT - 184 lbs.
2. NOTES ON THIS PAGE APPLY TO ALL PAGES OF THIS DRAWING.
3. ALL HARDWARE TO MEET ASME B18 STANDARDS.
4. SOURCE HOUSING, ITEM 3 MAY BE LEAD/BRASS, TUNGSTEN OR DU/STEEL FABRICATION.
5. " ( ) " DENOTES A REFERENCE DIMENSION PROVIDED FOR GENERAL INFORMATION ONLY. ACTUAL DIMENSION ON FINISHED ITEM MAY FALL OUTSIDE TOLERANCES SHOWN ON DRAWING.

A

ERF #	APPROVALS	DATE
3288	S.C.	24Jul15
	L.B.d.	24Jul15

QSA GLOBAL

40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE	MODEL 1911 SHIELD		
SIZE	DWG. NO. R1911		REV
B	SCALE: 1:2	SHEET 1 OF 6	G

8 7 6 5 4 3 2 1

[redacted]

AWS A2.4-93 STANDARD SYMBOLS FOR WELDING, BRAZING AND NONDESTRUCTIVE EXAMINATION

G 2. ALL WELDING AND INSPECTION SHOWN ON THIS PAGE WILL BE IN ACCORDANCE WITH:
AWS D1.6 STRUCTURAL WELDING CODE - STAINLESS STEEL

3. ALL WELDING CAN BE EITHER GTAW OR GMAW AND SHALL BE PERFORMED BY PERSONNEL
QUALIFIED IN ACCORDANCE WITH THE STANDARD AS LISTED ABOVE.

4. ALL WELDING SHOWN ON THIS PAGE TO BE VISUALLY (VT) INSPECTED BY INDIVIDUALS CURRENTLY QUALIFIED
TO ASNT SNT-TC-1 A.

G 5. STAINLESS STEEL PARTS MADE AFTER JUNE 2015 ARE 304 OR 304L STAINLESS STEEL PER ASTM A240.

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803		DESCRIPTIVE DRAWING	
TITLE	MODEL 1911 SHIELD		
SIZE B	DWG. NO. R1911		REV G
	SCALE: 1:2	SHEET 2 OF 6	

[redacted]

RETED PER:
.S FOR WELDING, BRAZING AND NONDESTRUCTIVE EXAMINATION

N ON THIS PAGE WILL BE IN ACCORDANCE WITH:
N 1 2009; BS EN 288 WELD PROCEDURE TESTS FOR ARC WELDING OF STEEL
2009; AWS D1.6 STRUCTURAL WELDING CODE - STAINLESS STEEL

R GMAW AND SHALL BE PERFORMED BY PERSONNEL
H THE STANDARD AS LISTED ABOVE.

O BE VISUALLY (VT) INSPECTED BY INDIVIDUALS CURRENTLY QUALIFIED

N 1 2009; BS 5500
2009; ASNT SNT-TC-1 A

NT TO SAFETY

ICATIONS ARE FOR ASSEMBLIES FABRICATED AFTER JUNE 1 2009
LESS STEEL PARTS WERE SPECIFIED AS "AUSTENITIC STAINLESS STEEL"

ITEM	TITLE	QTY	MATERIAL
8	M10 X 1.5 EYEBOLT	1	FORGED PLAIN STEEL
7	SCREW, M8X1.25 X 25mm, HEX HEAD, SS	4	ASTM F593 - ALLOY GROUPS 1,2,3 - CONDITION CW
6	OPTIONAL PLAIN WASHER	4	STEEL - NITS
5	CLOSURE PLATE, HUB	1	ASTM A276, 304 STAINLESS STEEL
4	CLOSURE PLATE, DISK	1	ASTM A240, 304 STAINLESS STEEL
3	1911 LEAD POT TOP PLATE	1	ASTM A240, 304 STAINLESS STEEL
2	M8X1.25 X1 THREADED BOSS	4	ASTM A276, 304 STAINLESS STEEL
1	LEAD BODY, 1911	1	LEAD, 99.9% PURE

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES
TOLERANCE: LINEAR ±1/8 ANGULAR ±5°

QSA GLOBAL

DESCRIPTIVE DRAWING

40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODEL 1911 SHIELD

SIZE	DWG. NO.		REV
B	R1911		G
	SCALE: 1:2	SHEET 3 OF 6	

D

[redacted]

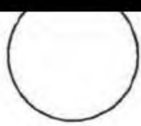
C

QSA GLOBAL 40 NORTH AVE, BURLINGTON, MA 01803		DESCRIPTIVE DRAWING
TITLE	MODEL 1911 SHIELD	
SIZE B	DWG. NO. R1911 SCALE: 1:2 — SHEET 4 OF 6	REV G

3 2 1

[redacted]

[redacted]



G

ITEM	TITLE	QTY	MATERIAL
3	OPTIONAL WIRE HANDLE	1	STAINLESS STEEL - NITS
2	TUNGSTEN PLUG	1	TUNGSTEN
1	TUNGSTEN INSERT	1	TUNGSTEN

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES
TOLERANCE: LINEAR ±1/8 ANGULAR ±5°

QSA GLOBAL

40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE: MODEL 1911 SHIELD

SIZE	DWG. NO.		REV
B	R1911		G
	SCALE: 1:2	SHEET 5 OF 6	

[redacted]

ITEM	TITLE	QTY	MATERIAL
3	OPTIONAL WIRE HANDLE	1	STAINLESS STEEL - NITS
2	DEPLETED URANIUM / STEEL PLUG	1	DU/CARBON STEEL
1	DEPLETED URANIUM / STEEL INSERT	1	DU/CARBON STEEL

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE INCHES
TOLERANCE: LINEAR ±1/8 ANGULAR ±5°

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE: MODEL 1911 SHIELD

SIZE	DWG. NO.		REV
B	R1911		G
	SCALE: 1:2	SHEET 6 OF 6	

Section 2 - STRUCTURAL EVALUATION

This section identifies and describes the principal structural engineering design of the packaging, components, and systems important to safety and compliance with the performance requirements of 10 CFR Part 71 and IAEA TS-R-1.

2.1 Description of Structural Design

2.1.1 Discussion

The Model 976 Series transport packages are described in Section 1.2, "Package Description."

2.1.2 Design Criteria

The Model 976 Series transport packages are designed to comply with the requirements for Type B(U) packaging as prescribed by 10 CFR 71, IAEA No. TS-R-1 (2009) and CNSC PTNS SOR/2015-145. All design criteria are evaluated by a straightforward application of the appropriate section of these requirements.

Some shields containers incorporated in the package were designed under previously approved QA programs, either in the USA under QSA Global, Inc. or its predecessors in the United Kingdom by competent authority under Nycomed Amersham plc. or its predecessors.

2.1.3 Weight and Centers of Gravity

The transport package weight varies from 190 lbs (86 kg) up to 300 lb (136 kg). The shipping cask weight varies from 114 lbs (52 kg) up to 225 lbs (102 kg). The center of gravity for all Model 976 Series transport packages is indicated on the drawings provided in Section 1.3.

2.1.4 Identification of Codes and Standards for Package Design

2.1.4.1 <u>Package Design</u>

See Section 2.1.2 relating to design criteria of the package. Any applicable, specific codes or standards related to the finished assemblies for the 976 Series transport packages are specified on the drawings contained in Section 1.3. In general, the design was based on the Type A and Type B(U) container requirements of 49 CFR, 10 CFR 71 and IAEA regulations as identified in Section 1.1.

2.1.4.2 Fabrication & Assembly

All drum and cork insert component fabrication (including assembly) is controlled under the QSA Global, Inc. Quality Assurance Plan approved by the USNRC and ISO. All welding under this plan adheres to the standards referenced on the drawings in Section 1.3. All hardware meets the standards referenced on the drawings in Section 1.3. All external fabrication deemed critical to safety is either verified to equivalent in-house standards or dedicated as appropriate for use prior to release as part of this transport package.

Some shield containers incorporated in the package were designed under previously approved QA programs, either in the USA under QSA Global, Inc. or its predecessors in the United Kingdom by competent authority under Nycomed Amersham plc. or its predecessors. Prior to the use of these shield containers as part of the Model 976 Series transport package, they are evaluated under the QSA Global, Inc. QA program for compliance to the transport package design. The only new manufacture of shield containers for use in the Model 976 Series packages is the Model 1911 shield container. There will be no manufacture of any new Model 855 or Model 3056 shield containers. Any new manufacture of shield containers to the Model 1911 design will be completed under the QSA Global, Inc. Quality Assurance Plan approved by the USNRC and ISO.

2.1.4.3 Maintenance & Use

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

2.2 Materials

2.2.1 Material Properties and Specifications

Table 2.2a lists the relevant mechanical properties (at ambient temperature) of the principal materials used in the Model 976 Series transport package. The location and use of these materials is shown on the drawings contained in Section 1.3. The reference for the table information is listed in the last column of the table.

Table 2.2a: Mechanical Properties of Principal Transport Package Materials

Material	Tensile Strength	Yield Strength	Source
Depleted Uranium	65 ksi	30 ksi	Reference #2
Copper	25 ksi	9 ksi	Reference #3, p. 224
Steel (nominal)	53 ksi	36 ksi	Reference #1, p. 205
Stainless Steel	75 ksi	30 ksi	Reference #1, p. 854
Tungsten	142 ksi	109 ksi	www.matweb.com
Cork (minimum)	80 psi	NA	Reference #4, RMR214 Issue C
Lead ($^{96}Pb/^{4}Sb$)	3,990 psi	NA	www.matweb.com

Resource references:

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

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

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

4. AEA Technology plc. RMR 214 Issue 5, Raw Material Requirement, (RMR) Cork for Transport Containers (see Section 2.12.1).

2.2.2 Chemical, Galvanic or Other Reactions

The materials used in the construction of the Model 976 Series transport package are depleted uranium metal, steel (carbon and stainless), tungsten, lead, copper, polyurethane foam and cork. In some shield container designs, copper separators were used between steel/uranium interfaces to reduce the possible formation of a eutectic during the Hypothetical Accident Conditions thermal scenario defined by 10 CFR 71.73(c)(4). In other constructions where steel/depleted uranium interfaces exist, the steel forms a welded seal around the depleted uranium surfaces which prevents contact by air needed to create the possible formation of a eutectic alloy. In some of the shield container designs there are steel/uranium interfaces without full enclosure or copper separation. The possibility of the formation of a steel/uranium eutectic alloy at temperatures below the melting temperatures of the individual metals has been considered. The steel-uranium eutectic alloy temperature is approximately 1,337°F (725°C). However, vacuum conditions and extreme cleanliness of the surfaces are necessary to produce the eutectic alloy at this low temperature. Due to the conditions in which the depleted uranium shield components are assembled and used in the shield containers, conditions sufficient to allow formation of this eutectic do not exist. The cork and steel interfaces will not cause any chemical, galvanic or other adverse reactions due to contact during transport. With these container constructions, there will be no significant chemical or galvanic reaction

between package components during normal or hypothetical accident conditions of transport.

2.2.3 Effects of Radiation on Materials

Lead, depleted uranium, tungsten, steel, polyurethane foam and cork have been used in transport packaging for decades without degradation of the package performance over time. The cork used in the drum liner inserts has been used in Type B transport packages in the United Kingdom for decades with no degradation in the material integrity over time due to irradiation from package contents.

2.3 Fabrication and Examination

2.3.1 Fabrication

Drum and cork inserts are procured, manufactured and inspected for use under QSA Global, Inc. NRC approved QA Program Number 0040. Existing shield containers were either originally manufactured by QSA Global, Inc. (or its predecessors) in the USA or the United Kingdom. All shield containers will be evaluated and documented for compliance to the drawings provided in Section 1.3 prior to initial use of the shield container as part of a Model 976 Series transport package.

2.3.2 Examination

Section 8 describes the acceptance testing and routine maintenance requirements for shield containers and package components used on the Model 976 Series packages.

2.4 General Requirements for All Packages

2.4.1 Minimum Package Size

The transport package exceeds the minimum size requirements since it is 19 ¾ inches (502 mm) in diameter by 21¼ inches (540 mm) tall.

2.4.2 Tamper-Indicating Feature

The Model 976 Series packages incorporates a steel seal wire attached to the lid closure band and lid closure band bolt. This seal wire is not readily breakable, therefore if it is broken during transport, it serves as evidence of possible unauthorized access to the contents.

2.4.3 Positive Closure

See Section 1.2.4.

2.5 Lifting and Tie-Down Standards for All Packages

2.5.1 Lifting Devices

The Model 976 Series packages are designed to be lifted by the base using a hand truck or other suitable mechanical means. For this analysis, the base is assumed to be a flat, circular plate 19 ¼ inches (502 mm) in diameter and 0.06 inches (1.5 mm) thick, supported about its outer edge. We take the supporting cylinder (the walls and bottom welded rim of the drum) to be essentially rigid for the magnitude of stresses encountered here. Any lifting would span all edges of the drum and thus allow the bottom to be supported and suspended by the edges. As such, the maximum axial stress on the base is:

$$\sigma_{max} = k\, wr^2/t^2$$

Where:

w	=	The pressure of the transport package weight (136 kg (300 lb)) distributed load over the base. = 300 lb/291 in^2 = 1.031 psi
t	=	The thickness of the base plate 0.06 inches (1.5 mm)
r	=	The radius of the base plate 9.6 inches (244 mm)
k	=	A tabulated factor for this case of flat plate. [1] = 0.75

[1] - Marks Handbook, 9th edition, pp 5-52 – 5-53, Case 2

Therefore, the stress generated in the base is 19,800 psi. With a Safety Factor of 3 applied, the maximum stress in the drum base is 59,400 psi. This is below the ultimate tensile strength of the stainless steel base which is 75,000 psi.

Calculation of the maximum deflection of the base and the bending stress at the junction of the base plate and side walls of the drum is assessed as follows. The base plate of the drum has a rolled rim that is welded to the drum wall. The inside diameter of the drum is 18 ⅛ inches (460 mm) and the drum material is 0.06 inches (1.5 mm) thick stainless steel. Conservatively the weight of the package is supported by the base plate. The maximum package weight is 300 lbs (136 kgs). The following calculation assumes the load is evenly distributed over the entire base plate. The following calculations in this Section are based on information contained in "Formulas for Stress and Strain", Fifth Edition, Raymond J. Roark and Warren C. Young, McGraw Hill Book Company, 1975.

$$D = \text{Plate Constant} = E\, t^3 / 12(1-\nu^2)$$

Where:

E	=	Modulus of elasticity of stainless steel 3 x 10^7 lb/in^2
t	=	The thickness of the base plate 0.06 inches (1.5 mm)
ν	=	Poisson ration = 0.285

This calculates to give a value for D of 588 lb-in.

The vertical deflection, y_c, is calculated as follows:

$$y_c = -q\, a^4 / 64\, D$$

Where:

a = base plate radius = 9.06 inches
q = pressure on the base plate = $300\ \text{lbs}/\pi\, a^2 = 1.16\ \text{lb/in}^2$

Therefore, $y_c = -0.208$ inches

The moment at the center M_c is calculated as follows:

$$M_c = q\, a^2\, (1 + D)/16 = 7.65\ \text{in-lb/in}$$

Producing a bending stress $\sigma = 6\,(M_c/t^2)$ which equals 12,750 psi. Combining the axial and bending stresses produces a σ_c as follows:

$$\sigma_c = \{\, \sigma_{axial}^2 + \sigma_{bending}^2 \,\}^{1/2} = \{\, (19{,}800\ \text{psi})^2 + (12{,}750\ \text{psi})^2 \,\}^{1/2} = 23{,}550\ \text{psi}$$

With a safety factor of 3 applied, the maximum combined axial and bending stress on the drum base is 70,650 psi which is below the ultimate tensile strength of the stainless steel base of 75,000 psi. Therefore the package meets the requirements of 10 CFR 71.45(a).

2.5.2 Tie-Down Devices

The Model 976 Series packages have no tie down attachments. The package can be blocked and braced according to standard transportation practices.

2.6 Normal Conditions of Transport

2.6.1 Heat

The heat source for the Model 976 Series transport packages are listed in Table 1.2d. Iridium-192, generates approximately 8.6 milliwatts per Curie based on assuming a decay energy of 1.46 MeV/decay. The thermal evaluation for the heat test is described in Section 3.

2.6.1.1 Summary of Pressures and Temperatures

Table 2.6.1.a: Summary Temperatures Normal Transport

Temperature Condition	Model 976	Comments
Insolation (38°C in full sun)	90.3°C (195°F)	Section 3.4.1.1.
Decay Heating (38°C in shade)	42.7°C (109°F)	Section 3.4.1.2

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

2.6.1.2 Differential Thermal Expansion

Any thermal expansion encountered during Normal Transport will be insignificant with respect to the manufacturing tolerances of the package. For example:

Expansion of the outer drum circumference is approximated by:

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

Where: $D =$ Diameter of the drum at top
$\alpha =$ Coefficient of Thermal expansion
$\Delta T =$ Cold temperature differential (from -40°F to 68°F)
$\Delta T =$ Hot temperature differential (from 68°F to 155°F)

Substituting we get: $E = \pi\ (19\ \tfrac{1}{4}\ \text{in})(9.9\mu\text{in/in°F})(108°\text{F}) = 0.06\ \text{in (cold)}$
$E = \pi\ (19\ \tfrac{1}{4}\ \text{in})(9.9\mu\text{in/in°F})(87°\text{F}) = 0.05\ \text{in (hot)}$

This translates to a diameter change of ± 0.02 inches. Manufacturing tolerance on this component is ± ¼ inch. Further, the lid closure band and lid cover will expand at approximately the same rate thus maintaining the security of the package.

Expansion of the cork circumference is approximated by:

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

Where: $D =$ Diameter of the cork

α = Coefficient of Thermal expansion
ΔT = Cold temperature differential (from -40°F to 68°F)
ΔT = Hot temperature differential (from 68°F to 155°F)

Substituting we get: $E = \pi$ (18 in)(100 μin/in°F)(108°F) = 0.61 in (cold)
$E = \pi$ (18 in)(100 μin/in°F)(87°F) = 0.49 in (hot)

This translates to a diameter change of +0.16/-0.19 inches. Manufacturing tolerance on this component is ± ¼ inch. All other drum and cork insert components have similar tolerances. Any expansion in this temperature range will be well within these tolerances.

Tolerances between the shield inserts and the cork are even greater. As such, no interference, even with the shields will occur.

2.6.1.3 Stress Calculations

As shown in Section 2.6.1.2, thermal differentials will have no adverse effect of the interfaces between the outer drum, cork inserts and shield inserts. Mechanical loads at the maximum weight of the series (300 lbs.) are well distributed across the package bottom and are small compared to the yield strength of the steel (30,000 psi – See Table 2.2a).

Inner diameter of drum = 18 1/8 inches
Area of drum bottom = 256 in^2
Stress on drum bottom = 300 lbs/256 in^2 = 1.2 psi

Stresses will develop within the gasketed cavities in the Model 855 shield (the Models 3056 and 1911 do not incorporate a gasket). The Model 976A with the Model 855 shield container, is described below. the increased pressure will exert the most force on the cover. A perfect seal and no escaping gasses is also assumed.

Force is estimated by: $F = (\pi D^2/4)P$

Where: D = Diameter of the shield cover over the void = 10 ¾ in
P = Pressure induced by the thermal gradient = 7 psi (from Section 3.4.2.)

Therefore: $F = \pi(10\ 3/4\ \text{in})^2/4(7\ \text{psi}) = 635$ lbf

The cover is held by eight (8) 3/8-16 300 series austenitic stainless steel bolts. This imparts a force of 79 lbf in each bolt. However, if all the stress is assumed to be taken by only one bolt, then the stress in that bolt equals:

$S = Fi/A$

Where: Fi = Force in each bolt
A = Stress area of the bolt (Machinery's Handbook, 24th Edition, by Industrial Press Inc., New York, NY for 3/8 inch bolt) = 0.0775 in^2

Solving for the bolt stress produces: $S = 635$ lbf(0.0775 in^2) = 8,152 psi

This value is well below the tensile strength value for an ungraded stainless steel bolt (75,000 psi nominal).

2.6.1.4 Comparison with Allowable Stresses

All stresses calculated in Section 2.6.1 are well below strengths for the materials of construction. Further, the Model 976 Series package was fully tested and passed under Normal Conditions of transport. It is therefore concluded that the Model 976 Series package will satisfy the performance requirements specified by the regulations.

2.6.2 Cold

The carbon steel components of the Model 976 Series transport packages are susceptible to brittle fracture at low temperature. The transport package successfully met Type B(U)-96 Normal Condition and Hypothetical Accident Condition Transport Tests requirements at temperatures below -40°C (-40°F), the minimum specified in the regulations. This testing is described under Test Plan 90 Report and Test Plan 163 Report (Sections 2.12.2 and 2.12.3 respectively). Thus, it is concluded that the Model 976 Series transport packages will withstand the normal transport cold condition.

2.6.3 Reduced External Pressure

Other than the Model 855 shield container, the Model 976 Series transport packages are open to the atmosphere and contains no components which could create a differential pressure relative to atmospheric conditions or components within the package. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR, 3.6 psi in 49 CFR and 8.7 psi (60 kPa) and 0.7 psi (5 kPa) in IAEA are met.

The authorized contents are special form source capsules that meet a minimum ISO 2919-2008 classification of Class 3 for pressure. This classification is more limiting than the reduced external pressure requirement as it covers 25 kN/m^2 to 2 MN/m^2. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR and 8.7 psi (60 kPa) in 49 CFR and IAEA will not adversely affect the package containment.

Reference: ISO 2919-2008, Radiation Protection – Sealed radioactive sources - General requirements and classification.

From Section 2.6.1.3, the maximum force generated within the cavities of the 855 shield due to temperature gradients is 635 lbf. at 7 psi internal. If the 8.7 psi were then superimposed on this pressure, the stress, if taken through a single bolt, would be 18,300 psi, still significantly below the bolt's yield strength. Therefore, the reduced external pressure requirements of 3.5 psi in 10 CFR, 8.7 psi (60 kPa) in 49 CFR and IAEA will not adversely affect the package containment.

2.6.4 Increased External Pressure

Other than the Model 855 shield container, the Model 976 Series transport packages are open to the atmosphere and contain no components which could create a differential pressure relative to atmospheric conditions.

Again, the authorized contents are special form source capsules that meet a minimum ISO 2919-2008 classification of Class 3 for pressure. This classification is more limiting than the increased external pressure requirement as it covers 25 kN/m^2 to 2 MN/m^2. Therefore, the increased external pressure requirements of 20 psi in 10 CFR 71 will not adversely affect the package containment.

Further, for the Model 855 shield container has a large plate above the gasketed cavity. If we use the same logic case of a uniformly loaded plate supported on all sides (as in Section 2.4.1) we find:

$$\sigma_{max} = k\, wr^2/t^2$$

Where:

w	=	The pressure (20 psi).
t	=	The thickness of the top plate (5/16 inches)
r	=	The radius of the top plate (5 5/32 inches)
k	=	A factor for this case of flat plate (0.75). [1]

[1] - Marks Handbook, 9th edition, pp 5-52 – 5-53

Therefore, the stress generated in the top is 4,074 psi. This is below the yield strength of the steel top (36,000 psi). All other shield containers have either thicker covers or smaller areas. Therefore, the increased external pressure requirements of 20 psi in 10 CFR 71 will not adversely affect the package containment.

2.6.5 Vibration

Analysis of the 976A container will be used to justify the remaining 976 configurations as this assembly is the heaviest. The package is delivered for transport as an assembled unit. Each package is considered to be self contained as far as vibration protection is concerned. Consequently, the analysis for normal vibration during shipment in a standard or self-secured trailer is considered for an individual package.

Having the packaging mass, insulation thickness, bearing area, insulation stiffness and vibration characteristics of the trailer (self-secure trailer used in this analysis), the mean square response of the container and its contents can be determined.

The power spectral densities (PSD) for the safe-secure trailer are shown at various frequencies (Figure C1). Vertical PSD dominates the horizontal PSD. (See Appendix C of Ref. 1, listed at the end of this section.).

The 855 in the 976A package is supported by 2 inches (50.8 mm) of cork. The shield lower bearing area is 90.76 in^2 based on a 10 ¾ inch diameter. The cork density of the package is 17 lbs/ft^3 (272 kg/m^3). The Young's modulus (E) of this cork (by interpolation) is 34.8 kg/cm^2 or 495 psi (See page 4 of Ref. 2 listed at the end of this section).

The spring rate of the cork in the vertical direction can be calculated as follows (See Appendix C of Ref. 1):

$$K = \frac{AE}{L} = \frac{(90.76\ in^2)(495\ psi)}{2\ in} = 22{,}463\ \ lb/in$$

Where: A = lower bearing area = 90.76 in^2
E = Young's Modulus for cork = 495 psi
L = support thickness of cork = 2 inches

The natural frequency of the shield and insulation spring-mass system can be calculated as follows:

$$f = \left(\frac{1}{2\,\Pi}\right)\left(\frac{K\,g}{W}\right)^{1/2}$$

Where: K = cork vertical spring rate = 22,463 lb/in = 269,556 lb/ft

g = gravitational acceleration = 32.2 ft/sec^2
W = net package weight = 267 lbs

The net package weight is obtained by subtracting the outer drum weight of 33 lbs from the package weight of 300 lbs, producing a net package weight of 267 lbs.

From this the natural frequency of the spring-mass system is calculated as:

$$f = \left(\frac{1}{2\Pi}\right)\left(\frac{(269{,}556\ in/ft)\,(32.2\ ft/\sec^2)}{267\ lbs}\right)^{1/2} = 28.7\ Hz$$

Conservatively estimated damping as 10% of critical, an amplification factor (Q) can be calculated:

$$Q = \left[\left(1 - r^2\right)^2 + \left(2rd\right)^2\right]^{-1/2}$$

Where: d = damping coefficient = 0.1
$r = \omega/\omega_r$, where worst case $\omega = \omega_r$, and r = 1

This produces an amplification factor of Q = 5.

The package is in resonance at 28.7 Hz and vibration above this frequency will be mechanically filtrated (isolated). Neglecting any amplification at resonance and using Fig. C1 from Reference 1 for the PSD at this frequency, the broadband, mean square g-level of input excitation on the packaging being transported in a safe-secure trailer can be calculated. The mean square acceleration response of an oscillator (in this case the package) can be defined as:

$$\text{Mean Square} = \frac{\pi\ f\ Q\ (PSD)}{2}$$

Then the Mean Square at 28.7 Hz is $\frac{\pi\ (28.7\ Hz)(5)(0.00112)g^2}{2} = 0.252\ g^2$

Therefore, the Root Mean Square at 28.7 Hz is 0.502 g.

Maximum vibration is three to four times the root mean square, or about 1.51 g to 2.01 g. This magnitude of vibration will have little effect on the package as the package has demonstrated it can withstand greater forces under the 9 m Hypothetical Accident drop testing. (This testing is described in Test Plan 90 Report and Test Plan 163 Report Sections 2.12.2 and 2.12.3 respectively).

The largest vibration envisioned for the transport package would be due to a truck wheel or tire out of balance due to manufacture, mounting, under-inflation or damage. A truck tire with a 42 inch or 3.5 foot diameter wheel has a circumference of 11 feet. When traveling between 0 and 70 MPH, the wheels will rotate between 0 and 9.3 revolutions per second, producing vibrations between 0 and 9.3 Hz. All of these frequencies are below the package resonance of 28.7 Hz. For comparison 30 inch train wheels travelling at 0 to 70 MPH create frequencies of 0 to 14.4 Hz. Still below the packages resonance.

Other components of truck vibration due to engine or driveshaft imbalances have frequencies up to and above the resonant frequency of the package. Normal amplitudes would be very small, however, especially on large trucks where these vibrations are separated from the cargo by the trailer hitch. If the amplitude of these vibrations were large, the truck would most likely break down. Airplane turbine vibrations are very high frequency, above the primary resonant frequency of the package, and very low in amplitude. (For reference 1 MPH = 1 mile/hour * 5280 feet/mile * 1 hour/3600 sec = 1.47 feet/sec).

Further, the inner shield designs used in the Model 976 Series transport packaging have been used in Type B shipments on trucks, trains and planes for decades without vibration induced failure of any shield fasteners. Shield fasteners on these containers were functionally inspected prior to use to check thread condition and engagement and general fastener condition (e.g., not bent or damaged). The same or similar fasteners on the shield containers and the outer drum assembly have been used for many transport shipments under these inspection conditions without failure of any kind in use (See Section 1.2.1 for prior transport approval references).

The steel drum and lid closure band are established designs used routinely in transport which can reasonably be expected to withstand the vibration normally incident to transport. The Model 976 Series packages also incorporate an additional level of drum securement by means of four drum lid bolts that further secures the package containment during transport. The cork used in the drum liner inserts has also been used in Type B transport packages in the United Kingdom for decades again with no degradation in the material integrity over time due to vibration during shipment. It is therefore concluded that the Model 976 Series packages will withstand vibration normally incident to transport.

References:

1. Safety Guide 100. "The Guide for Packaging and Offsite Transportation of Nuclear Components, Special Assemblies, and Radioactive Materials Associated with the Nuclear Explosives and Weapons Safety Program." Martin Marietta Energy Systems, Inc., Oak Ridge, TN 37830, November 7, 1994.

2. Antonio P.O. Carvalho, Ph.D, "Cork as a lightweight partition material…", Civil Engineering Department, College of Engineering, University of Porto, Portugal, 1997.

2.6.6 Water Spray

The Model 976 Series transport packages are constructed of water-resistant materials throughout. Therefore, the water spray test would not reduce the shielding effectiveness or structural integrity of the package.

2.6.7 Free Drop

The drop test pad used in the multiple 1.2 m free drop, 9 m drop, and puncture tests complied with the requirements of 10 CFR 71.71(c)(7) and 71.73(c). Before and after testing the drop pad is visually inspected for damage which could have a significant impact on package testing.

Test specimen TP90A was subjected to the 1.2 meter (4 foot) free drop as described in Test Plan 90 Report (Section 2.12.2). The orientation of the 1.2 meter (4 foot) free drop was selected because of its potential to cause significant deformation of the closure bolt assembly in an effort to open the drum. The specimen was dropped at approximately a 45° angle with the closure bolt down. The test specimen temperature was less than -40°C (-40°F). Photographs of the drop orientation are provided in the Test Plan 90 Report (Section 2.12.2).

The test specimen impacted the test pad as intended. Very little damage to the drum was noted. The bottom of the drum was scuffed and slightly bowed out. Upon disassembly, the cork liner had fractured and separated at the base. The Model 855 was undamaged. Profile results of the Model 855 unit without the drum assembly were within regulatory limits for normal transport (see Section 5.1). The 855 is the heaviest container used in the Model 976 Series packages. Damage to test unit TP90A was determined to be more severe then would be expected for any other inner shield configuration in the package series, therefore representative of all packages in the series.

As described in Test Plan 90 Report, test specimens TP90B and TP90G were dropped at an angle onto the lid and drum edge causing them to buckle inward. The heavier test specimen (TP90B containing an 855 shield container, with a total package weight of 276 lbs) was dropped at a 45° angle. The deformation in TP90B was about 2 ¼ inches deep. The lid and drum rim buckled inward, folded together and an air gap was created. The cork was cracked by this buckling, but the shield container inside was undamaged.

As described in Test Plan 163 Report (Section 2.12.3), the Model 976 Series drum assembly was redesigned to incorporate four (4) bolt blocks welded to the underside of the lid and four (4) lid closure bolts which are inserted through clearance holes in the

drum sides and secure into these bolt blocks on the lid. This modification provides a secondary safety mechanism should the lid clamp band fail under the Hypothetical Accident test conditions and provides added bracing to the inside of the drum which reduces buckling deformation.

In described in Test Plan 163 Report (Section 2.12.3), all the test specimens were dropped at angles (either 17.5° or 45°) onto the lid and drum edge. The buckling observed was less than seen for the test specimens under Test Plan 90 Report (Section 2.12.2). Test specimen TP163(A) containing an 855 shield with a total test specimen weight of 298 lbs was dropped at a 45° angle. The deformation in this test specimen was 1 ¾ inches deep. The lid and drum rim were flattened together but no air gap was created. The interior cork was cracked by the drum deformation but held in place by the drum structure and the inner shield container was undamaged.

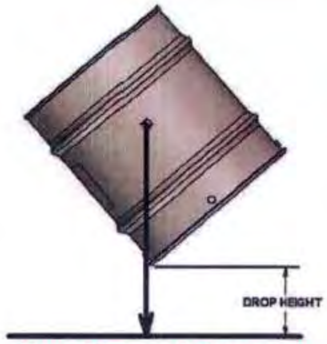
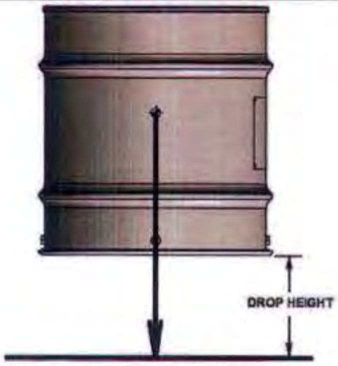
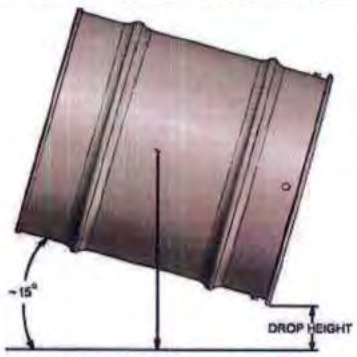
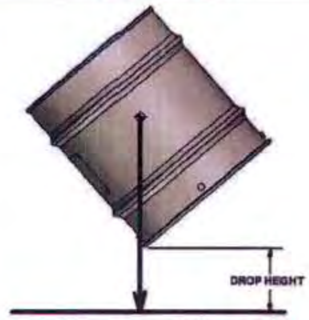
Additional testing was performed under Test Plan 214 (Section 2.12.10) to assess an alternate clamp band construction for the transport package designs. Six test specimens were tested to the normal condition drop test criteria as described under Test Plan 214 Report (Section 2.12.11). The test specimens evaluated the package performance under the following modified configurations:

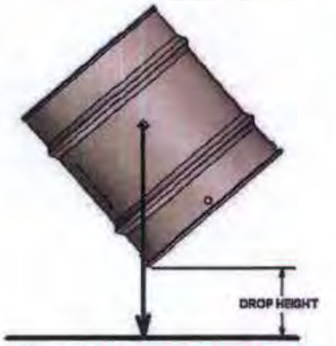
- The same as currently approved but without use of a clamp band on the drum.
- The same as currently approved but without use of a clamp band on the drum and with floating nuts replacing the fixed nuts welded to the cover.
- The same as currently approved but with the approved clamp band replaced by a standardly available clamp band.

Testing to the Normal Condition Drop test criteria was carried out as described in Table 2.6.7.a:

Table 2.6.7.a: Normal Transport Drop Test Results for Test Plan 214

Specimen	Package Configuration	Drop Test Orientation	Test Results
TP214-NCB-1	Without Clamp Band	 Bottom Surface Orientation	No damage identified. Cover remained secured, bolts intact, no lid/base gaps.

Specimen	Package Configuration	Drop Test Orientation	Test Results
TP214-NCB-2	Without Clamp Band	 Top Corner Orientation	Slightly crushed cover and drum edge, about 0.5-inch. Cover remained secured, bolts intact, no lid/base gaps.
TP214-NCB-3	Without Clamp Band	 Top Surface Orientation	No damage identified. Cover remained secured, bolts intact, no lid/base gaps.
TP214-NCB-4	Without Clamp Band	 15° Shallow Angle Orientation	Slight flattening of drum outer wall. Cover remained secured, bolts intact, no lid/base gaps.
TP214-FSB-1	Without Clamp Band Fixed Lid Nuts Replaced with Floating Lid Nuts	 Top Corner Orientation	Minor crushed cover and drum edge. Cover remained secured, bolts intact, no lid/base gaps.

Specimen	Package Configuration	Drop Test Orientation	Test Results
TP214-ASB-1	Approved Clamp Band Replaced with Standardly Available Clamp Band	 Top Corner Orientation	Minor crushed cover and drum edge. Cover remained secured, bolts intact, no lid/base gaps.

As assessed in this Section, and under Test Plan 163 Report (Section 2.12.3) and Test Plan 214 Report (Section 2.12.11), the modifications to the drum securement described in these test plans will not adversely impact the testing results performed under Test Plan 90 Report. Therefore, the Model 976 Series packages, as described in the drawings contained in Section 1.3, will comply with the requirements of 10 CFR 71.71(c)(7).

2.6.8 Corner Drop

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

2.6.9 Compression

The Test Plan 90 Report (Section 2.12.2) documents that the Model 976 Series transport package maintained its structural integrity and shielding effectiveness under the Normal Conditions of Transport compression test. The TP90A test specimen was subjected to a compressive load of 1,465 lbs (664.5 kg) for a period of 24 hours. Assessment of the package to five times the maximum package weight of 300 lbs (136 kg) is contained in Test Plan 163 Report (Section 2.12.3). This assessment demonstrates that the Model 976 Series packages will comply with the requirements of this section even at the increase package weight based on that the physical testing performed in Test Plan 90 Report. The actual compressive weight of 1,465 lbs (664.5 kg) and the maximum calculated compressive weight of 1,500 lbs (680 kg) are greater than 13 kPa (2 lb/in^2) multiplied by the vertically projected area of the transport package. Following the compression test in Test Plan 90 Report, no damage to the specimen was observed.

Configurations evaluated under Test Plan 214 (Section 2.12.10), were assessed for conformance based on compression test results performed under Test Plan 90.

2.6.10 Penetration

Test specimen TP90A was subjected to a penetration test, as described in Test Plan 90 Report (Section 2.12.2). The penetration bar impacted as intended. The bar bent the closure bolt slightly and left a slight impression on the threads. No other damage was noted. There was no loss of structural integrity or reduction of shielding efficiency as a result of the impact. As assessed under Test Plan 163 Report (Section 2.12.3) and Test Plan 214 (Section 2.12.10), the drum modifications covered by these test plans will have no impact on the results of the testing performed under Test Plan 90 Report. Therefore, the Model 976 Series packages as described in the drawings contained in Section 1.3 will comply with the requirements of 10 CFR 71.71(c)(10).

2.7 Hypothetical Accident Conditions of Transport

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

Nine (9) test specimens were used to conduct the hypothetical accident tests. Each test specimen consisted of a separate drum and set of cork inserts. Under Test Plan 90, two (2) Model 855 shield containers were used in two (2) separate Free Drop and Puncture tests. A third test configuration, under Test Plan 163 Report (Section 2.12.3) was conducted with a Model 1911 shield container. Six (6) additional test specimens consisting of separate drum/cork inserts but using the same 855 shield container, were tested to the Free Drop and Puncture test requirements under Test Plan 214 Report (2.12.11).

2.7.1 Free Drop

Justification for all test unit drop orientations are included in Test Plan 163 Report (Section 2.12.3) and Test Plan 214 (Section 2.12.10).

2.7.1.1 End Drop

This orientation was used for some of the test samples under Test Plan 90 Report (Section 2.12.2) and Test Plan 214 Report (Section 2.12.11). Results of this testing detailed under Test Plan 90 Report produced less damage to the package than was seen in the other drop orientations, therefore additional End Drop testing was not performed for test specimens under Test Plan 163 Report (2.12.3).

2.7.1.2 Side Drop

The side drop was not performed. In a side drop, most of the energy generated at impact is used in deforming the outer package and is not transmitted into the shield. A side drop would deform the outer drum resulting in a very slow deceleration, thus limiting the energy generated at impact and transmitted to the shield.

2.7.1.3 Corner Drop

Although the 976 Series package is a drum which does not have corners, the lid/drum interface was impacted under Test Plan 214 Report (Section 2.12.11) to evaluate the impact of changes to the lid securing mechanisms. See Test Plan 214 (Section 2.12.10) for justification of this drop orientation.

2.7.1.4 Oblique Drops

This orientation was used for five (5) of the test samples. Test samples were evaluated at three orientations, 45° impacts, 17.5° impacts and 15° impacts. See Test Plan 90 Report (Section 2.12.2), Test Plan 163 Report (Section 2.12.3) and Test Plan 214 (Section 2.12.10) for justification of these drop orientations.

2.7.1.5 Summary of Results

See Table 2.7.8.1 for test unit results summary.

2.7.2 Crush

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

2.7.3 Puncture

The puncture bar is a 6 inch diameter x 12 inch long, mild steel solid bar attached to a 12 inch x 12 inch x ½ inch thick mild steel base. The bar is attached to the base with a ¼ inch circumferential fillet weld (Reference drawing T10119). The puncture is attached to the drop test pad steel plate by four ½"-13 x ¾" long stainless steel bolts.

Justification for all test unit puncture orientations are included in Test Plan 90 Report (Section 2.12.2), Test Plan 163 Report (Section 2.12.3), and Test Plan 214 (Section 2.12.10) and Test Plan 214 Report (Section 2.12.11).

2.7.4 Thermal

Because no damage occurred during the Hypothetical Accident Conditions of Transport Tests that could result in oxidation of the DU shield or melting of the lead or tungsten shielding, thermal testing was not performed on the 976 Series test specimens. See Test Plan 163 Report (Section 2.12.3) and Test Plan 214 Report (2.12.11) for a more detailed justification and assessment of compliance for the Model 976 Series packages to these requirements.

2.7.4.1 Summary of Pressures and Temperatures

Table 2.7.4.1.a: Summary Table of Temperatures

Surface Temperature Condition	Model 976 Series Packages	Cork Inserts	Shield Containers
Fire Test During	90.3°C to 800°C[3] (195°F to 1,472°F)	109.4°C to 800° C[4] (229°F to 1,472°F)	109.4°C to 159° C[2] (229°F to 318°F)
Post-Fire (Maximum Temperature)	800°C[1] (1,472°F)	800° C[1] (1,472°F)	159°C[2] (318°F)

[1] – From actual testing of similar packages. Reference Section 2.12.3 (See section 5.5 of Test Plan 163 Report)

[2] – Maximum temperature based on thermal increase of 50°C seen in actual package testing (See section 5.5 of Test Plan 163 Report – Section 2.12.3).

[3] – Maximum initial temperature of the package assumed to be bounded by the external surface reading of the Model 976 package in full sun (insolation).

[4] – Maximum initial temperature of the cork inserts assumed to be bounded by the calculated external surface temperature of the shield container for the package.

All outer drum components are vented to atmosphere. As such, no pressure will build up in the units under Hypothetical Accident conditions. However, the Model 855 shield container does have a small gasketed cavity. As noted below, the Model 855 shield container will not develop sufficient internal pressure to detrimentally effect the device.

Table 2.7.4.1.b: Summary Table of Maximum Pressures

Package Configuration	Void Volume in^3	Fire Conditions 800°C (1,472°F) Pressure Developed	Comments
976A	285	14 psig[1,2]	¼" steel cover retained with (8) 3/8" bolts
976C	0	0 psig[2,3]	J-Tubes without sealed cover
976F	21	0 psig[2,3]	4 mm steel cover retained by (4) M8 bolts

[1] – Pressure at 171°FC (350°F). After which the gasket will burn and allow release of any pressure.

[2] – Initial temperature taken to be -40°C as a worst case scenario.

[3] – No gasket to seal void, pressure equal to ambient.

2.7.4.2 Differential Thermal Expansion

Actual testing on similar packages has shown that any differential thermal expansion has no detrimental effect on the packages ability to pass the thermal testing portion of the Hypothetical Accident Conditions.

For the Model 976 package in whole, under the Nycomed Amersham plc. Test 1835, two (2) damaged drums were fire tested (See Test Plan 163 Report Appendix F as contained in Section 2.12.3 of this document). These drums are very similar in design to the Model 976). The tested drum measured 32.5 cm in diameter by 40.5 cm tall with minimum cork thickness on the bottom of 4 cm, on the top of 4.5 cm and on the sides of 5 cm. In contrast the Model 976 package measures 50 cm in diameter by 54 cm tall. The Model 976 Series packages have a minimum cork thickness, which is based on the Model 976A configuration containing the least cork material, of 5 cm on the bottom, 12.7 cm on the top and 8.3 cm on the sides. Neither of the packages tested under Test 1835 opened, burst or were otherwise compromised. Both test units easily passed.

It can be drawn from these actual testing results that thermal expansion will not have a significant effect on the Model 976 Series packages.

Expansion of the package circumference is approximated by:

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

Where: D = Outer Diameter of the drum at the top = 19 ¼"
α = Material Coefficient of Thermal Expansion
ΔT = Fire temperature differential (from 688F to 1,4758F)

Substituting gives: $E = \pi(19\ ¼")(9.9\ \mu in/in8F)(1{,}4048F) = 0.84$ in drum
$E = \pi(18")(100\ \mu in/in8F)(1{,}4048F) = 7.9$ in cork

This translates to a diameter increase of 0.26 inches for the drum and 2.5 inches for the cork. Since the cork modulus of elasticity is more than 5,000 times less than stainless steel (0.032 Pa versus 210 GPa, from Mechanics of Materials, Fall 1999), the drum will keep the cork compressed within its volume. This was shown experimentally in Nycomed Amersham plc. Test 1835 (See Section 2.12.3 Test Plan 163 Report Appendix F). The lid closure band and lid will expand at approximately the same rate as the drum, thus maintaining the security of the package.

2.7.4.3 Stress Calculations

As was shown in Section 2.7.4.2, thermal differentials will have no detrimental effect on the interfaces between the outer drum, cork inserts and shield containers.

Stresses may develop within the gasketed cavity of the Model 855 shield container. The Model 976A with the Model 855 shield container, is described below. Assuming a perfect seal and no escaping gasses, then no pressure will exist after ~350°C since the gasket will burn away and allow release of any pressure.

The force on the cover bolts is estimated by:

$$F = (\pi D^2/4)P$$

Where: D = Diameter of the shield cover over the void = 10.3 in
P = Pressure induced by the thermal gradient = 14 psig (From Table 2.7.4.1.b)

Therefore: $F = \pi(10\ \tfrac{3}{4}\ \text{in})^2/4(14\ \text{psig}) = 1{,}167\ \text{lbf}$

The cover is held by eight (8) 3/8-16 stainless steel bolts. This imparts a force of 158 lbf in each bolt. However, if all the stress is assumed to be taken by only two bolts, then the stress in those bolts equals:

$$S = F/A\#$$

Where: F = Force in each bolt
A = Stress area of the bolt = 0.0775 in^2
\# = Number of bolts = 2

Solving for the bolt stress produces:

$$S = 1{,}470\ \text{lbf}/0.0775\ \text{in}^2(2) = 9{,}483\ \text{psi}$$

This value is well below the tensile strength value for an un-graded stainless steel bolt (75,000 psi nominal). Although the strength of stainless steel would decrease at this temperature, it would still be much greater than the induced stress. All other shield containers would have lower stresses as they have significantly smaller areas.

2.7.4.4 Comparison of Allowable Stresses

All stresses calculated in Section 2.7.4 are well below strengths for the materials of construction. Further, the Model 976 Series package was fully tested and passed under Normal and Hypothetical Accident Conditions of transport. It is therefore concluded that the Model 976 Series package will satisfy the performance requirements specified by the regulations.

2.7.5 Immersion - Fissile Material

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

2.7.6 Immersion - All Packages

Other than the Model 976A package with the 855 shield container, the Model 976 Series transport packages are open to the atmosphere and contain no other components that would create a differential pressure under immersion. All materials are impervious to water and would not be affected.

The Model 976A with the 855 shield containers has a cavity with a neoprene gasket. If the neoprene gasket remains intact, the package would be subjected to an increased external pressure of 21.7 psig (10 CFR) and 290 psi (IAEA). The Model 855 shields will withstand this pressure without loss of structural integrity.

If a gasket fails, the cylindrical special form source (primary containment) will be vulnerable to collapse due to the required assumed pressure increases of 21.7 psig and 290 psi for the respective regulatory references. The primary containment system in these packages is a special form source, which minimally meets the ANSI N43.6-2007 and ISO 2919:2012(E) requirements for Class 3 pressure testing (2 MPa absolute). Therefore the Models 976 Series packages could withstand the immersion test criteria since the Class 3 pressure test requirements of the source capsule are in excess of the required 21.7 psig and 290 psi.

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

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

2.7.8 Summary of Damage

Table 2.7.8.1 summarizes the results of the Normal Conditions of Transport and Hypothetical Accident testing performed on the Model 976 Series transport packages.

Table 2.7.8.1: Summary of Damages During Test Plan 163 and Applicable Portions of Test Plan 90 and 214

Specimen	Test Performed	Test Results
TP90A 855 sn 9	Compression test	No damage
	1 meter (40 inch) penetration bar closure bolt assembly	Bolt on the retaining ring was bent with witness marks on threads. No other damage.
	1.2 meter (4 foot) closure bolt assembly down. ~45° angle.	• Bottom of drum scuffed and slightly bowed out.
	Post-Drop Inspection	• Cork liner cracked and separated at the base but still held form inside the drum. • Model 855 undamaged. • Unit profiled after Type B testing. Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter after both normal transport and hypothetical accident condition testing. (See Section 2.12.2)
TP163(A) 855 sn 8	9 meter (30 foot) drop, lid closure band assembly down. 45° angle	• Lid closure band bolt assembly was crushed. • Lid closure band bolt broken. • Drum lid and top of the drum were creased together and folded under the bolt assembly. • Side of the drum slightly flattened and the bottom ring weld dented. • Drum lid closure bolts intact.
	1 meter (40 inch) puncture, opposite side of closure bolt, 45° angle	• Popped lid closure band off drum. Lid still secured by the 4 lid closure bolts. • Some minor denting on the side of the lid and drum.
	Post-Drop Inspection	• Model 855 undamaged. • Cork cracked but still held form inside drum. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.3 and Section 5.1.2)
TP163(B) 855 sn 9	9 meter (30 foot) drop, lid closure band bolt assembly up. 17.5° angle	• Lid closure band was flattened. • Drum lid and top of the drum were creased together and folded under the lid closure band. • Side of the drum slightly flattened and the bottom ring weld dented. • Lid closure band bolt as well as drum lid closure bolts intact.

Specimen	Test Performed	Test Results
	1 meter (40 inch) puncture, opposite side of lid from lid closure band bolt, 17.5° angle	• Unit dropped twice to achieve desired impact point. • Two witness marks on the side of the drum opposite the bolt, near the lid closure band. • Witness mark on the lid closure band opposite bolt. • Lid closure band bolt as well as drum lid closure bolts intact.
	Post-Drop Inspection	• Model 855 undamaged. • Cork cracked but still held form inside drum. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.3 and Section 5.1.2).
TP163(C) 1911 sn 13	9 meter (30 foot) drop, lid closure band bolt assembly up. 17.5° angle	• Lid closure band was flattened. • Drum lid and top of drum were creased together and under the lid closure band. • Side of the drum slightly flattened and the bottom ring weld dented. • Lid closure band bolt as well as drum lid closure bolts intact.
	1 meter (40 inch) puncture, same impact point as 9 m drop, 17.5° angle	• Dent from 9 meter impact increased. • Slight dent in side of drum. • Lid closure band bolt as well as drum lid closure bolts intact.
	Post-Drop Inspection	• Model 1911 undamaged. • Cork cracked but still held form inside drum. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.3 and Section 5.1.2).
TP214-NCB-1 855 sn 10	1.2 meter (4 foot) bottom surface orientation	• No Damage. • Cover remained secured, bolts intact. • Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter.
	9 meter (30 foot) drop, bottom surface orientation	• Slight compression dent on outer side wall & drum base. • Cover remained secured, bolts intact.
	1 meter (40 inch) puncture, bottom surface orientation	• No additional damage.
	Post-Drop Inspection	• Model 855 undamaged. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.11).

Specimen	Test Performed	Test Results
TP214-NCB-2 855 sn 10	1.2 meter (4 foot) bottom surface orientation	• Slightly crushed cover and drum edge ~0.5 inch. • Cover remained secured, bolts intact. • No lid/base gaps. • Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter.
	9 meter (30 foot) drop, bottom surface orientation	• Significantly crushed cover and drum edge. • Cover remained secured, bolts intact. • No lid/base gaps.
	1 meter (40 inch) puncture, bottom surface orientation	• No additional damage.
	Post-Drop Inspection	• Model 855 undamaged. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.11).
TP214-NCB-3 855 sn 10	1.2 meter (4 foot) bottom surface orientation	• No Damage. • Cover remained secured, bolts intact. • Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter.
	9 meter (30 foot) drop, bottom surface orientation	• Slight outer drum wall compression. • Cover remained secured, bolts intact. • No lid/base gaps.
	1 meter (40 inch) puncture, bottom surface orientation	• No additional damage.
	Post-Drop Inspection	• Model 855 undamaged. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.11).
TP214-NCB-4 855 sn 10	1.2 meter (4 foot) bottom surface orientation	• Slight flattening of drum outer wall. • Cover remained secured, bolts intact. • Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter.
	9 meter (30 foot) drop, bottom surface orientation	• Significant flattening of drum outer side wall. • Cover remained secured, bolts intact. • No lid/base gaps.
	1 meter (40 inch) puncture, bottom surface orientation	• Imprint of puncture billet on drum. • No other additional damage.
	Post-Drop Inspection	• Model 855 undamaged. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.11).

Specimen	Test Performed	Test Results
TP214-FSB-1 855 sn 10	1.2 meter (4 foot) bottom surface orientation	• Minor crushed cover and drum edge. • Cover remained secured, bolts intact. • Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter.
	9 meter (30 foot) drop, bottom surface orientation	• Two gaps between cover & drum created ~180 degrees apart. Each gap ~ 0.3 inch wide maximum, tapering down to no gap. Each gap ~6 inches long. • Cover remained secured, bolts intact.
	1 meter (40 inch) puncture, bottom surface orientation	• No additional damage.
	Post-Drop Inspection	• Model 855 undamaged. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.11).
TP214-ASB-1 855 sn 10	1.2 meter (4 foot) bottom surface orientation	• Minor crushed cover and drum edge. • Cover remained secured, bolts intact. • Surface and 1 meter dose rates remained within limits of 200 mR/hr at the surface and 10 mR/hr at one meter.
	9 meter (30 foot) drop, bottom surface orientation	• Significant cover & drum edge crushed. • Cover remained secured, bolts intact. • No lid/base gaps.
	1 meter (40 inch) puncture, bottom surface orientation	• No additional damage.
	Post-Drop Inspection	• Model 855 undamaged. • 1 meter dose rates remained within limit of 1 R/hr (See Section 2.12.11).

Based on these results and assessments for the remaining Model 3056 & 1911 shield containers addressed in this testing, it is concluded that the Model 976 Series transport packages maintain structural integrity and shielding effectiveness during Hypothetical Accident Conditions and Normal Conditions of Transport when assembled for transport in accordance with the drawings contained in Section 1.3 and when using either clamp band described on drawing RCLM009 or RCLM011.

2.8 Accident Conditions for Air Transport of Plutonium

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

2.9 Accident Conditions for Fissile Material Packages for Air Transport

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

2.10 Special Form

The Model 976 Series transport packages are designed for use with a variety of special form source capsules. Typical special form sources transported in these containers include the Models 875XX, X540/1, 900 Series, X444, X9103 etc. Based on performance testing, any source capsule that has been tested and achieved special form classification from a Competent Authority can be safely transported in the Model 976 Series packages so long as the capsule dimensions fit and secure within the applicable shield container. Therefore, any source capsule meeting these criteria should be approved for transport without requirement of amendment to the Type B(U) certification.

Examples of typical special form certifications, including the current approved capsule drawings, are included in Section 2.12

2.11 Fuel Rods

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

2.12 Appendix

2.12.1 AEA Technology plc. RMR 214 Issue 5, Raw Material Requirement, (RMR) Cork for Transport Containers

2.12.2 Test Plan 90 Report Revision 2 dated April 2005 (minus Appendix B-D).

2.12.3 Test Plan 163 Report Revision 1 dated April 2005 (minus Appendix C).

2.12.4 USDOT Special Form Certificate USA/0392/S-96 Rev 12

2.12.5 USDOT Special Form Certificate USA/0335/S-96 Rev 12

2.12.6 USDOT Special Form Certificate USA/0502/S-96 Rev 11

2.12.7 USDOT Special Form Certificate USA/0179/S-96 Rev 12

2.12.8 USDOT Special Form Certificate USA/0497/S-96 Rev 6

2.12.9 USDOT Special Form Certificate USA/0805/S-96 Rev 0

2.12.10 Test Plan 214 Rev 0 dated July 2017

2.12.11 Test Plan Report No. 214 dated March 2018 (minus Appendices C and D).

Section 2.12.1 Appendix: AEA Technology plc RMR 214 Issue 5, Raw Material Requirement, (RMR) Cork for Transport Containers

AEA Technology plc

Quality and Safety Assurance

Raw Material Requirement, (RMR)

Title	:	Cork for Transport Containers	
Prepared by	:	[signature]	Date: 8/12/01
Approved by	:	C. Hendry Quality Assurance	Date: 18.12.2001

Scope

This document gives detail of the specification and approval procedure for cork used as part of transport containers used for the transportation of radioactive material. The cork in a number of shapes and sizes defined in Packaging Group (International Division) manuals.

Contents

1. Specification

   Compressed cork manufactured with resin binder and medium sized cork granules. See attached.

2. Sample Procedure

   One item per batch

3. Test Schedule

   Check dimensions to drawing
   Check density – see 1.2 under specification
   Check paperwork – see 1.11

4. Approval Procedure

   QCP 100
   (All cork used by AEA Technology QSA is approved by QSA)

1. Specification

1.1 Resin type: Urea formaldehyde

1.2 Density: 270kg/m^3 (17ib/cu ft)

1.3 Tensile Strength: 5.5kg/cm^2 min (80lb/in^2 min)

1.4 Compressibility: 7.0kg/cm2 (100lb/in2) expressed in % 20-40

1.5 Recovery: 80% min, dimensional change 1.5%

1.6 Flexibility: No breakage

1.7 Fluid resistance: 3 hours in boiling water – no disintegration, 24 hours in test fuel at room temperature – no disintegration

1.8 Bonding between segments: Urea formaldehyde resin. Clamp for six hours or until fully set.

1.9 Example of material: Chingford 22

1.10 Identification: Each item must be identified with a batch number, e.g. month/year.

1.11 Documentation: AEA Technology order will include reference to this specification its issue number, the appropriate drawing number and issue number. Copies of the documents are available on request.

Certificate of Conformity is required, cross referencing at least the specification number, the order number and batch number.

1.12 Each item within a batch must be identified with a batch number to indicate the month and year of manufacture e.g. 0588.

Section 2.12.2 Appendix: Test Plan 90 Report Revision 2 dated April 2005 (minus Appendix B-D).

TEST PLAN 90 Report
Revision 2

MODEL 976
TYPE B
TRANSPORT PACKAGE

AEA Technology QSA Inc.
40 North Avenue
Burlington
MA 01803

April 2005

Department	Printed Name	Signed Name	Date
Originator	STEPHEN FORASTE	Stephen Foraste	14 APRIL 2005
Engineering	H.R. KACZOWKA	HR Kaczowka	14 APRIL 2005
Quality Assurance	C. Roughan	C. Roughan	15 Apr 05
Regulatory	L. Podolak	L. Podolak	15 Apr 05

CONTENTS

Section 1. Purpose

The purpose of this test was to qualify the design of the Model 976 Transport Drum to Type A and Type B transport requirements through testing or analysis, either reasoned or calculated. The majority of the samples were subjected to the most onerous portion of Hypothetical Accident Conditions, the drop sequence (9m (30-foot) and 1m (~3-foot) puncture). The resultant damage from the drop, along with results of thermal testing conducted in the UK is used to assess the packages response to the thermal portion of the test sequence.

Model 97630 specimen TP90A through TP90E were tested on 05 FEB 2002. Models 97633 specimen TP90F and Model 97636 specimen TP90G were tested on 13 FEB 2002.

Test specimen TP90A was tested for Normal Transport conditions and test samples TP90B through TP90G were tested and/or assessed for Hypothetical Accident Conditions in accordance with 10 CFR Part 71 and IAEA TS-R-1 (1996 Edition).

Section 2. Scope of Testing

Section 2.1 Normal Conditions of Transport

The tests for Normal Conditions of Transport described in 10 CFR 71.71 are the compression test, penetration test and 1.2m (4-foot) free drop test. Test Specimen TP90A (Model 855) was used in the following tests.

2.1.1 Compression Test

One test performed, described in the following sections.

2.1.2 Penetration Test

One test performed, described in the following sections.

2.1.3 1.2m (4-foot) Free Drop Test

One test performed, described in the following sections.

2.1.4 The Water Spray Preconditioning

Not necessary as the Model 976 Transport Drum, in all its configurations, is constructed of waterproof materials throughout. The water spray would not contribute to any degradation in structural integrity.

Section 2.2 Hypothetical Accident Conditions

The Hypothetical Accident Tests described in 10 CFR 71.73 are the 9m (30-foot) drop, the 1m (~3-foot) puncture drop and thermal test.

The crush test described in 10 CFR 71.73(c)(2) does not apply and therefore was not performed. Items transported in the drum are sources qualified as Special-Form radioactive material or empty devices with depleted uranium, lead or tungsten shielding.

2.2.1 9m (30-foot) Drop Test

Seven (7) tests were performed (one unit was dropped twice). They are described in the following sections.

2.2.2 1m (~3-foot) Puncture Trop Tests

Six (6) tests were performed. They are described in the following sections.

2.2.3 Thermal Test

The response of the package, in its various configurations, to the thermal test of 10 CFR 71.73(c)(4) is assessed in the following sections.

The shield container Models 3056, 3078, 3015 and 3018 have been used in the field for over twenty (20) years without incident or problem as part of USDOT Type B endorsements of Great Britain Type B(U) approved packages. The Model 855 has been used in the field for over twenty (20) years without incident or problem as part of a USNRC and USDOT Type B approval. These containers and their associated Type B endorsement certifications are listed in Figure 1.

Inner Shield Container	USNRC Type B(U) Certificate	USDOT Type B(U) Endorsed Certificate	Great Britain Type B(U) Certificate	Intended Model 976 Package Designation
855	USA/9165/B(U)	USA/9165/B(U)	None	976A
3015	None	USA/0590/B(U)-85	GB/3605A/B(U)-85	976B
3018	None	USA/0592/B(U)-85	GB/3605B/B(U)-85	976D
3056	None	USA/0316/B(U)	GB/0924BZ/B(U)	976C
3078	None	USA/0250/B(U)	GB/0924BP/B(U)	976E

FIGURE 1 – CROSS REFERENCE TABLE OF INNER SHIELD CONTAINER TRANSPORT APPROVAL HISTORY

Section 3. Test Unit Descriptions

All specimens were prepared per Test Plan 90 (See Figure 2). Test specimens were fabricated and designed using the same materials, methods and quality assurance as the ones to be used in the transportation package. Route cards in Appendix C document the materials and methods of fabrication/acceptance of package components. All test specimens were subjected to the same design and quality assurance requirements as are required for approved Type B packaging under AEA Technology QSA, Inc. USNRC Quality Assurance Program Number 0040. Any discrepancies from the criteria specified in Test Plan 90 are listed below in the sections specific to the specimens.

Two (2) Model 855 units were used in the testing. Serial number 8 was used in Specimens TP90C and TP90E. Serial number 9 was used in Specimens TP90A, TP90B and TP90D. Separate drums and cork inserts were used for each Specimen.

The locks in the Model 855 serial number 8 were fitted to hold eight (8) 424-9 style source assemblies. Four of the locks in serial number 9 were modified (spacers inserted) to hold 969 style source assemblies. The modified positions were alternated with un-modified locks. If there was any direction biased damage, the shimmed locks would be affected.

All units were less labels and seal wires. The labels would have no effect on the packages ability to withstand any of the testing. Labels that are to be installed are of a standard design which has been shown to pass all physical and thermal testing. Holes drilled in the drums to attach the label would perform in a manner similar to the larger holes drilled in the test units for the thermocouple wires. The omission of the seal wire is a worst case scenario. If installed, the wire would only help to hold the lid clamp band together.

Three (3) thermocouples were attached to each Specimen; one internal to the shield, one to the inside of the cork insert cavity and one to the outside of the drum. The drum thermocouple was attached with a small screw threaded into the lid. A hole was cut in the lid of the drums to allow access to the internal thermocouples. Any material removed, or holes cut into the device will only serve to exacerbate the stresses induced during impact and would constitute a worse case scenario for the package. Production packages will not have these holes.

Test Specimen	Drawings Referenced	Test Condition	Comments	Source Assemblies in Test Specimen During Normal and Hypothetical Test Conditions[1]
TP90 (A)	B97630 Rev 2 D85501 Rev G R42409 Rev C 96900XL Rev A	Normal	Model 855 transport package Sn. 9 Contains a Model 855 source changer	Four, Inactive Model 424-9 source wire assemblies and Four, Inactive Model 969 source wire assemblies.[2]
TP90 (B)	B97630 Rev 2 D85501 Rev G R42409 Rev C 96900XL Rev A	Hypothetical	Model 855 transport package Sn. 9 Contains a Model 855 source changer	Four, Inactive Model 424-9 source wire assemblies and Four, Inactive Model 969 source wire assemblies.
TP90 (C)	B97630 Rev 2 D85501 Rev G R42409 Rev C	Hypothetical	Model 855 transport package Sn. 8 Contains a Model 855 source changer	Eight, Inactive Model 424-9 source wire assemblies
TP90 (D)	B97630 Rev 2 D85501 Rev G R42409 Rev C 96900XL Rev A	Hypothetical	Model 855 transport package Sn. 9 Contains a Model 855 source changer	Four, Inactive Model 424-9 source wire assemblies and Four, Inactive Model 969 source wire assemblies.
TP90 (E)	B97630 Rev 2 D85501 Rev G R42409 Rev C	Hypothetical	Model 855 transport package Sn. 8 Contains a Model 855 source changer	Eight, Inactive Model 424-9 source wire assemblies
TP90 (F)	B97633 Rev 2 D61610 Rev F B60006X Rev J	Hypothetical	Model 616 transport package Sn. 402 Contains a Model 616 Projector	One, Inactive Model 60006 source capsule.
TP90 (G)	B97636 Rev 2 3A21773 Rev B R42409 Rev C	Hypothetical	Model 3056 family transport package. Contains a Model 3056 Lead Pot Sn. P0745-060	Ten, Inactive Model 424-9 source wire assemblies

[1]Note: Active radiation sources contained in the test specimens during the pre and post-testing radiation profiles are identified in Section 6.0 of this report. Inactive sources comply with the applicable source drawings referenced above, however, the sources were manufactured without the addition of Ir-192.

[2]Note: The inactive source wire assemblies were not present in this test specimen during performance of the compression test. See Section 3.1.

FIGURE 2. TABLE OF SPECIMEN CONSTRUCTION DATA

Section 3.1 Test Specimen TP90A

This unit was subjected to the Normal transport condition testing.

The unit was tested with four (4) inactive 424-9 style sources and four (4) inactive 969 style sources for the penetration and 4-ft drop. These sources simulate the maximum carrying capacity and the varied type of sources transported. The inactive sources were not installed prior to the compression test. However, the compression weight used in the test was sufficiently great to encompass the additional weight the sources would have contributed. Further, as there was no damage to the outer package post test, the omission of the sources within the device would have had no influence on the outcome of the test.

The gross weight of the Model 976 Specimen TP90A was 278 lbs. Drawings may be found in Appendix A.

FIGURE 3. MODEL 855 IN MODEL 976 OUTER DRUM

Section 3.2 Test Specimen TP90B

This unit was subjected to the Hypothetical Accident condition testing (30-ft and puncture drops only). It was dropped at approximately a 45° angle with the closure bolt down.

The unit was tested with four (4) inactive 424-9 style sources and four (4) 969 style sources. These sources simulate the maximum carrying capacity and the varied type of sources transported.

The gross weight of the Model 976 Specimen TP90B was 276 lbs. Drawings may be found in Appendix A.

Section 3.3 Test Specimen TP90C

This unit was subjected to the Hypothetical Accident condition testing (30-ft and puncture drops only). It was dropped top down along its axis of symmetry.

The unit was tested with eight (8) inactive 424-9 style. These sources simulate the maximum carrying capacity and the most common configuration of sources transported.

The gross weight of the Model 976 Specimen TP90C was 275 lbs. Drawings may be found in Appendix A.

Section 3.4 Test Specimen TP90D

This unit was subjected to the Hypothetical Accident condition testing (30-ft and puncture drops only). It was dropped bottom down along its axis of symmetry.

The unit was tested with four (4) inactive 424-9 style sources and four (4) 969 style sources. These sources simulate the maximum carrying capacity and the varied type of sources transported.

The gross weight of the Model 976 Specimen TP90D was 276 lbs. Drawings may be found in Appendix A.

Section 3.5 Test Specimen TP90E

This unit was subjected to the Hypothetical Accident condition testing (30-ft and puncture drops only). It was dropped at approximately a 45° angle with the closure bolt toward the ground but at the top of the drum.

The unit was tested with eight (8) inactive 424-9 style. These sources simulate the maximum carrying capacity and the most common configuration of sources transported.

The gross weight of the Model 976 Specimen TP90E was 275 lbs. Drawings may be found in Appendix A.

Section 3.6 Test Specimen TP90F

This unit was subjected to the Hypothetical Accident condition testing (30-ft and puncture drops only). It was dropped at approximately a 45° angle with the closure bolt down.

The unit was tested with a Model 616 serial number 402 fitted with an inactive source to drawing B60006 Rev J. This source simulates the maximum carrying capacity and the only used configuration of transport.

The gross weight of the Model 976 Specimen TP90F was 133 lbs.

NOTE: Although included in the original testing, the package configuration for the Model 616 is no longer needed and will be dropped from this report. If needed in the future, a separate report will be generated.

Section 3.7 Test Specimen TP90G

This unit was subjected to the Hypothetical Accident condition testing (Two (2) 30-ft drops and a puncture drop). It was dropped at approximately a 45° angle with the closure bolt down.

The unit was tested with a Model 3056 shield container (serial number P0745-060) fitted with ten inactive Model 424-9 style sources. These sources simulate the maximum carrying capacity and are representative of the type of sources transported in the Model 3056 shield. This configuration simulates the maximum anticipated weight capacity of the various packages in this series.

Results of testing on this unit are used to assess compliance of the Model 976 package when containing shield Models 3056, 3015 and 3018, which are all of similar construction and composition.

The gross weight of the Model 976 Specimen TP90G was 180 lbs. Drawings may be found in Appendix A.

Section 4. Changes to Test Conditions or Orientations

Section 4.1 Normal and Accident Conditions of Transport

No changes from plan, save for the omission of inactive sources during the compression test (explained earlier).

Section 4.2 Hypothetical Accident Conditions (71.51(a))

TP90B

a. 9m (30-foot) Drop - No variations from plan.
b. Puncture Drop - No variations from plan. See Section 5.2.2.

TP90C

a. 9m (30-foot) Drop - No variations from plan.
b. Puncture Drop - No variations from plan. See Section 5.3.2.

TP90D

a. 9m (30-foot) Drop - No variations from plan.
b. Puncture Drop - No variations from plan. See Section 5.4.2.

TP90E

a. 9m (30-foot) Drop - No variations from plan.
b. Puncture Drop - No variations from plan. See Section 5.5.2.

TP90F

a. 9m (30-foot) Drop - No variations from plan. Orientation 8.10.2 (TP90B) was deemed most severe as it incorporated both a direct primary impact on the bolt and a slap-down of the drum to induce shock to the device and to the lid. In previous testing, this was the only orientation in which the lid clamp band was knocked off the package.
b. Puncture Drop - No variations from plan. See Section 5.6.2.

NOTE : Although included in the original testing, the package configuration for the Model 616 is no longer needed and will be dropped from this report. If needed in the future, a separate report will be generated.

TP90G

a. 9m (30-foot) Drop - Orientation 8.10.2 (TP90B) was deemed most severe as it incorporated both a direct primary impact on the bolt and a slap-down of the drum to induce shock to the device and to the lid. In previous testing, this was the only orientation in which the lid clamp band was knocked off the package.

The test specimen was dropped twice in the same orientation. On the first drop attempt, the angle of initial drop was not steep enough and did not impart the desired impact on the closure bolt. The second drop, although not exactly as intended, did significant damage to the package. Both drops, in combination, imparted more damage to the package than would a single drop that impacted exactly as intended as they both hit the object point (the closure screw) upon initial impact. It can be seen from the photographs in the results section that the drum was actually deformed more than the single drop of TP90B which had considerably more (~53%) mass. As such, the test is valid.

b. Puncture Drop - No variations from plan. See Section 5.7.2.

Section 5. Test Specimen Results

Section 5.1 Specimen TP90A

5.1.1 Compression Test

The unit was subjected to a weight of 1,465 lbs for more than 24 hours. This was 5.3 times the maximum weight of the package and accounted for any tolerance stack-up in the scales used.

No damage noted. The unit was profiled prior to testing and at the end of the Hypothetical Accident Transport sequence of tests.

FIGURE 4. COMPRESSION TEST IN PROGRESS : SPECIMEN TP90A

5.1.2 Penetration Test

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the binder resin, any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

The penetration bar impacted as intended. The bar bent the closure bolt slightly and left a slight impression on the threads. No other damage was noted. There was no effect to the integrity of the package.

FIGURE 5. PENETRATION BAR DAMAGE : SPECIMEN TP90A

5.1.3 1.2m (4-ft) Drop Test

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the binder resin, any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

The test unit impacted the test pad as intended. Very little damage to the drum was noted. The bottom of the drum was scuffed and slightly bowed out. Upon disassembly with normal hand tools, the cork liner had fractured and separated at the base. The Model 855 was undamaged. The Model 855 was released for use in Specimen TP90B, for Hypothetical Accident testing.

Survey results were taken after completion of the hypothetical accident testing using this Model 855. Surveys were taken with the Model 855 outside of the drum and cork assembly. This produced dose rates higher than if the Model 855 had been placed inside the test drum and cork assembly. Profile results of the Model 855 after testing were within expected tolerances of the initial shield profile results taken on 7 Mar 96. (See Appendix C for profile result sheets included as part of the manufacturing records, and Figure 26 in Section 6 for a comparison of the Model 855 survey results before and after testing.)

FIGURE 6. NORMAL CONDITIONS DRUM DAMAGE: (NOTE: Package as shown above does not reflect the package configuration immediately after testing. This package had been disassembled and inspected, then the components re-assembled without engagement of the clamp band bolt at the time this photograph was obtained.)

FIGURE 7. NORMAL CONDITIONS CORK DAMAGE : SPECIMEN TP90A

Section 5.2 Specimen TP90B

The test specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the binder resin, any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.2.1 30-ft Drop

The unit impacted the test pad as intended. The closure bolt assembly was crushed. The welds holding the bolt retainer side of the closure assembly were completely sheared from the lid clamp band. The drum lid and top rim of the drum side were crimped together and folded under the bolt assembly. This was caused by the primary impact.

FIGURE 8. PRIMARY IMPACT DAMAGE : SPECIMEN TP90B

Secondary impact, the slap down, caused the side of the drum to be slightly flattened and the bottom ring weld to be dented. No rips or tears were noted in the steel. The lid and lid clamp band, although damaged, did not separate from the drum even when inverted. The 855 was retained within the drum.

FIGURE 9. SECONDARY IMPACT DAMAGE : SPECIMEN TP90B

5.2.2 Puncture Test

It was decided to attempt to remove the lid clamp band and lid with the puncture test. The unit was impacted at approximately 45° on the opposite side of the closure bolt. The lid clamp band came off the package and the puncture bar further dented the side of the drum. The lid remained on the drum due to the initial impact and crimping of the lid with the top rim of the drum. As before, the Model 855 was retained by the drum even when inverted. The Model 855 was released for use in Specimen TP90D.

5.2.3 Post Test Examination

After considerable effort, the lid was pried from the drum. The top cork was cracked in several pieces. Due to the angle of the cracks, however, the first few pieces of cork had to be pried out before others could be removed. The bottom cork sides were fractured into two halves. The Model 855 was undamaged. After examination it was determined that the sources had not moved, the locks were still all engaged and the bolts were undamaged.

FIGURE 10. CORK DAMAGE : SPECIMEN TP90B

FIGURE 11. CORK DAMAGE : SPECIMEN TP90B

Section 5.3 Specimen TP90C

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the binder resin, any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.3.1 30-ft Drop

The unit impacted the test pad as intended. The top of the drum was dented. Some deformation and bending of the lid clamp band and top flange of the drum was noted. Scratching and scuffing of the top of the drum was also noted.

5.3.2 Puncture Test

It was decided to exacerbate the damage by dropping the test specimen onto the puncture bar in the same orientation as the 30-ft drop. The unit impacted as expected. The puncture bar left a witness mark in the top of the drum. Some denting of the upper flange was noted as a secondary impact when the drum fell off the bar. No other significant damage was noted. As before, the Model 855 was retained by the drum. The 855 was released for use in Specimen TP90E.

5.3.3 Post Test Examination

The drum was opened with normal hand tools. The top cork was cracked in several pieces, although not as severely as on TP90B. The Model 855 was undamaged. After examination it was determined that the sources had not moved, the locks were still all engaged and the bolts were undamaged.

FIGURE 12. DRUM DAMAGE : SPECIMEN TP90C

FIGURE 13. CORK DAMAGE : SPECIMEN TP90C

Section 5.4 Specimen TP90D

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the binder resin, any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.4.1 30-ft Drop

The unit impacted the test pad as intended. The bottom of the drum was dented. Some deformation and bending of the bottom flange of the drum was noted. Scratching and scuffing of the bottom of the drum was noted.

5.4.2 Puncture Test

It was decided to exacerbate the damage and drop onto the puncture bar in the same orientation as the 30-ft drop. The unit impacted as expected. The puncture bar left a witness mark in the base of the drum slightly off-center. Some denting of the upper flange was noted as a secondary impact when the drum fell off the bar. No other significant damage was noted. As before, the Model 855 was retained by the drum.

5.4.3 Post Test Examination

The drum was opened with normal tools. The bottom cork was fractured in to two pieces similar to the Normal Conditions testing. The Model 855 was undamaged. After examination it was determined that the sources had not moved, the locks were still all engaged and the bolts were undamaged. The unit was released for final profile.

FIGURE 14. CORK DAMAGE : SPECIMEN TP90D

Section 5.5 Specimen TP90E

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the binder resin any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.5.1 30-ft Drop

The unit impacted the test pad as intended. The lower corner of the drum was deformed approximately 3 inches at the angle of impact. Although folded over, the lower flange did not tear or split. This damage was caused by the primary impact. Secondary impact, the slap down, caused the side of the drum to be very slightly flattened and the lid clamp band and top flange ring weld to be nicked. No rips or tears were noted in the steel. The lid and lid clamp band did not separate from the drum even when inverted. The 855 was retained within the drum.

FIGURE 15. PRIMARY IMPACT DAMAGE : SPECIMEN TP90E

5.5.2 Puncture Test

It was decided to exacerbate the damage and drop the test unit onto the puncture bar in the same orientation as the 30-ft drop. The unit impacted as expected. The puncture bar left a slight witness mark on the previously bent area. Some denting of the upper flange was noted as a secondary impact when the drum fell off the bar. No other significant damage was noted. As before, the Model 855 was retained by the package. The lid remained on the drum. As before, the Model 855 was retained by the drum even when inverted.

5.5.3 Post Test Examination

The drum was opened with normal tools. The bottom cork was fractured into two pieces, although not as severely as other tests. The bottom cork sides were fractured into two halves. The Model 855 was undamaged. After examination it was determined that the sources had not moved, the locks were still all engaged and the bolts were undamaged. The unit was released for final profile.

FIGURE 16. CORK DAMAGE : SPECIMEN TP90E

Section 5.6 Specimen TP90F

Although included in the original testing, the package configuration for the Model 616 is no longer needed and will be dropped from this report. If needed in the future, a separate report will be generated.

Section 5.7 Specimen TP90G

The specimen was chilled to at least -40°C. The Model 3056, being constructed of lead and stainless steel, is not particularly susceptible to brittle fracture upon shock loading. The binder resin, any water resident in the cork and the cork material itself may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.7.1 First 30-ft Drop

The unit did not impact the test pad exactly as intended. The angle of attack was 10-15° too shallow (from the intended 45°) causing the impact to be less severe on the top/bolted edge and transferring force to the opposite end as rotational damage (slap down). The top corner of the drum was deformed very similar to TP90B, but to a somewhat lesser extent. The closure bolt assembly was bent, but intact and held the lid on the drum. The lid and top rim of the drum were folded and crimped, as with TP90B. This damage was caused by the primary impact.

Secondary impact, the slap down, caused the side of the drum to be flattened and the lower corner of the drum to be deformed along the angle of impact. Although folded over, the lower flange did not tear or split. No rips or tears were noted in the steel. The lid and lid clamp band did not separate from the drum even when inverted. The Model 3056 was retained within the drum.

As the impact was not quite as desired, it was decided on site to drop the same package again without repair or modification as a worst case scenario.

5.7.2 Second 30-ft Drop

The unit did impact the test pad very close to the intended angle and after review of the drop, was almost identical to TP90B. The damage at the top corner of the drum was exacerbated by the second drop. Final damage was very similar to TP90B, except that the closure bolt assembly was bent, but intact and held the lid on the drum. The lid and top edge were folded and crimped, as with TP90B.

FIGURE 17. PRIMARY IMPACT DAMAGE : SPECIMEN TP90G

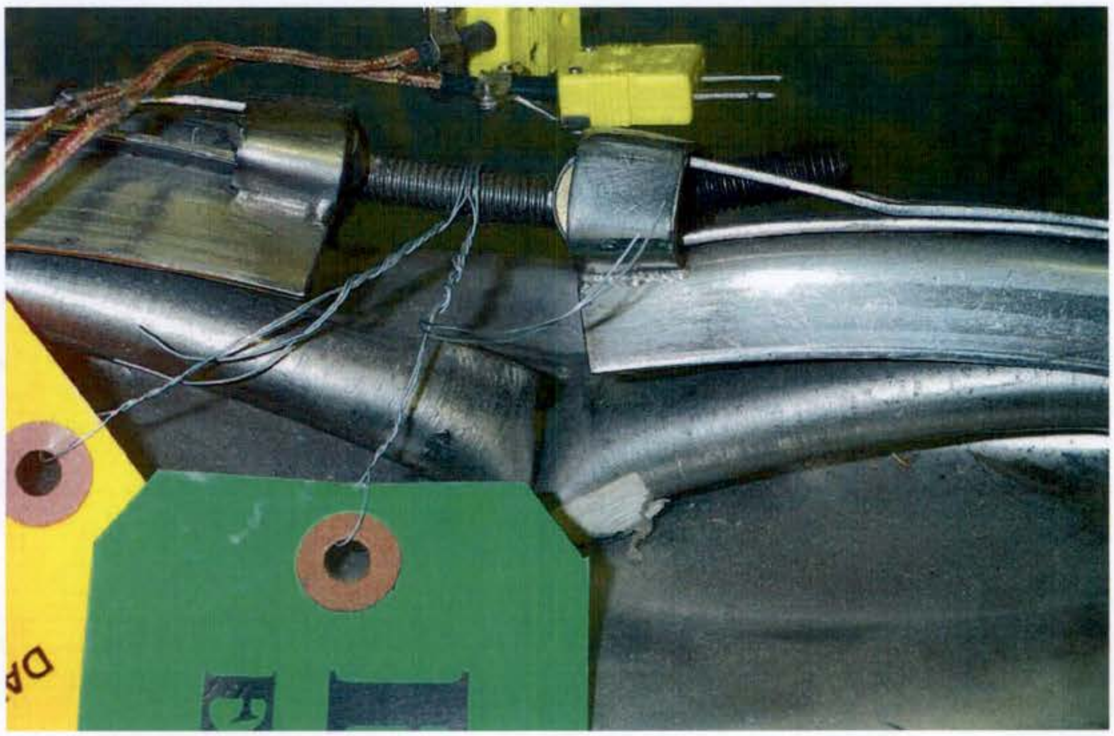


FIGURE 18. PRIMARY IMPACT DAMAGE: SPECIMEN TP90G

FIGURE 19. SECONDARY IMPACT DAMAGE (Bottom of Drum) : SPECIMEN TP90G

5.7.3 Puncture Test

It was decided to attempt to remove the lid clamp band and lid with the puncture test (as with TP90B). The unit was impacted at approximately 45° on the opposite side of the closure bolt. The lid clamp band remained on the drum and the lid remained secure. The puncture bar slightly dented the side of the drum. As before, the Model 3056 was retained by the drum even when inverted.

5.7.4 Post Test Examination

The lid clamp band was removed by cutting the closure bolt as it would not turn with normal hand tools. After considerable effort, the lid was pried from the drum. The top cork was cracked in several pieces. Due to the angle of the cracks, however, the first few pieces of cork had to be pried out before others could be removed. The bottom cork was fractured into a few pieces. The cork spacer rings and the inner cork insert were fractured. The damage from the three drops (two 9m and one puncture) was slightly less than in TP90B. The Model 3056 was undamaged. After examination it was determined that the sources had not moved, the retainer nuts and lid were still all engaged and the bolts were undamaged. The unit was released for final profile.

FIGURE 20. CORK DAMAGE : SPECIMEN TP90G

FIGURE 21. CORK DAMAGE, SHIELD COVER ON: SPECIMEN TP90G

FIGURE 22. CORK DAMAGE, SHIELD COVER OFF, CAPS SHOWN: SPECIMEN TP90G

FIGURE 23. MODEL 3056 POST TEST, SHIELD COVER ON: SPECIMEN TP90G

Section 5.8 – 9M and Puncture Test Assessments

The shield containers used in the Model 976 drum assembly are of two general types: (1) those which use depleted uranium for their primary shielding (e.g., 855 and 3078), and (2) those that use lead for their primary shielding with supplemental materials as part of the inner assembly shielding design (e.g., 3015, 3018 and 3056).

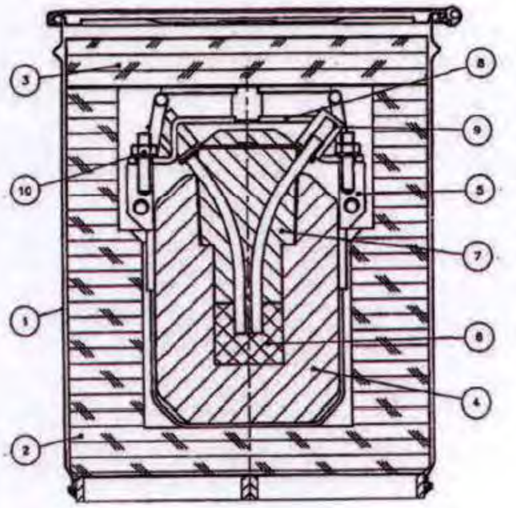
Based on container construction similarities and since the Model 855 shield container is heavier than the Model 3078 shield container, the Model 855 drop test specimen results can be used to assess compliance of the Model 3078 for the 9M and puncture drop testing requirements. In the case of the lead/composite shield containers, the Models 3015 and 3018 shield containers are lighter than the Model 3056 shield container design which was tested in the 9 m and puncture drop tests. Therefore the Model 3056 design can be used to assess compliance of the Models 3015 and 3018 package configurations.

In all cases, the test specimen inner containers were physically undamaged after the 9 m and puncture drop testing. The Model 3078 being lighter than the Model 855 and would therefore be expected to sustain less damage in the drop configurations than was seen for the Model 855 package assemblies. Both shield container designs incorporate a lid cover which is attached by securing bolts. There was no damage to any of the eight securing bolts used on the Model 855 shield container, therefore drop testing of the Model 3078 would also not produce damage to the lid bolts used to secure the lid to the shield container. By assessment, the Model 976E (with 3078) package design would perform as well if not better than the Model 976A (with 855) package design under the 9 m and puncture test requirements.

In the case of the lead/composite shield containers, the Models 3015 and 3018 are lighter than the Model 3056 design which was tested in the 9 m and puncture drop tests. In the drop testing, the Model 3056 was retained by the drum even when inverted and the drum retained the lid clamp band after drop testing. As such the Model 976 package configurations using either the Model 3015 or the Model 3018 shield containers would sustain less physical damage than was seen on the test specimen containing the Model 3056 shield container. There was no damage or loss of integrity to the securing mechanism of the Model 3056 shield container after the 9 m and puncture drop testing. Drop testing of the Models 3015 and 3018 in the Model 976 drum assembly would also produce no damage to the source containment of these shield containers. By assessment, the Model 976B (with 3015) package design and the Model 976D (with 3018) package design would perform as well if not better than the Model 976C (with 3056) package design under the 9 m and puncture test requirements.

Section 5.9 - Thermal Assessments

Thermal testing was performed for a similar drum design to support approval of a Type B container in Great Britain (See Figure 24).



Item	Description	Material	No. off
1	DRUM	STEEL	1
2	PACKING INSERT	CORK	1
3	PACKING SPACER	CORK	1
4	LEAD POT	LEAD	1
5	POT CRADLE	CARBON STEEL	1
6	CORE SHIELD	TUNGSTEN ALLOY / DEPLETED URANIUM	1
7	SHIELDING INSERT	LEAD	1
8	RETAINING STRAP	CARBON STEEL	1
9	TUBE CAP	BRASS	4
10	M10 COMBI NUT	STAINLESS STEEL	2

FIGURE 24 – TEST SPECIMEN CONFIGURATION FOR TEST NUMBER 1835

Test Number 1835 (see Appendix F) documents testing of a Model 3018 inner shield container (lead shielded device) inside of a cork lined steel drum assembly. The cork used in these test units was the same as the cork used for the test specimens under this Test Plan Report, however, the overall cork thickness is greater in the Model 976 style packages than was used in the specimens tested under Test Number 1835.

Testing included 9 m drop tests and puncture tests in similar orientations as were performed for the test specimens under this test plan report. The test specimens under Test Number 1835 were tested at ambient temperature and were not cooled to -40°C prior to the 9 m and puncture drop tests.

As was seen with the Model 976 style test specimens, the test units described under Test Number 1835 also experienced drum deformation but no loss of the lid from the drum base. Though cracking of the cork was not specifically referenced on the sides of the cork liners in the test units from Test Number 1835, cracking of the bottom cork inserts was noted. The bottom of the cork cavity was cracked around the circumference and across diagonals in line with the drum reinforcement bars.

Thermal testing of the specimens under Test Number 1835 placed the specimens into a furnace maintained at an ambient temperature between 800°C - 820°C for a period of 30 minutes. The test specimens did not contain any radioactive contents during the thermal testing performed under Test Number 1835. The test specimens were allowed to cool for at least 18 hours before disassembly and evaluation.

Upon evaluation it was found that the top cork inserts exhibited slight charring (e.g. 22-25 mm depth) with a 26 mm thickness of the insert remaining intact. In both cases the lead shield container was undamaged, exhibiting only the presence of a resin condensate and soot on the lead pot exterior. For both test specimens, the maximum temperature recorded by temperature strips on the exterior surface of the lead pot was 82°C. This temperature rise was less than ¼

of the rise needed to reach the melting point of the lead pot (300°C), therefore no change melting or slumping of the lead shielding occurred.

The shield containers used in the Model 976 drum assembly are of two general types: (1) those which use depleted uranium for their primary shielding (e.g., 855 and 3078), and (2) those that use lead for their primary shielding with supplemental materials as part of the inner assembly shielding design (e.g., 3015, 3018 and 3056).

In the case of the depleted uranium shield containers, there was no breach or weld cracking of the shield container which would allow oxygen to reach the inner depleted uranium shield. Without the presence of a continuing source of oxygen, these shields will remain intact during the thermal test. As seen in testing performed on the Model 650L (Reference USNRC CoC USA/9269/B(U)-85, Test Plan 80 Report Revision 1) thermal testing of this device where cracking to allow air to the shield had occurred resulted in production of only a small amount of depleted uranium oxide. With an air path and air circulation during the thermal test, the radiation dose rate at one meter from this unit increases by approximately 10% remaining less than 3% of the regulatory limit.

Without sufficient oxygen provided to the interior of the depleted uranium shield containers (e.g., welds intact) there will be no appreciable oxidation of the depleted uranium shield inside the steel container housings, and the 800°C temperature is well below the melting point of depleted uranium (1,130°C) therefore the shield will retain its original shape throughout the thermal test.

The thermal test will not adversely effect the structural integrity of the Model 855 or Model 3078 shield containers. The Model 855 containers were physically undamaged after the 9 m and puncture drop testing. The Model 3078 is lighter than the Model 855 and would therefore sustain less damage in the drop configurations than was seen for the Model 855 package assemblies. Both shield container exteriors are a steel weldment which does not melt below 1,427 °C. For the Model 976A (with the Model 855 inner shield container) and the Model 976E (with the Model 3078 inner shield container), performance of the thermal test would not reduce the shielding efficiency or containment efficiency of the shield containers within the 976 drum assembly. By assessment, both the Model 976A and 976E package designs would meet the thermal test requirements.

In the case of the lead/composite shield containers, the Models 3015 and 3018 are lighter than the Model 3056 design which was tested in the 9 m and puncture drop tests. As such the Model 976 package configurations using either the Model 3015 or the Model 3018 shield containers would sustain less physical damage than was seen on the test specimen containing the Model 3056 shield container. The container designs are similar and therefore evaluation of the Model 3056 test specimen against the thermal requirements will encompass the Models 3015 and 3018 shield designs by direct comparison.

There was no breach or weld cracking of the Model 3056 shield container. Based on thermal testing under Test Number 1835, the maximum surface temperature of the lead inner shield was 82°C. This temperature is well below the melting point of the steel weldment (1,427°C) therefore performance of the thermal test would not reduce the shielding efficiency or containment efficiency of the shield containers within the 976 drum assembly. Therefore, by assessment, the Model 976B (with the Model 3015 inner shield container), the Model 976C (with the Model 3056 inner shield container) and the Model 976D (with the Model 3018 inner shield container) package designs will meet the thermal test requirements.

Section 6. PROFILE RESULTS AND COMPARISON ASSESSMENT

Section 6.1 Profile Results

Radiation measurements included in this Section were adjusted to the maximum activity capacity for the package (e.g., activity correction factor) and the surface measurements were also adjusted to correct for off-set of the survey meter probe from the true surface of the package.

Activity correction factors (CF_A) were obtained by using the following relationship:

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

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

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

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

Radiation measurements at the surface of the container were also adjusted to compensate for the off-set of the survey meter probe from the true surface of the package.

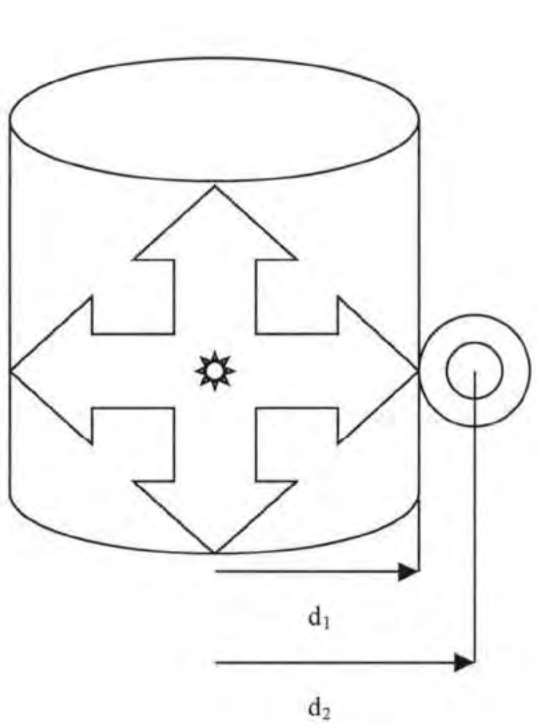
Surface correction factors (SCF) were obtained by using the following relationship:

$$SCF = \frac{d_2}{d_1}\ where\ d_1\ and\ d_2\ are\ determined\ as\ shown\ in\ Figure\ 25.$$

$$For\,Example,\ if\ d_1 = 9\,inches\ and\ d_2 = 9.5\,inches,\ then$$

$$SCF = \frac{9.5\,inches}{9\,inches} = 1.06$$

Therefore in the example shown, all original surface profile measurements located along the side of the drum shown in Figure 25 would also be multiplied by a factor of 1.06 to account for surface correction of the detector to the drum. Different SCF's would be calculated for the any dimension of the container where the minimum distance from the center of the activity to the center of the radiation probe is different.



d_1 = distance from activity center to surface of container.

d_2 = distance from activity center to surface of container plus radius of the survey meter probe.

FIGURE 25. SAMPLE SURFACE CORRECTION FACTOR DISTANCE CRITERIA

The radiation profile data showed no increase in radiation dose after testing beyond normal measurement variations. All test specimens met the regulatory requirements.

The following table (Figure 26) shows profile results pre and post testing. Figure 27 shows the source information for the pre and post testing radiation profiles for the test specimens. The various 976 Type B package specimens are listed along with the shield containers they contained, along with the amount of testing each specimen was subjected to. The data will show, save for normal measurement variations, no increase in dose post-test. All units passed.

Figure 28 shows profile results for each Model 976 Series package configuration rated to the maximum activity to be transported under that configuration. The profile results in Figure 28 demonstrate compliance with package survey requirements of 10 CFR. 71.47.

Radiation profiles described in this section were obtained using either an AN/PDR-27T, sn SM392401 or sn SM392402, Tech-50 sn B814S or an ND-500P sn 42363 or sn 42365. All instruments have Geiger-Mueller detectors that meet the requirements of ANSI N432-1980.

976 Type B Package Model and Capacity	Shield Model	Used in Test Specimen	Testing Endured	PRE-TEST @ SURFACE (millirem/hour) PRE-TEST @ 1 m (millirem/hour): TOP	RIGNT	FRONT	LEFT	REAR	BOTTOM	Post-TEST @ SURFACE (millirem/hour) [1] Post-TEST @ 1 m (millirem/hour): TOP	RIGNT	FRONT	LEFT	REAR	BOTTOM
Profile Sheet Identification for 976 Configuration following:				855 (sn 9) Original Device Profile Upon Manufacture (Without 976 drum/cork overpack) original measurements taken 7 Mar 96						855 (sn 9) Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan 90 Report and Pre-Test Results under Test Plan Report 163 original measurements taken 29 Apr 02.					
976A (1000 Ci)	Model 855 Sn # 9[2] (1000 Ci)	TP90A TP90B TP90D	Normal Conditions + Hypothetical Accident Conditions: (3) 30-ft Drops (3) Puncture Drops	159	42	33	42	46	110	141	32	32	32	38	75
				2.4	0.6	0.6	0.6	0.7	1.0	1.9	0.3	0.3	0.3	0.3	0.8
Profile Sheet Identification for 976 Configuration following:				855 (sn 8) Original Device Profile Upon Manufacture (Without 976 drum/cork overpack) original measurements taken 8 Aug 95						855 (sn 8) Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan 90 Report and Pre-Test Results under Test Plan Report 163 original measurements taken 29 Apr 02					
976A (1000 Ci)	Model 855 Sn # 8 (1000 Ci)	TP90C TP90E	Hypothetical Accident Conditions: (2) 30-ft Drops (2) Puncture Drops	163	35	34	31	31	65	141	38	32	32	38	62
				2.4	0.5	0.6	0.6	0.7	0.8	1.9	0.3	0.3	0.3	0.3	0.6
Profile Sheet Identification for 976 Configuration following:				976C (3056 Device Capacity Profile with 976 drum/cork overpack) – Performed Prior to Testing under Test Plan 90 – Test Specimen TP90G original measurements taken 12 Feb 02						976C (3056 Device Capacity Profile with 976 drum/cork overpack) – Performed After Testing under Test Plan 90 – Test Specimen TP90G original measurements taken 25 Feb 04					
976C[3] (800 Ci)	Model 3056 (800 Ci)	TP90G	Hypothetical Accident Conditions: (2) 30-ft Drops (1) Puncture Drops	72	93	65	56	93	182	59	134	144	134	124	224
				3.7	3.3	2.2	1.9	3.1	3.5	0.5	1.2	0.5	0.5	1.6	0.5

[1] - Model 855 shields, Sn 8 and 9 were profiled outside of the 976 overpack assembly (drum and cork) during the post-test profiles.
[2] – The Model 855 shield, Sn 9 was profiled before and after testing using only 424-9 style source assemblies and standard lock assemblies. No damage was sustained by the internal lock mechanisms of the Model 855 and there was no change in source position of the Model 969 source assemblies after the package was tested in the 30-ft drop and 1-m puncture testing. Therefore, profiling of the device using standard lock assemblies and 424-9 source assemblies which place the source in the same shield location at the bottom of the J-tube is valid to assess the package before and after testing.
[3]- Initial radiation survey results for this container are assumed to have been performed in a high background area to explain the apparent reduction in the 1 meter dose rate measurements for this container after testing.

FIGURE 26. TABLE OF PROFILES

976 Type B Package Model and Capacity	Shield Model	Used in Test Specimen	Pre-Testing Radiation Profile Sources[1,2,3]		Post-Testing Radiation Profile Sources[1,2,3]	
976A (1000 Ci)	Model 855 Sn # 9 (1000 Ci)	TP90A TP90B TP90D	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 885.5 Ci on 7 Mar 96. Source serial numbers and individual activities as follows:		Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 914.4 Ci on 29 Apr 02. Source serial numbers and individual activities as follows:	
			Source Serial Number	Source Activity (Ci)	Source Serial Number	Source Activity (Ci)
			A7774	102.5	04256B	114.5
			A7775	104.0	04257B	114.5
			A7776	113.4	04258B	114.3
			A7777	119.6	04259B	116.4
			A7778	113.6	04260B	116.7
			A7779	113.9	04261B	117.2
			A7780	112.9	04262B	110.7
			A7781	105.6	04263B	110.1
976A (1000 Ci)	Model 855 Sn # 8 (1000 Ci)	TP90C TP90E	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 861.5 Ci on 8 Aug 95. Source serial numbers and individual activities as follows:		Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 914.4 Ci on 29 Apr 02. Source serial numbers and individual activities as follows:	
			Source Serial Number	Source Activity (Ci)	Source Serial Number	Source Activity (Ci)
			A5799	109.4	04256B	114.5
			A5800	110.6	04257B	114.5
			A5803	108.5	04258B	114.3
			A5804	106.5	04259B	116.4
			A5805	108.8	04260B	116.7
			A5806	108.2	04261B	117.2
			A5807	104.8	04262B	110.7
			A5808	104.7	04263B	110.1
976C (800 Ci)	Model 3056 (800 Ci)	TP90G	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 920.1 Ci on 12 Feb 02. Source serial numbers and individual activities as follows:		Eight Model 424-9 Source Wire Assemblies. Specific source serial numbers not recorded. Total activity of all eight sources equaled 866.4 Ci on 25 Feb 04.	
			Source Serial Number	Source Activity (Ci)		
			03513B	116.4		
			03540B	114.4		
			03541B	113.6		
			03542B	115.5		
			03543B	111.5		
			03544B	111.8		
			03551B	123.4		
			03552B	113.5		

[1]Decay of Ir-192 calculated based on $A_t = A_0 e^{-(0.693/74\ d)\ t}$ where t = time in days since initial activity. This equates to a decay rate of 1% per day.

[2]The Model 424-9 radioactive source assemblies comply with the specifications of drawing R42409 Rev C where the Model 87501 capsule assembly contains Ir-192 as a metal.

[3] Model 855 shields, Sn 8 and 9 were profiled outside of the 976 overpack assembly (drum and cork) during the profiles.

FIGURE 27. TABLE OF RADIATION SOURCES USED IN PROFILES

976 Type B Package Model and Capacity	Shield Model	Profile Sheet Identification	Radiation Profile Sources[1,2]	Capacity Results @ SURFACE (millirem/hour)[1] Capacity Results @ 1 m (millirem/hour) TOP	RIGNT	FRONT	LEFT	REAR	BOTTOM
976A (1000 Ci)	Model 855 Sn # 9	976A (855 Device Profile with 976 drum/cork overpack)	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 874.3 Ci on 30 Jan 02. Source serial numbers and individual activities as specified on the referenced profile sheet.	29	9	7	6	10	22
				1.1	0.3	0.2	0.2	0.3	0.5
976B (350 Ci)	Model 3015 Sn # P500/2128	976B (3015 Device Capacity Profile with 976 drum/cork overpack)	Three Model 87555 Source Capsules. Total activity of all three sources equaled 336.1 Ci on 04 Mar 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	11	186	186	186	186	60
				0.5	6.2	6.7	6.2	5.7	1.4
976C (800 Ci)	Model 3056 Sn #P0745-060	976C (3056 Device Capacity Profile with 976 drum/cork overpack) – Performed Prior to Testing under Test Plan 90 – Test Specimen TP90G	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 874.3 Ci on 30 Jan 02. Source serial numbers and individual activities as specified on the referenced profile sheet.	72	93	65	56	93	182
				3.7	3.3	2.2	1.9	3.1	3.5
976D (500 Ci)	Model 3018 Sn #P500/2057	976D (3018 Device Capacity Profile With 976 drum/cork overpack)	Three Model 424-9 Source Wire Assemblies. Total activity of all three sources equaled 331.6 Ci on 26 Feb 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	45	151	134	134	134	191
				1.5	3.6	3.5	3.6	3.6	3.6
976E (1,000 Ci)	Model 3078 Sn #3078.04	976E (3078 Device Capacity Profile with 976 drum/cork overpack)	Nine Model 87555 Source Capsules. Total activity of all nine sources equaled 1,025 Ci on 03 Mar 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	63	15	15	15	15	18
				6.4	0.5	0.5	0.5	0.5	0.5

[1]Decay of Ir-192 calculated based on $A_t = A_0 e^{-(0.693/74\ d)\,t}$ where t = time in days since initial activity. This equates to a decay rate of 1% per day.
[2]The Model 424-9 radioactive source assemblies comply with the specifications of drawing R42409 Rev C where the Model 87501 capsule assembly contains Ir-192 as a metal. The Model 87555 radioactive capsules comply with the specifications of drawing 875 Inner Rev A where the Model 87555 capsules contain Ir-192 as a metal.

FIGURE 28. TABLE OF 976 SERIES CONFIGURATION CAPACITY PROFILES

Section 7. Summary and Conclusions

The package performed very well in all testing. None of the orientations, deemed the worst through examination and extensive experience, inflicted even minor damage to the shields containers within the drum assemblies. All units retained the sources and passed final profile.

The shield containers (855, 616 and 3056) obtained from the population of old field units, gave worst case scenarios. The Model 3056 has been in service for over twenty (20) years and was not specially modified for testing, save for standard shipping maintenance (cleaning, replacing worn hardware, etc.). The Model 855's used in the testing have been in service for at least nine (9) to ten (10) years. Other than some material changes for some of the hardware (carbon steel to stainless steel) along with standard shipping maintenance (cleaning, replacing worn hardware, lock assembly variants incorporated, etc.), the units were not otherwise modified. All shield containers passed the testing without damage. Each unit could be returned to field service without repair or modification.

The 976 packaging was assessed for compliance to the Type A requirements of 10 CFR 71 and IAEA TS-R-1. This assessment is included in Appendix G.

From the test data, and the analysis contained within this report, we conclude that the Model 976 with shield Model 855, Model 3056, Model 3015, Model 3018, or Model 3078:

1. Complies with the requirements for the Normal Conditions of Transport.
2. Complies with the requirements for the Hypothetical Accident Conditions of Transport.

Section 8. APPENDIX A – DRAWINGS

[redacted]

ERF #	836

APPROVALS

[illegible signature]	5 May 04
[illegible signature]	6 May 04

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/32
X ± 0.1
XX ± 0.05
XXX ± 0.005

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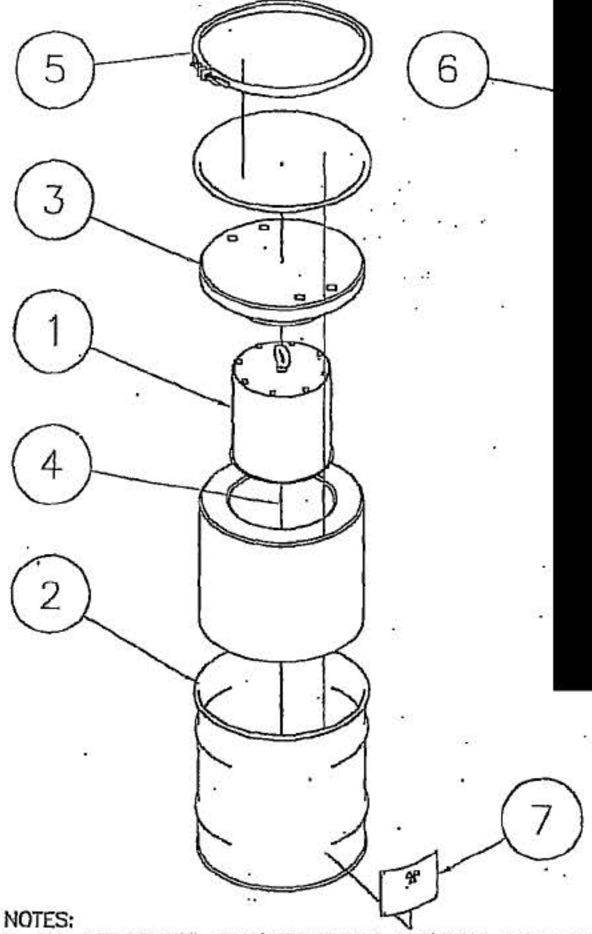
QSA
40 NORTH AVE. BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 424-9 SOURCE ASSY

SIZE	DWG. NO.	REV
A	R42409	C

SCALE: NONE SHEET 1 OF 1



[redacted]

ITEM NO.	DRWNG NO.	QTY.	DESCRIPTION
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	R97608	1	20 GAL, 16GA SS BARREL
1	R85590	1	MODEL 855 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75−1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT − 280 lbs.

APPROVALS	DATE
[signature]	9 MAR 04
C. [signature]	9 MAR 04

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

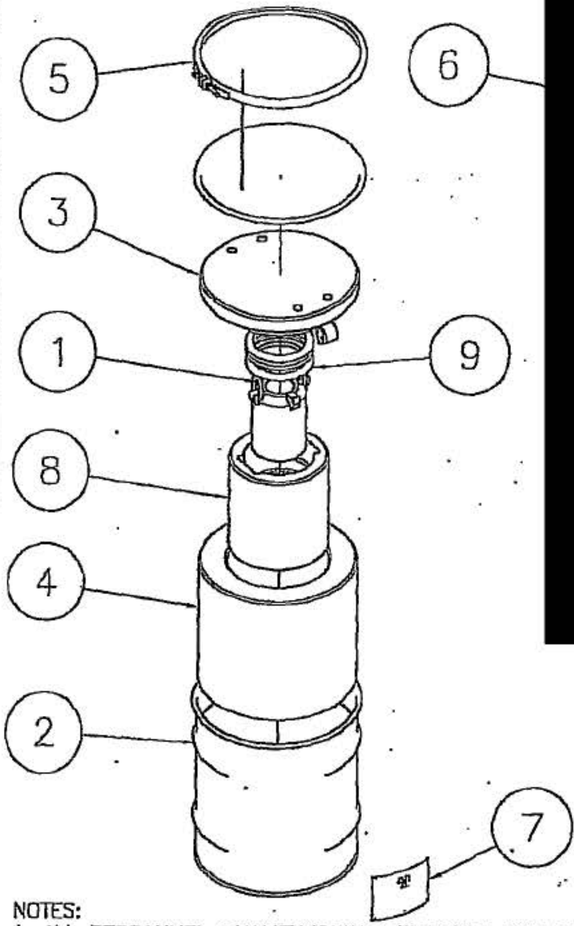
UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

ERF# 799

TITLE 976A TYPE B PACKAGE WITH 855 SHIELD CONTAINER

SIZE B | DWG. NO. R976A | REV A

SCALE: NONE | SHEET 1 OF 1



[redacted]

ITEM NO.	DRWNG NO.	QTY.	DESCRIPTION
9	R97637	4	TOP INNER CORK SPACER
8	R97623	1	BOTTOM INNER CORK INSERT
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	R97608	1	20 GAL, 16GA SS BARREL
1	R3015	1	MODEL 3015 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75–1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT – 180 lbs.

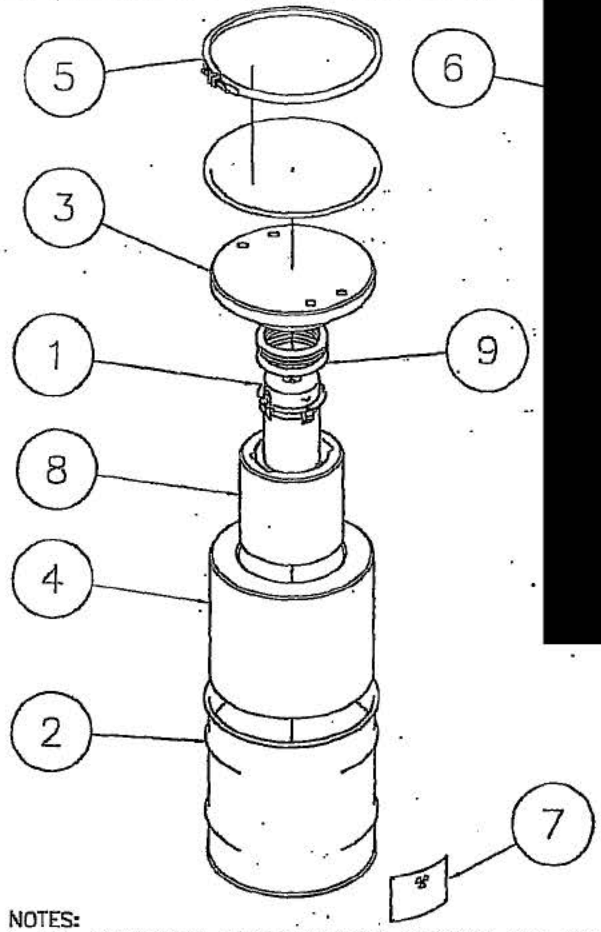
ERF#	APPROVALS	DATE		
800	[illegible signature]	9/10/04	AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING
	C. [illegible signature]	9/10/04		

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE: 976B TYPE B PACKAGE WITH 3015 SHIELD CONTAINER

SIZE: B | DWG. NO. R976B | REV A
SCALE: NONE | SHEET 1 OF 1

5 | 4 | 3 | 2 | 1



[redacted]

ITEM NO.	DRWNG NO.	QTY.	DESCRIPTION
9	R97637	4	TOP INNER CORK SPACER
8	R97623	1	BOTTOM INNER CORK INSERT
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	R97608	1	20 GAL, 16GA SS BARREL
1	R3056	1	MODEL 3056 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75–1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT — 180 lbs.

APPROVALS	DATE
[signature]	9/14/04
[signature]	9/14/04

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DESCRIPTIVE DRAWING

ERF# 802

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.03
X.XXX ± 0.020

TITLE 976C TYPE B PACKAGE WITH 3056 SHIELD CONTAINER

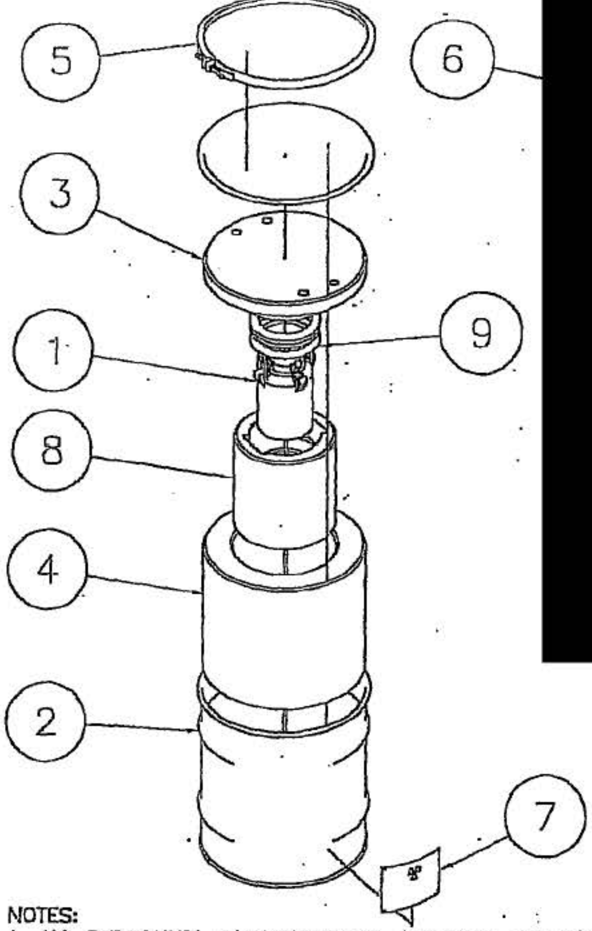
SIZE B | DWG. NO. R976C | REV A

SCALE: NONE | SHEET 1 OF 1

5 | 4 | 3 | 2 | 1

5 4 3 2 1

D



[redacted]

ITEM NO.	DRWNG NO.	QTY.	DESCRIPTION
8	R97623	1	BOTTOM INNER CORK INSERT
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	R97608	1	20 GAL, 16GA SS BARREL
1	R3018	1	MODEL 3018 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75−1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT − 180 lbs.

APPROVALS	DATE
[signature]	9MAR04
C. [signature]	9 mar 04

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DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

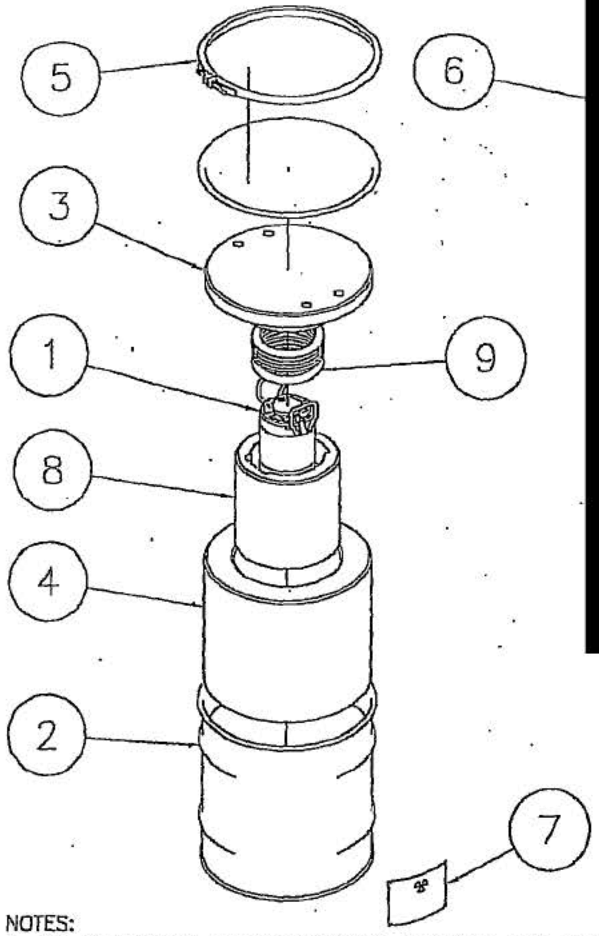
TITLE 976D TYPE B PACKAGE WITH 3018 SHIELD CONTAINER

ERF#. 801.

SIZE B DWG. NO. R976D REV A

SCALE: NONE SHEET 1 OF 1

5 4 3 2 1



[redacted]

ITEM NO.	DRWNG NO.	QTY.	DESCRIPTION
9	R97637	6	TOP INNER CORK SPACER
8	R97623	1	BOTTOM INNER CORK INSERT
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	R97608	1	20 GAL, 16GA SS BARREL
1	R3078	1	MODEL 3078 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75−1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT − 212 lbs.

ERF# 803

APPROVALS	DATE
[signature]	9MAR04
C. [signature]	9mar04

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

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DESCRIPTIVE DRAWING

TITLE 976E TYPE B PACKAGE WITH 3078 SHIELD CONTAINER

SIZE B | DWG. NO. R976E | REV A
SCALE: NONE | SHEET 1 OF 1

[redacted]

NOTES:
1. MAXIMUM DEVICE WEIGHT – 225 LBS.
2. ALL PERSONNEL QUALIFICATION, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE WELDING CODE CURRENT AT THE TIME OF FABRICATION AND INSPECTION. NEW FABRICATIONS WILL BE IN ACCORDANCE WITH THE AWS WELDING CODE.

COVER SCREW	8	STAIN. STEEL	3/8–16 x¾ LG

APPROVALS	
N. Kaszuba	9Mar04
C. Longman	9mar04

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DESCRIPTIVE DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

TITLE MODEL 855 SOURCE CHANGER

SIZE	DWG. NO.	REV
A	R85590	C

SCALE: NONE SHEET 1 OF 6

ERF # 798

[redacted]

DESCRIPTIVE DRAWING

ERF #	798

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

TITLE MODEL 855 SOURCE CHANGER

SIZE	DWG. NO.		REV
A	R85590		C
	SCALE: NONE	SHEET 2 OF 6	

[redacted]

TITLE MODEL 855 SOURCE CHANGER		
SIZE A	DWG. NO. R85590	REV C
	SCALE: NONE	SHEET 3 OF 6

[redacted]

SHIELD

STANDARD
LOCK ASSEMBLY

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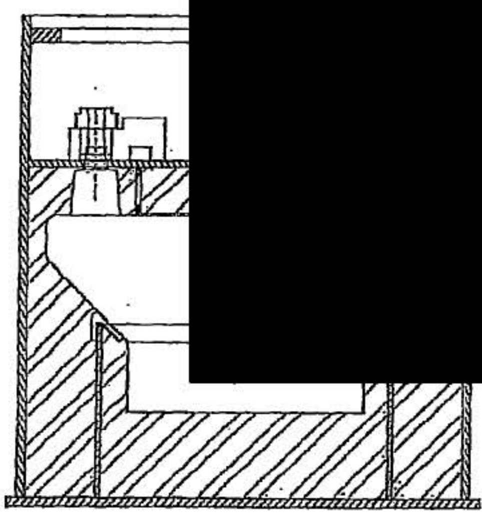
DESCRIPTIVE
DRAWING

DIMENSIONS IN INCHES TOLERANCES: FRACTIONS ±1/8 X ± 0.1 XX ± 0.05 XXX ± 0.005	TITLE MODEL 855 SOURCE CHANGER		
	SIZE A	DWG. NO. R85590 SCALE: NONE SHEET 4 OF 6	REV C

ERF #	798

[redacted]



ERF #	798

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

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DESCRIPTIVE DRAWING

TITLE MODEL 855 SOURCE CHANGER

SIZE	DWG. NO.	R85590	REV
A	SCALE: NONE	SHEET 5 OF 6	C

[redacted]

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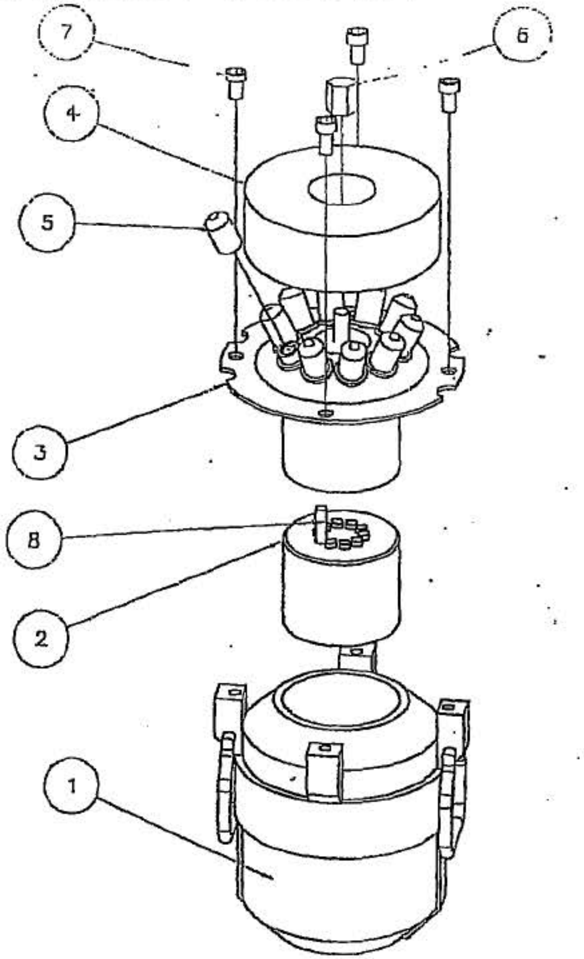
DESCRIPTIVE DRAWING

ERF #	798	DIMENSIONS IN INCHES TOLERANCES: FRACTIONS ±1/8 X ± 0.1 XX ± 0.05 XXX ± 0.005	TITLE MODEL 855 SOURCE CHANGER SIZE A · DWG. NO. R85590 · SCALE: NONE · SHEET 6 OF 6	REV C



[redacted]

ITEM NO.	QTY.	DESCRIPTION
8	10	LOWER INSERT TUBE, SS
7	4	M10 X 20mm LG SOCKET HEAD SCREW, SS
6	1	RETAINING NUT, SS
5	10	CAP NUT
4	1	TOP HAT, SS
3	1	UPPER INSERT, LEAD INSIDE SS
2	1	LOWER INSERT, DU
1	1	LEAD POT ASSY

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT BRITISH STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. MAXIMUM WEIGHT = 104 lbs.

APPROVALS	DATE
[signature]	7MAY04
C. [signature]	9MAY04

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DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES TOLERANCES:
FRACTIONS ± 1/8
X.XX ± 0.12
X.XX ± 0.05
X.XXX ± 0.020

ERF# 806

TITLE MODEL 3056 SHIELD CONTAINER TOP LEVEL ASSY

SIZE B | DWG. NO. R3056 | REV A | SCALE: NA | SHEET 1 OF 4

5 4 3 2 1

D D

C C

B B

A A

[redacted]

AEA TECHNOLOGY QSA

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DESCRIPTIVE DRAWING

TITLE	MODEL 3056 SHIELD CONTAINER TOP LEVEL ASSY		
SIZE B	DWG. NO. R3056		REV A
	SCALE: NA	SHEET 2 OF 4	

5 4 3 2 1

[redacted]

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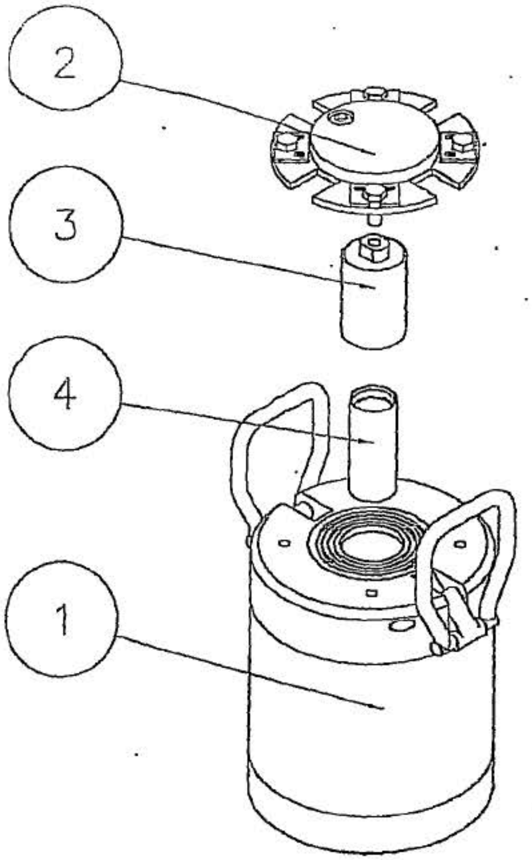
DESCRIPTIVE DRAWING

TITLE	MODEL 3056 SHIELD CONTAINER TOP LEVEL ASSY		
SIZE B	DWG. NO. R3056		REV A
	SCALE: NA	SHEET 3 OF 4	

[redacted]

AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING
TITLE	MODEL 3056 SHIELD CONTAINER TOP LEVEL ASSY
SIZE: B	DWG. NO. R3056
SCALE: NA	SHEET 4 OF 4
REV	A



[redacted]

4	1	CAN (OPTIONAL)
3	1	DU PLUG, MAX WEIGHT OF DU = 2.8 lbs.
2	1	POT LID ASSY
1	1	DU POT ASSY, MAX WIEGHT OF DU = 110 lbs.
ITEM NO.	QTY.	DESCRIPTION

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT BRITISH STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. MAXIMUM WEIGHT = 136 lbs.
4. MAXIMUM DU WEIGHT = 113 lbs.

APPROVALS	DATE
[signature]	9 MAR 04
C. [signature]	9 MAR 04

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DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE: MODEL 3078 SHIELD CONTAINER TOP LEVEL ASSEMBLY

ERF# 807

SIZE: B | DWG. NO. R3078 | REV A

SCALE: NA | SHEET 1 OF 4

[redacted]

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DESCRIPTIVE DRAWING

TITLE	MODEL 3078 SHIELD CONTAINER TOP LEVEL ASSEMBLY		
SIZE B	DWG. NO. R3078		REV A
	SCALE: —	SHEET 2 OF 4	

[redacted]

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DESCRIPTIVE DRAWING

TITLE MODEL 3078 SHIELD CONTAINER TOP LEVEL ASSEMBLY

SIZE	DWG. NO.		REV
B	R3078		A
	SCALE: —	SHEET 3 OF 4	

[redacted]

ITEM 4 CAN (OPTIONAL)
STAINLESS STEEL OR ALUMINUM CAN.
DIMENSIONS SHOWN REPRESENT
THE LARGEST OBJECT THAT CAN
BE PLACED WITHIN THE CAVITY.

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DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE	MODEL 3078 SHIELD CONTAINER TOP LEVEL ASSEMBLY
ERF#	807
SIZE	B
DWG. NO.	R3078
REV	A
SCALE:	NA
SHEET	4 OF 4

[redacted]

M8 SCREW	1	SOCKET HEAD ST.STEEL
INSERT P524	1	SEE R3018 SH.2
PIN	2	.2 DIA ST.STEEL ROD 1.9" LNG
SHIELD	1	SEE R3018 SH.4
DU INSERT	1	DEPLETED URANIUM
RING	1	SEE R3018 SH.3
M10 FLAT WASHER	2	STAINLESS STEEL
M10 BOLT	2	20mm LNG STAINLESS STEEL
TUBE CAP	4	SEE R3018 SH.4
SIDE BRACKET	4	SEE R3018 SH.3
TOP BRACKET	1	SEE R3018 SH.4
JACKET	1	SEE R3018 SH.3
PART NAME	QTY.	DESCRIPTION

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT BRITISH STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. MAXIMUM WEIGHT = 104 lbs.

ERF# 805

APPROVALS	DATE
[signature]	9 Mar 04
C. Roffham	9 Mar 04

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

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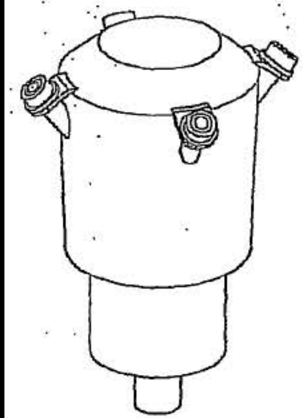
DESCRIPTIVE DRAWING

TITLE 3018 SHIELD CONTAINER TOP LEVEL ASSEMBLY

SIZE B | DWG. NO. R3018 | REV A
SCALE: NTS | SHEET 1 OF 4

[redacted]



PART NAME	QTY.	DESCRIPTION
COLLAR	4	STAINLESS STEEL
BRACKET	2	STAINLESS STEEL
TUBE	4	9.5mm OD x 0.6mm WALL SS
SHIELD	1	LEAD

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DESCRIPTIVE DRAWING

TITLE 3018 SHIELD CONTAINER

SIZE	DWG. NO.		REV
B	R3018		A
	SCALE: NTS	SHEET 2 OF 4	

4 3 2 1

D

[redacted]

C

B

PART NAME	QTY.	DESCRIPTION
PIN	4	.2DIA S.ST ROD
RING	1	STAINLESS ST. THK .23
LINK	4	.4DIA S.ST ROD
SIDE BRACKET	4	STAINLESS ST.
JACKET	1	2mm THICK STAINLESS ST

A

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DESCRIPTIVE DRAWING

TITLE 3018 SHIELD CONTAINER

SIZE B | DWG. NO. R3018 | REV A
SCALE: NTS | SHEET 3 OF 4

5 4 3 2 1

5 4 3 2 1

D

C

B

A

[redacted]

PART NAME	QTY.	DESCRIPTION
TUBE CAP	4	BRASS
SHIELD	1	LEAD
DETAIL 2	1	STAINLESS STEEL
DETAIL 1	1	STAINLESS STEEL
DISK	1	STAINLESS STEEL
PLATE	1	STAINLESS STEEL

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DESCRIPTIVE DRAWING

TITLE 3018 SHIELD CONTAINER

SIZE B | DWG. NO. R3018 | REV A

SCALE: NTS | SHEET 4 OF 4

5 4 3 2 1

4 3 2 1

D

[redacted]

C

B

PART NAME	QTY.	DESCRIPTION
HANDLE	1	.18 DIA BRASS ROD
M3 SCREW	2	ST.STEEL .5"LNG
BRACKET	1	1/16 THK BRASS
BODY	1	LEAD
TOP PLUG	1	SEE R3015 SH. 4
CAPSULE HOLDER	1	TUNGSTEN
LINK	2	SEE R3015 SH.3
SHIELD POT	1	SEE R3015 SH.2
M10 WASHER	2	STAINLESS STEEL
M10 SCREW	2	STAINLESS STEEL
POT LID	1	SEE R3015 SH.2
D.U. INSERT	1	SEE R3015 SH.2
JACKET	1	SEE R3015 SH.3

A

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DESCRIPTIVE DRAWING

TITLE 3015 SHIELD CONTAINER TOP LEVEL ASSEMBLY

SIZE B | DWG. NO. R3015 | REV A

SCALE: NTS | SHEET 1 OF 4

5 4 3 2 1

[redacted]

GASKET	1	NEOPRENE OR EPDM
CLAMP BAR	2	STAINLESS STEEL
TOP HAT	1	STAINLESS STEEL
POT LID	1	STAINLESS STEEL
LEAD POT	1	LEAD 95% MIN PURE
PART NAME	QTY.	DESCRIPTION

UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS ARE IN INCHES. SEE NOTE 1.

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DESCRIPTIVE DRAWING

TITLE 3015 SHIELD CONTAINER

SIZE	DWG. NO.		REV
B	R3015		A
	SCALE: NTS	SHEET 2 OF 4	

[redacted]

PART NAME	QTY.	DESCRIPTION
PIN	4	.2DIA S.ST ROD
RING	1	STAINLESS ST.
LINK	4	.4DIA S.ST ROD
BRACKET	4	STAINLESS ST.
JACKET	1	2mm THICK SS

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DESCRIPTIVE DRAWING

TITLE 3015 SHIELD CONTAINER

SIZE	DWG. NO.	REV
B	R3015	A
	SCALE: NTS	SHEET 3 OF 4

[redacted]

PART NAME	QTY.	DESCRIPTION
M8 SCREW	4	STAINLESS STEEL
TOP PLATE	1	STAINLESS STEEL
BODY	1	LEAD

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QSA
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DESCRIPTIVE DRAWING

TITLE 3015 SHIELD CONTAINER

SIZE	DWG. NO.	REV
B	R3015	A
	SCALE: NTS SHEET 4 OF 4	

[redacted]

CORK
UREA FORMALDEHYDE
RESIN BINDER
DENSITY - 17±2 LBS./ CU. FT.

S	DATE		
	9MAR04	AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING
	9mar04		
RWISE SPECIFIED N INCHES		TITLE	BOTTOM INNER CORK INSERT
± 1/8 ± 0.12 ± 0.06 ± 0.020		SIZE B	DWG. NO. 97623 REV A
			SCALE: NONE SHEET 1 OF 1

5 4 3 2 1

D

C

B

A

[redacted]

APPROVALS	DATE
[illegible]	9MAY04
C. [illegible]	9may04

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

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DESCRIPTIVE DRAWING

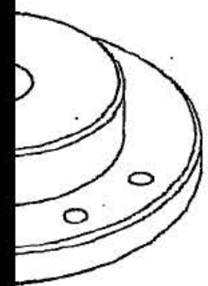
TITLE CORK SPACER TOP INNER

ERF#	SIZE	DWG. NO.	REV
808	B	R97637	A

SCALE: NONE SHEET 1 OF 1

5 4 3 2 1

[redacted]



UREAFORMALDEHYDE RESIN
BINDER, DENSITY
17±2 LBS./CU FT

DESCRIPTION

APPROVALS	DATE
N Klasowski	9/15/04
C. Koffman	9/16/04

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QSA
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DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

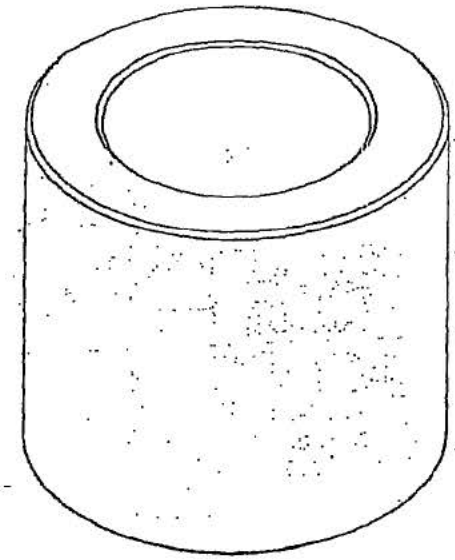
TITLE TOP OUTER CORK INSERT

ERF #	808

SIZE A | DWG. NO. R97615 | REV B

SCALE: NONE | SHEET 1 OF 1

[redacted]



PART NAME	QTY.	DESCRIPTION
CORK		UREA FORMALDEHYDE RESIN BINDER, DENSITY 17±2 LBS./CU FT

ALS	DATE
...ula	9MAR04
...lan	9mar04

HERWISE SPECIFIED
IN INCHES
S:
S ± 1/8
.X ± 0.12
XX ± 0.06
XX ± 0.020

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QSA
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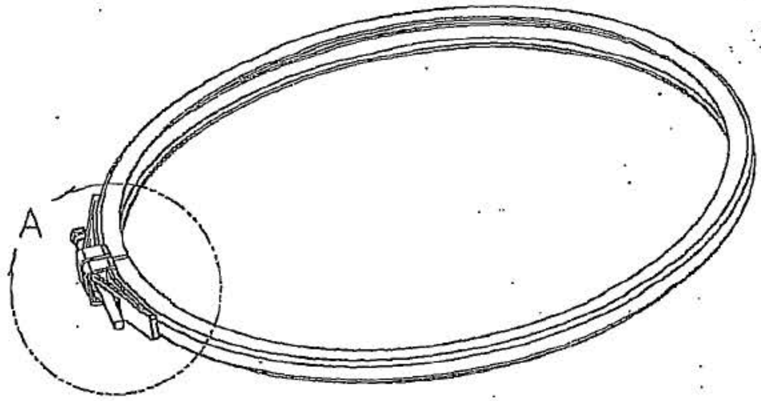
DESCRIPTIVE DRAWING

TITLE
BOTTOM OUTER CORK INSERT

SIZE	DWG. NO.	REV
A	R97616	B

SCALE: NONE SHEET 1 OF 1



[redacted]

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS STRUCTURAL WELDING CODE (OR EQUIVALENT INTERNATIONAL STANDARDS) CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. SEE SHEET 2 of 2 FOR DETAILS OF ITEMS 1,3,4 AND 5.

ITEM	QTY.	DESCRIPTION
5	2	STRAP, .07 THICK STAINLESS STEEL
4	2	SST SHROUD
3	1	M8X1.25, 14MM BRASS NUT
2	1	M8X1.25 130mm LG SST BOLT
1	1	CLAMPBAND, STAINLESS STEEL

APPROVALS	DATE
[signature]	9Mar04
C. [signature]	9Mar04

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

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DESCRIPTIVE DRAWING

TITLE: CLAMP, BAND

ERF# 809

SIZE: B | DWG. NO. RCLM009 | REV B

SCALE: NA | SHEET 1 OF 2

[redacted]

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DESCRIPTIVE DRAWING

TITLE	CLAMP, BAND		
SIZE B	DWG. NO. RCLM009		REV B
	SCALE: NA	SHEET 2 OF 2	

[redacted]

NOTES:
1. MATERIAL: 16 GAUGE (.06) STAINLESS STEEL.

APPROVALS	DATE
[signature]	9 MAR 04
C. [signature]	9 mar 04

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DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/2
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE 20 GALLON DRUM MODEL 976

ERF# 809

SIZE B | DWG. NO. R97608 | REV B

SCALE: NONE | SHEET 1 OF 1

Section 12. APPENDIX E – ORIGINAL TEST PLAN

TEST PLAN 90

MODEL 976
TRANSPORT DRUM

AEA Technology QSA Inc.
Burlington, MA 01803

Contents

Section 10 List:

Drawing Number	Rev.	Description
97608	A	20 GAL. Barrel, Model 976
97610	A	Overpack Assy, Model 855
97613	A	Overpack Assy, Model 616
97615	A	Top Cork Insert, Model 855
97616	A	Bottom Cork Insert, Model 855
97619	A	Bottom Cork Insert, Model 616
97620	1	Top Cork Insert, Model 616
97622	A	Clamp Band
97623	1	Bottom Cork Insert, Model 3015/3056/864
97630	1	Mod. 855 Transport Package
97633	1	Mod. 616 Transport Package
97635	1	Overpack Assy, Model 3015/3018
97636	1	Model 3015/3056/3018 Transport Package
97637	1	Cork Spacer 0.5" Thick
3A21773	D	Pot design number 3056 (P616)

Figures:

Figure	Description
Fig. 8.6.1.1	Specimen TP90 (A) Compression Test Set-up
Fig. 8.7.2.1	Specimen TP90 (A) Orientation for the Penetration Test
Fig. 8.8.2.1	Specimen TP90 (A) Orientation for the 1.2m Drop Test
Fig. 8.10.2.1	Specimen TP90 (B) Orientation for the 9m Drop Test.
Fig. 8.10.3.1	Specimen TP90 (C) Orientation for the 9m Drop Test
Fig. 8.10.4.1	Specimen TP90 (D) Orientation for the 9m Drop Test
Fig. 8.10.5.1	Specimen TP90 (E) Orientation for the 9m Drop Test
Fig. 8.10.6.1	Specimen TP90 (F) Orientation for the 9m Drop Test
Fig 8.10.6.1	Specimen TP90 (G) Orientation for the 9m Drop Test

Tables:

Table	Description
Table: 6.1	Model 976 Series Variations

Section 1 Introduction

This document describes the mechanical test plan for the Model 976 Transport Drum package to meet NRC requirements for Type B (U) packages as described in the Code of Federal Regulations, 10 CFR Part 71, revised as of January 1, 1997. The test plan also covers the criteria stated in the IAEA Regulations for the Safe Transport of Radioactive Material, Safety Series No.6 1985 Edition, (As Amended 1990).

The Model 976 Transport Drum is designed to transport various families of projectors, changers and transport casks. These include the Model 855, 864 bulk source changer, the Model 616 projector, Model 3056 Lead Pot family which include also 3055,3078,3077,1911,667,3015 and 3018.

This document describes the test package specification, testing equipment, testing scenario, justifies the package orientations for the different test specimens, and provides test checklists to record essential steps in the testing sequence.

Section 2 Transport Package Description

The 976 Transport Drum consists of an open head stainless steel drum with a high density cork liner. The lid is secured with a stainless steel band clamp. The arrangement of the cork liner will vary with respect to the type of package being transported within the drum. Specifics on the base container follow:

DRUM
- Manufactured of 16 gage 304 stainless steel.
- All seams seal welded against ingress of fluids.
- Sides re-enforced with two (2) ¾ to 1-inch outward side ribs.
- In accordance with (IAW) 97608 Rev A (see Section 10 for referenced drawing).
- 20 gallon capacity.

CLOSURE BAND
- All stainless steel construction.
- Stainless steel closure bolt – UN-lubricated.
- IAW drawing (97622) (see Section 10 for referenced drawing).

REV A

LINER
- Medium-high density cork (17 lbs/ft^3) manufactured from medium size granules with a resin binder and bonded with urea formaldehyde resin.
- The liners are formed and cut to block and brace the various packages within the drum.
- The standard liner is designed for the Model 855 family. This liner is present in all drums and is manufactured to R97610 Rev A The remaining families of devices have supplemental liners that provide additional blocking and bracing within the cavity formed by the standard liner. Supplemental liners are:
- For the 616 family -Manufactured to B97613 Rev A (See Section 10 for referenced drawing).
- For the 3056 Manufactured to B97636 Rev 1 (See Section 10 for referenced drawing).

The families of containers/projectors to be transported within the 976 follow:

Model 855 Family Source Changer
- The units manufactured comply with D85501 Revision G (See Section 10 for referenced drawing).
- The maximum capacity of the device is 1000 Ci of Ir192.
- The gross weight of the unit is approximately 195 lbs.

- The depleted uranium shield is saucer shaped and contains eight (8) titanium source tubes. The tubes are welded at the distal end into a titanium disk imbedded in the shield.
- The shield is encased by a welded, carbon steel cylindrical shell. Smaller cylinders support the shield within the outer weldment. The interstitial space is filled with 20-lbs./ft^3 Polyurethane foam. All depleted uranium/steel interfaces are separated by copper sheeting to prevent formation of the eutectic during extreme thermal conditions.
- The sources are retained within the device by a sliding lock assembly. The lock plate directly actuated by the plunger type lock, captures either the spiral wrap of the teleflex wire or the stop ball, depending on the source design being transported. The plunger lock is constructed of brass, the locking body and slide are carbon steel. The lock assembly is secured to the top plate of the weldment by four (4) steel screws.
- The cover of the container, which is bolted to a ring welded to the top of the cylindrical weldment during transport, consists of a plate with a small cylinder welded to its underside. During transport, this cylinder stops the slides from withdrawing by preventing horizontal movement of the locks. Additionally, the sources are retained by a cap, which threads onto the lock assembly over the proximal end of the source.
- Model 864 Source changer will fall under 855-test plan, due to similarities in both designs. Model 864 will not be tested and results from 855 will be assessed.

Model 616 Projector

- The maximum capacity of the device is 240 Ci of Ir192.
- The packages are constructed in accordance with Technical Operations Inc. drawing numbers D61610 Rev. F (see section 10 for Ref. Drawing).
- The gross weight of the package is approximately 60 lbs.
- The unit is a depleted uranium shielded, steel encased radiographic device. The source is contained at the bottom of a source rod and kept in the shield position by a depression lock which prevent movement of the source rod during shipment. The source changer is approximately 11 ½ - inches long, 6 ¼ inch in diameter and provided with a 6 7/16-inch wide leg base and a steel handle (1/2-inch diameter). The radioactive source assembly is housed in SS tube. The tube is surrounded by depleted uranium metal as a shielding material encased within a steel housing.

Model 3056 Family Lead Pot

- The maximum capacity of the device is 1513 Ci of Ir192.
- Model 3056 package is constructed in accordance with AEA Technology QSA Inc./ Amersham Drawing number A21773 Rev – (see section 10 for referenced drawing).
- The gross weight of the Package is approximately 103.6 lbs.
- The unit is a depleted uranium, Tungsten alloy, lead and carbon steel encased Pot. The device is approximately 11.0 inches long and 6.14-inches in diameter and provided with a protective cap. The radioactive source assembly is housed in a Zircalloy or titanium tube. The tube is surrounded by Lead metal as a shielding material.
- Family Models (3055,3056, 3078, 3077, 1911, 667, 3015, 3018) lead Pot will fall under 3056 test plan, due to similarities in outside envelop design. Family models will not be tested and results from 3056 will be assessed.

Section 3 Regulatory Compliance

The purpose of this plan, which was developed in accordance with AEA Technology QSA Inc. Engineering Work Instruction Document Number E-1808, is to demonstrate that the Model 976 Transport Drum, meets the Type B transport package test requirements of 10 CFR 71 and the IAEA Safety Series No.6.

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

Water spray preconditioning of the package is not performed. The Model 976 Transport Drum is constructed of waterproof materials throughout and while it contains cork liners, no damage or degradation is expected in the short term from exposure to water.

The Hypothetical Accident Tests (10 CFR 71.73) to be performed are the 9m (30 foot) free drop test, puncture test. The thermal test will be assessed if needed.

The crush test (10 CFR 71.73(c)(2)) will not be performed because the radioactive contents are qualified as Special-Form radioactive material.

The immersion test and all other conditions specified in 10 CFR 71 will be separately evaluated in the text of the Safety Analysis Report.

Section 4 Discussion on System Failure Modes of Interest

4.1 General

The location of the source relative to its stored position in the shield is an important safety element. Displacement of the source and/or shield from its original stored position could elevate the dose at the surface of the package above regulatory limits.

The tests in this plan focus on damaging those components of the package which could cause displacement of the source, relative to its stored position, within the shield and which affect the integrity of the shield itself.

There are two possible mechanisms to cause these types of failures:

a) The shield could move away from the source if the internal components restricting the movement of the shield were damaged and the source tubes and outer shells were fractured during testing.
b) The source could move away from the shield if the lock assembly became loose or was removed from the outer shell/body.

Both mechanisms described above may occur simultaneously

4.2 Normal Conditions of Transport

4.2.1 Damage to the fixture of the drum lid from the penetration test could cause a reduction in its ability to remain closed.

4.2.2 Following the compression and penetration tests, a 1.2m drop test may cause the weakened lid to open and allow the projector/source changer to fall out.

4.3 Hypothetical accident Conditions of Transport.

4.3.1 Failure of the drum to adequately protect the projector/source changer from the shock of the impact thereby causing displacement of the source and/or shield by mechanism 4.1(a) and/or 4.1(b) resulting in a dose rate increase above the allowable limit.

4.3.2 Failure of the drum to adequately protect the projector/source changer from the shock of the impact combined with failure of the of the unit itself and the failure of the drum to remain intact, causing exposure of the either Cork or depleted uranium shields within the bodies. Degradation of the cork and/or oxidation of the shield in the subsequent fire test could then result in displacement of the

source and/or shield as described in 4.1(a) and/or 4.1(b) leading to a dose rate increase above the allowable limit.

Section 5 Assessment of Package Conformance

5.1 Regulatory Requirements

5.1.1 Normal Conditions of Transport Tests (71.43(f))

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

IAEA Safety Series No. 6 para. 537 stipulates the same criteria except that it states in paragraph 537(b) 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.

5.1.2 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/h at 1m from the external surface with the maximum radioactive contents which the package is designed to carry.

5.2 Test Package Contents

The Model 976 Transport Drum is designed to carry Special Form Sources. Containment of the radioactive source is tested at manufacture. The source capsule design have been certified by the Competent Authority in accordance with the performance requirements for Special Form as specified in 10 CFR Part 71 and 49 CFR.

This test plan therefore does <u>not</u> discuss/specify tests of the containment of the radioactive source. The purpose of the tests is to demonstrate that the shielding remains effective within the limits specified by the regulations.

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

Section 6 Construction and Condition of Test Specimens

The test specimens will be Model 976 Transport Drum units constructed in accordance with AEA Technology QSA Inc. drawings as enumerated in the Table 6.1. The units will contain the various projectors and/or source changers as mentioned in Section 2.

Except for the normal condition tests and the thermal test, the test temperature of the package must be at or below -40°C at the time of each test, a minimum temperature required by IAEA Safety Series 6 and 10 CFR 71. The low temperature represents the worst-case condition for the package because of the potential for brittle fracture of the shield and the outer shell of the projectors or source changers.

Every attempt will be made to keep the entire package below -40°C. however, as the liner is constructed of Cork, a natural insulator, this may prove to be impossible by merely chilling the exterior of the drum package. As such, the projector or source changer to be tested will be chilled below -40°C separately and re-inserted into the drum just prior to testing. The drum and liners will also be chilled. However, as they are constructed of very thin section stainless steel and cork respectively, this lowered temperature will have virtually no effect on the outcome of the testing with respect to the drum and liners.

Seven (7) test specimens are to be tested. One will be subject to normal condition tests and the remaining six (6) for Hypothetical tests. All are at or above the maximum observed field weight for the various devices within, achieved (if necessary) by placing lead sheets around the body of the device within the drum to insure maximum weight similarities. Adding lead will only simulate the weight not the performance of the device. All profiles will be performed without the lead.

All projector/source changer units tested will be pulled from the field population. As these units have seen years of service in varying conditions, they represent a worst case scenario with respect to the drums ability to prevent damage.

Sample Number	Drawings Referenced	Test Condition	Comments
TP90 (A)	B97630 Rev A D85501 Rev G	Normal	Model 855 transport package Contains a Model 855 source changer
TP90 (B)	B97630 Rev A D85501 Rev G	Hypothetical	Model 855 transport package Contains a Model 855 source changer
TP90 (C)	B97630 Rev A D85501 Rev G	Hypothetical	Model 855 transport package Contains a Model 855 source changer
TP90 (D)	B97630 Rev A D85501 Rev G	Hypothetical	Model 855 transport package Contains a Model 855 source changer
TP90 (E)	B97630 Rev A D85501 Rev G	Hypothetical	Model 855 transport package Contains a Model 855 source changer
TP90 (F)	B97633 Rev A D61610 Rev F	Hypothetical	Model 616 transport package Contains a Model 616 Projector
TP90 (G)	B97634 Rev A D61622 Rev F	Hypothetical	Model 3056 family transport package. Contains a Model 3056 Lead Pot

Table 6.1: Model 976 Test Variations

Note: See Section 10 for all referenced drawing.

Section 7 Material and Equipment List

The test checklists in Section 9 list the equipment to the specification required by 10 CFR 71 and all other necessary equipment and measuring instruments needed to perform the tests.

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

Section 8 Test Procedure

8.1 General

Seven (7) specimens are to be tested to determine the transport integrity of package. The testing sequence is presented below with testing focusing on three areas.

- Disruption of the containment of the drum such that the device is caused to exit after the 9m drop.
- The ability of the drum and liners to absorb the impact energy, and substantially protect the internal container in the 9m drop test.
- To inflict damage to projector components within the drum.

Should the unit fail resulting in exposure of the container inside, further testing will concentrate on damaging or removing the lock system, disrupting the container integrity or attempting to add to previous damage whichever is considered more appropriate. Furthermore, if the drum has failed and damage has occurred to the inner container such that the cork surrounding the shield or the shield itself is exposed as described in Section 8.12, the package will be evaluated to see if thermal test will be necessary.

The 976 Transport Drum packages are not hand held items and there is no requirement to "condition" a package by subjecting it to normal condition of transport prior to the hypothetical accident conditions of transport testing. For this reason, one specimen, TP90 (A), will be subjected to the normal conditions of transport tests. The remaining six (6) specimens will be subjected to the hypothetical accident conditions of transport in the orientations shown in Section 8.10

The tests have the following sequence:

1. Test specimen preparation and inspection.

Normal Conditions of Transport Tests. (Specimen TP90 (A))

2. Compression test (10CFR 71.71(c)(9)).

3. Penetration test, (10 CFR 71.71(c)(10)).

4. Free drop test at 1.2m (Four-foot); (10 CFR 71.71(c)(7)).

5. First intermediate test inspection.

Hypothetical Accident Conditions Tests. (Specimens TP90 (B), TP90(C), TP90 (D), TP90 (E), TP90 (F), and TP90 (G))

6. 9 m (30-foot) free drop tests (10 CFR 71.73(c)(1)).

7. Puncture tests (10 CFR 71.73(c)(3)).

8. Second intermediate test inspection.

9. Thermal tests (if applicable).

10. Final test inspection.

8.2 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 and 10 CFR 71.

- **Quality Assurance** oversees test execution and test report generation to assure compliance with the AEA Technology QSA Inc. Quality Assurance Program.

- **Engineering, Regulatory Affairs** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71.

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

8.3 Specimen Temperature Measurement

8.3.1 The Normal Condition tests (penetration, drop and puncture) are to be carried out while the ambient air temperature before and after the tests remained constant at that value between -29°C (-20°F) and +38°C (+100°F). The test will be carried out while the package is at or below -40°C.

8.3.2 For the Hypothetical Condition, tests will be carried out at or below -40°C, temperature measurements will be made by positioning thermocouples on the shield or where possible of the inner container as well as on the drum.

8.4 Test Specimen Preparation and Inspection

Use *Checklists 1a-1c*: *Specimen Preparation and Inspection.*

To prepare the test units:

1. Manufacture: Seven (7) Model 976 Transport Drum units per drawing B97610, five (5) units will be used per B97630, one (1) unit per B97733 Rev 1, and one (1) unit per B97734 Rev 1. (See Section 10 for all referenced drawings)

2. Secure two (2) Model 855 source changers (which will be interchanged for the five 855 drum tests), One (1) 3056 lead pot and one (1) Model 616 projector. Determine if any of the units to be tested need additional weight. Add lead sheets if necessary. Record and photograph all weight modifications.

3. Inspect the units to ensure that all fabrication and inspection records are documented in accordance with the AEA Technology QSA Inc. Quality Assurance Program in effect at the time of manufacture and comply with test plan requirements.

4. Place the units in the respective Transport Drums in accordance with Table 6.1.

5. Clearly and indelibly, mark the units with identification per Table 6.1.

6. Perform and record the radiation profile in accordance with AEA Technology QSA Inc. Quality Assurance Program.

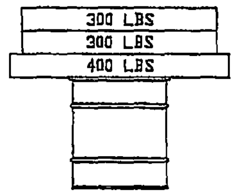
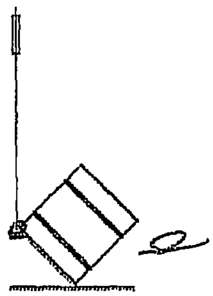
7. Quality Control, Engineering, Regulatory Affairs and Quality Assurance will jointly verify that each test specimen complies with the AEA Technology QSA Inc. Quality Assurance Program.

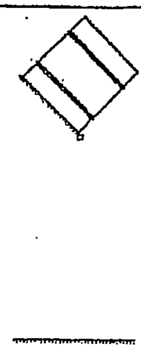
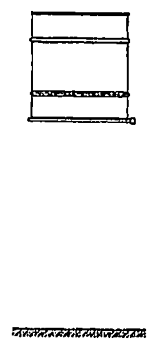
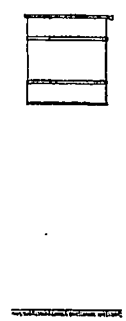
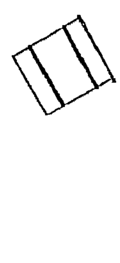
8. Measure and record the location of the simulated source in each specimen using appropriate method.

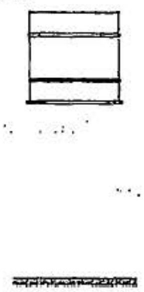
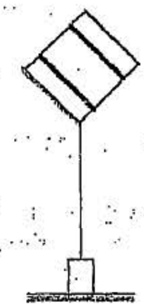
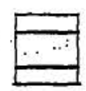
9. Prepare the units for transport in accordance with their respective operating instructions.

10. Measure and record the weight of each complete package.

8.5 Summary of Test Schedule

Normal Conditions Test	Parameter	Specimen	Diagram
Compression (See Sec. 8.6)	71.71(c)(9)	TP90(A)	
Penetration (See Sec. 8.7)	71.71(c)(10)	TP90(A)	
1.2m Drop (See Sec. 8.8)	71.71(c)(7)	TP90(A)	

Accident Conditions Test	Parameter	Specimen	Diagram
9m Drop 45° Angle (See Sec. 8.10.2)	71.73(c)(1)	TP90(B)	
9m Drop (See Sec. 8.10.3)	71.73(c)(1)	TP90(C)	
9m Drop (See Sec. 8.10.4)	71.73(c)(1)	TP90(D)	
9m Drop 30° Angle (See Sec. 8.10.5)	71.73(c)(1)	TP90(E)	

9m Drop (See Sec. 8.10.5)	71.73(c)(1)	TP90(F) TP90(G)	Orientations for each unit are to be determined for worst case scenario following completion of TP90 (B...E) 9m drop test. 
Puncture (See Sec. 8.10.6)	71.73(c)(3)	TP90(B)? TP90(C)? TP90(D)? TP90(E)? TP90(F) TP90(G)	Orientations for each unit are to be determined following completion of 9m drop test 
Thermal Will be assessed if needed.	71.73(c)(4)	TP90(B) TP90(C) TP90(D) TP90(E) TP90(F) TP90(G)	Requirement for thermal test to be determined following completion of drop and puncture tests 

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

The first test is the compression test described in 10 CFR 71.71(c)(9). For this test, the package in its heaviest configuration is placed under a load equal to five times the total package weight for at least 24 hours.

Use *Checklist 2: Compression Test* to date and initial all action items and to record required data.

8.6.1 Compression Test Set-up

Only Specimen TP90 (A) is to be tested.

To prepare the specimen for the compression test:

1. Review the set-up shown in Figure 8.6.1.1.

   Place the specimen upright on its base above the steel plate.

   Orient the package to its normal transport position.

   Photograph package. Record measurements at each corner.

2. Gradually and uniformly, place a load equal to 5 times the total package weight plus sufficient additional to account for scale tolerances (minimum of 1- percent additional weight), as shown in Figure 8.6.1.1.

   The load is five times the package weight and is greater than 13kPa multiplied by the vertically projected area:

   Photograph package. Record measurements A (height of the barrel) and B (width of the barrel).

3. After 24 hours have elapsed photograph package and record measurements A and B.

4. Remove the weights and record measurements A and B as well as any permanent damage to the package.

See Figure 8.6.1.1for Compression Test Set-up.

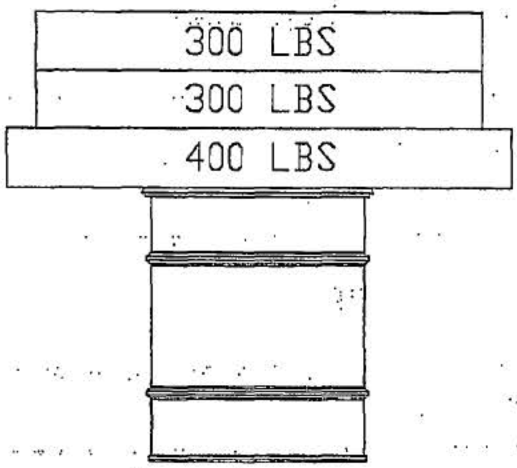


Figure 8.6.1.1

8.6.2 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.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.
- Assess the damage to the specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of the specimen to determine if any changes are necessary in package orientation in the 1.2m drop test to achieve maximum damage.

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

The second test to be carried out will be the penetration test as described in 10 CFR 71.71(c)(10)), in which a penetration bar is dropped from a height of 1m (40") to impact a specified point on the package.

Use *Checklist 3: Penetration Test* to ensure that the test sequence is followed. Date and initial all action items and record required data.

NOTE: *The checklist identifies those steps which must be witnessed by Engineering, Regulatory Affairs and Quality Assurance.*

8.7.1 Penetration Test Set-up

There is a specific orientation so that the penetration bar is aimed at the component or assembly of interest.

NOTE: *Because each test is designed to add to damage inflicted on a specific component or assembly in the proceeding 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 prepare a specimen for the penetration test:

1. Measure the units internal and surface temperature to ensure that the package is at or below -40°C.
2. Place the specimen on the drop surface and position it according to the specimen-specific orientation described below.
3. Use shims to position the package, if necessary.
4. Position the 3.0" inner Diameter guide tube directly above the specified point of impact, and raise the penetration bar 1m (40") above the target. Photograph the test set-up.
5. Drop the test bar. Record damage and take photographic record.

8.7.2 Specimen TP90 (A) Orientation for Penetration Test

The penetration target for specimen TP90 (A) is the drum SS band, which hold the lid to the drum package using M8 fastener. Such an impact could loosen or shear the bolt off the band assembly. This may in turn either result directly in the lid lifting in this area, or result in sufficient damage so that subsequent testing raises or even removes the lid. This penetration test will therefore test the effectiveness of the lid fastener.

TP90 (A) is laid 45° on its side (hinged side facing the penetration bar) so that it rests as shown in figure 8.7.2.1. The penetration bar is arranged to ensure that the impact point is above the bolted fastener.

Figure 8.7.2.1: Specimen TP90 (A) Orientation for the Penetration Test

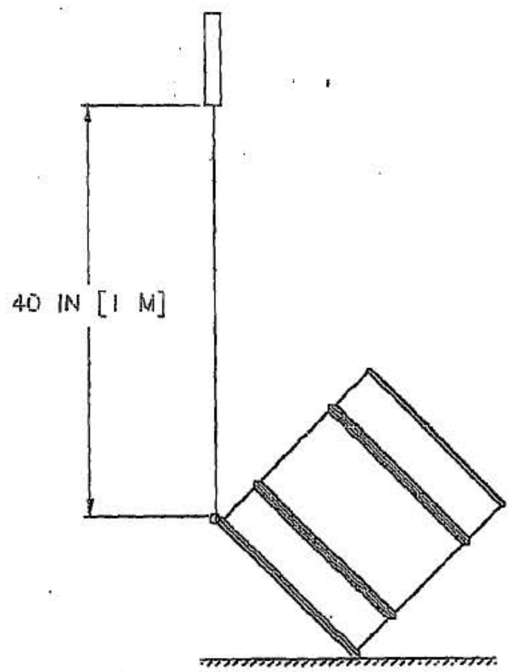


Figure 8.7.2.1

8.7.3 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.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.
- Assess the damage to the specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of the specimen to determine what changes, if any are necessary in package orientation in the four-foot drop to achieve maximum damage.

8.8 1.2m Free Drop Test (10 CFR 71.71(c)(7))

The final Normal Transport Conditions test is the 1.2m (four-foot) drop test as described in 10 CFR 71.71(c)(7). These drop compounds any damage caused in the previous tests. Upon completion, the intermediate test inspection shall be performed.

Use *Checklist 4: 1.2m drop Test* to ensure that the test sequence is followed. Date and initial all action items and record required data on the checklist.

NOTE: *The checklist identifies those steps which must be witnessed by Engineering, Regulatory Affairs and Quality Assurance.*

8.8.1 1.2m Free Drop Test Set-up

In this test, the package is released from a height of 1.2m (four feet) and lands on the steel drop surface. There is a specific orientation for the specimen so that the package lands on the component or assembly of interest.

To set up a package for the 1.2m drop test:

1. Measure the units internal and surface temperature to ensure that the package is at or below -40°C.
2. Place the specimen on the drop surface and position it according to the specimen's specific orientation described below.
3. Establish the center of gravity and arrange the lifting mechanism/system such that the center of gravity is as shown in Figure 8.8.2.1.
4. Raise the package so that the impact target is 1.2m (4.0 feet) above the drop surface.
5. Photograph the set-up.
6. Drop the package.
7. Record the damage to the package and take a photographic record.

8.8.2 Specimen TP90 (A) Orientation for 1.2m Free Drop Test

The 1.2m (4ft) drop test set-up for Specimen TP90 (A) is shown in Figure 8.8.2.1. The objective of this drop is to test the ability of the package to absorb the energy from an impact on its normal position, and maintain the containment of the inner container. Such impact might cause the locks to shear, or the outer source container to distort, forcing the lid to open and the device to exit. Additionally, the drum may prove inadequate in providing protection for the internal components and damage of those components might occur.

Upon impact, the top lid is most likely to be forced open due to the internal momentum of the internal container. It is important to position test specimen TP90 (A) so that its center of gravity is directly above the impact line.

Figure 8.8.2.1: Specimen TP90 (A) Orientation for the 1.2m Drop Test

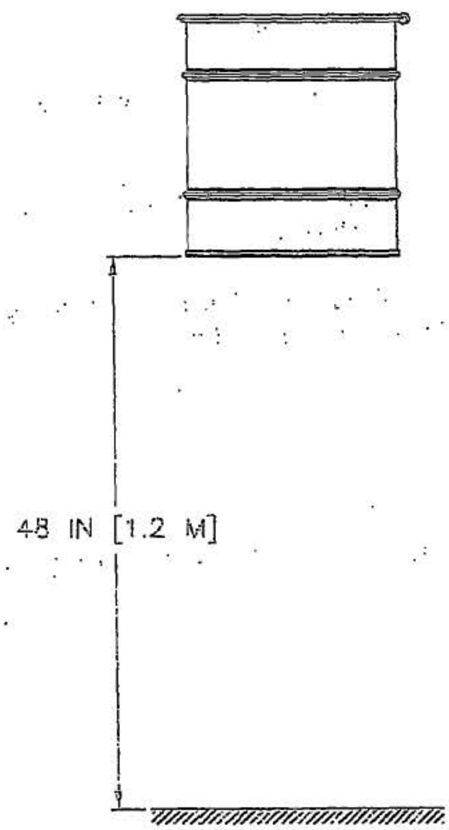


Figure 8.8.2.1

8.8.3 1.2m Drop 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.
- Assess the damage to the specimen.

8.9 First Intermediate Test Inspection

Following the 1.2m (four-foot) drop test, an intermediate test inspection will be performed.

1. Measure and record any damage to the test specimen.
2. Disassemble the package and remove the inner container.
3. Remove and assess the condition of the simulated source.
4. Reassemble the package using an active source, making sure that the source position and the package configuration are the same as they were immediately after the second 1.2m (4.0ft) drop test.
5. Measure and record a radiation profile of the test specimen in accordance with standard practice.
6. Assess the significance of any change in radiation at the surface or at one meter from the package.

Engineering, Regulatory Affairs and **Quality Assurance** team members will make a final assessment of the test specimen and jointly determine whether the specimen meets the requirements of 10 CFR 71.71 set out in section 5, para.5.1.1.

8.10 9m Free Drop Test (10 CFR 71.73(c)(1))

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

Use *Checklist 5: 9m Drop Test* to ensure that the test sequence is followed. Date and initial all action items, and record required data on the checklist.

NOTE: *The checklist identifies those steps which must be witnessed by Engineering, Regulatory Affairs and Quality Assurance.*

Figures 8.10.2.1, 8.10.3.1, 8.10.4.1 and 8.10.5.1 illustrate the orientations for the four test units.

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

8.10.1 9m Free Drop Test Set-up

To set up a package for the 9m (30-foot) drop test:

1. Measure the specimen's internal and surface temperature to ensure that the package is at or below -40°C.
2. Place each specimen on the drop surface and position it according to the specimen-specific orientation described below.
3. Establish the center of gravity and arrange the lifting mechanism/system such that the center of gravity is as shown in Figure 8.10.2.1, 8.10.3.1, 8.10.4.1 or 8.10.5.1.
4. Raise each specimen so that the impact target is 9m (30 feet) above the drop surface.
5. Photograph the set-up.
6. Drop the package.
7. Record the damage to the specimen and take a photographic record.
8. Measure and record the temperature of the package.

8.10.2 Specimen TP90 (B) Orientation for the 9m Drop Test

Figure 8.10.2.1 shows the package orientation for Specimen TP90 (B). The drop will be on the top edge, about 45° angle of the package, around the lid fastener. The intention is try to shear the lid off by subjecting the drum to the full force of a 9m impact with 45° angle. If the lid were to shear off then the projector inside would be exposed to direct targeting from the following puncture testing.

It is important to ensure that the test specimen is positioned so that its center of gravity is directly above the impact point, in this case, the top front edge of the drum.

Figure 8.10.2.1: Specimen TP90 (B) Orientation for the 9m Drop Test

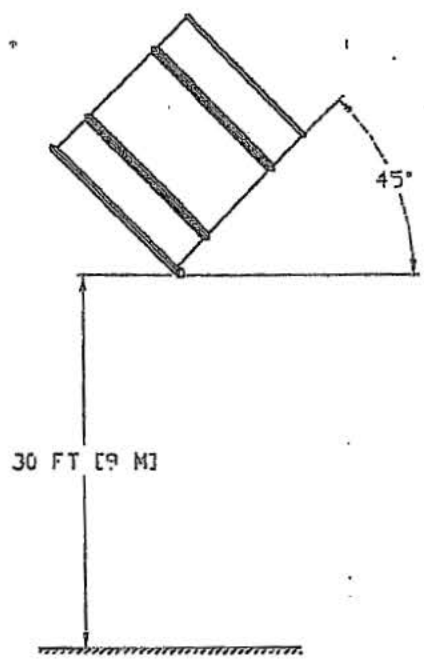


Figure 8.10.2.1

8.10.3 Specimen TP90(C) Orientation for the 9m Drop Test

This drop is designed to test the ability of one of the packages surfaces to crush and absorb the energy from an impact while retaining the contents and protecting them from damage. The intention is to try to deform the outer drum by inflicting damage to the lid and then the internal device. The effectiveness of the Cork protection and its ability to absorb shock loading will also be tested from a drop in this orientation.

The impact edge of the drum will be top down. Figure 8.10.3.1 shows the package orientation for Specimen TP90(C).

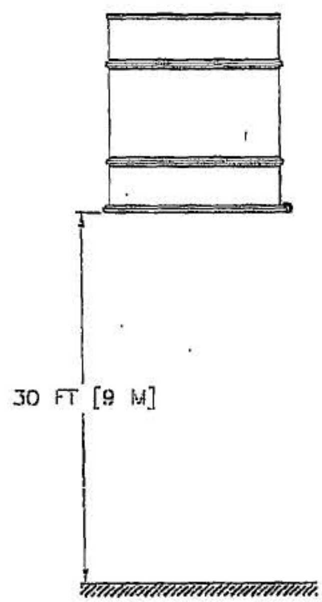


Figure 8.10.3.1

8.10.4 Specimen TP90 (D) Orientation for the 9m Drop Test

The intention of this drop is to subject the Bottom of the package to the full force of a 9m drop to see to what degree they crush and therefore absorb impact energy. A consequence of a lack of deformation would be that the heavy internal container, and in particular the shield, might retain enough momentum to be able to punch through the top of the outer drum. This might result in damage to the inner container components and even movement of the shield within the Cork, as this is ineffective as a shock absorber in this orientation.

TP90 (D) will impact on the Bottom of the drum as indicated in Figure 8.10.4.1. It is important to position the test specimen so that its center of gravity is directly above the impact point.

Figure 8.10.4.1: Specimen TP90 (D) Orientation for the 9m Drop Test

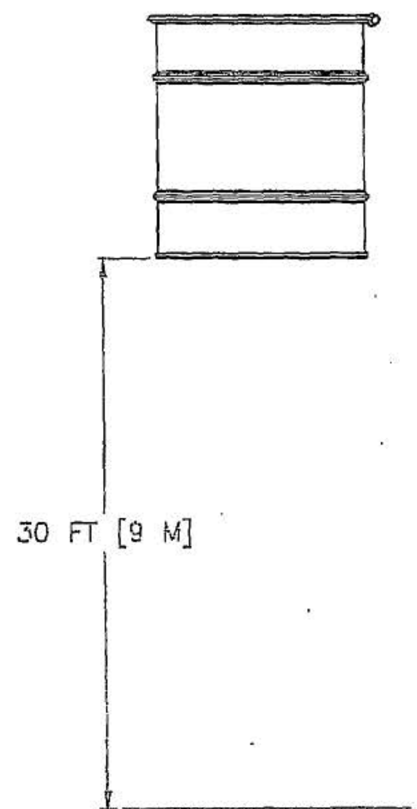


Figure 8.10.4.1

8.10.5 Specimen TP90 (E) Orientation for the 9m Drop Test

This test will be carried out with the impact being on the bottom end of the drum, at 30° Angle from the end of the locking system. The intention is to determine whether the second slap down impact on the drum could cause the lid to come off, thereby transmitting the energy from impact directly onto the inner container, and in particular to the lock system.

TP90 (E) will impact on the end plate as indicated in Figure 8.10.5.1. It is important to position the test specimen so that its center of gravity is directly above the impact point.

Figure 8.10.5.1: Specimen TP90 (E) Orientation for the 9m Drop Test

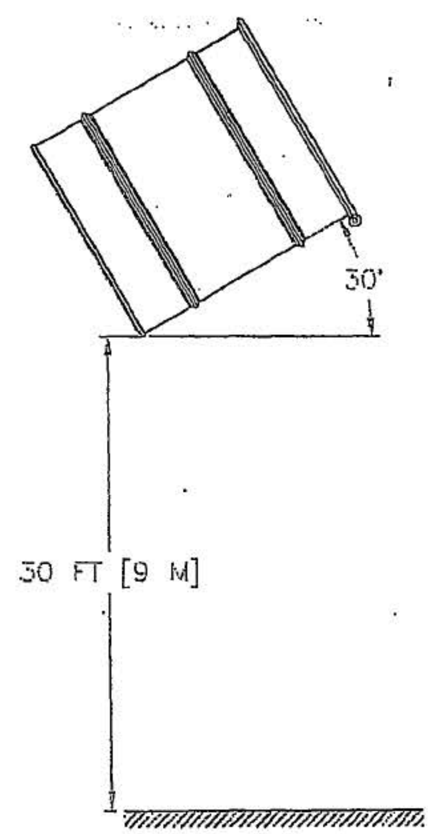


Figure 8.10.5.1

8.10.6 Specimen TP90 (F) and TP90 (G) Orientation for the 9m Drop Test

NOTE: *Upon completion of the previous four tests, Engineering, Regulatory Affairs and Quality Assurance team members will jointly assess the damage to each of the specimens to determine what orientation of the package will achieve maximum damage for specimen orientation. Using this orientation, proceed with tests TP90 (F) and TP90 (G).*

Worst case will be considered to proceed with testing for each specimen.

Figure 8.10.6.1: Typical specimen TP90 (F) and TP90 (G) Orientation for the 9m Drop Test

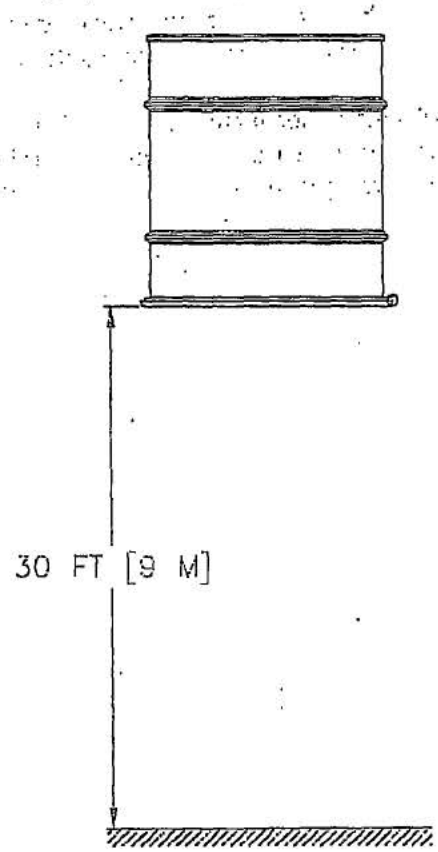


Figure 8.10.6.1

8.10.6 9m Free Drop 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.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.
- Assess the damage to each of the specimens and take one of the following actions based on that assessment.

  I. If the package remains intact, i.e. the lid remains in place evaluate the condition of the specimen to determine what orientation of the package will achieve maximum damage for specimen orientation for the puncture test.

  II. If the package is not intact, i.e. the lid has opened or broken away, remove the projector from inside and examine the projector for damage. The puncture test should be arranged to add or exacerbate this damage. If there is no obvious damage then target its lock system.

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

The 9m free drop test is followed by the puncture test per 10 CFR 71.73(c)(3), in which a package is dropped from a height of 1m (40") onto the puncture billet.

The billet is to be bolted to the drop surface used in the drop tests.

Use *Checklist 6: Puncture Test* to ensure that the test sequence is followed. Date and initial all action items and record required data on the checklist.

NOTE: *The checklist identifies those steps which must be witnessed by Engineering, Regulatory Affairs and Quality Assurance.*

8.11.1 Puncture Test Set-up

The orientation for each specimen will be determined from assessment of the condition of the specimen following the 9m drop testing

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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.*

This test requires that the test specimen be at or below -40°C at the time of the test. The checklist calls for measuring and recording the specimen temperature before and after the test.

The test uses the 12" or 16" (as appropriate with respect to orientation) high puncture billet. The billet meets the minimum height (8") required in 10 CFR 71.73(c)(3). The billet will be selected with respect to orientation of the package so that no projections or overhanging members could act as impact absorbers, thus allowing the billet to cause the maximum damage to the specimen.

To set up a package for the puncture test:

1. Measure the specimen's internal and surface temperature to ensure that the package is at or below -40°C.

2. Position it according to the specific orientation determined from assessment after the 9m drop testing.

3. Raise the package so that there is 1m (40") between the impact point on the package and the top of the puncture billet.

4. Photograph the set-up.

5. Drop the package.

6. Record the damage to the package and take a photographic record.

7. Measure and record the temperature of the package.

Figure 8.11.1.1: Typical specimen TP90 (B)…TP90 (G) Orientation for the 9m Puncture Test

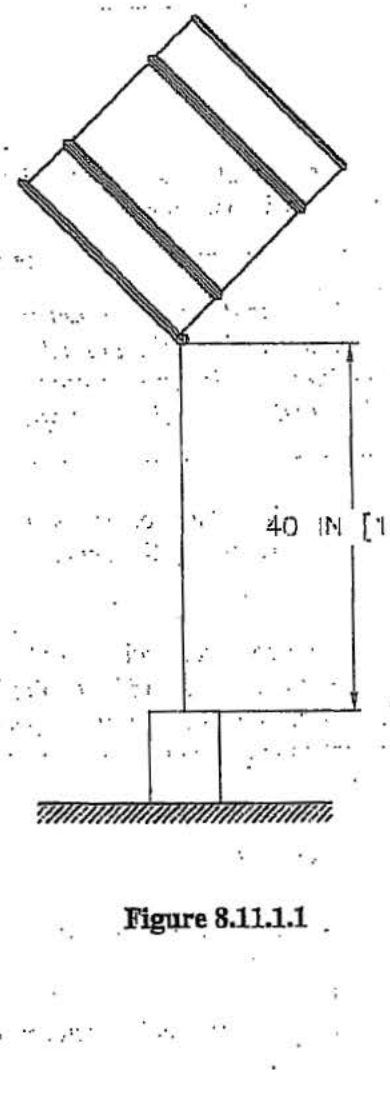

Figure 8.11.1.1

8.11.2 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 test was performed in accordance with 10 CFR 71.

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

- Assess the damage to the specimen to decide whether testing of that specimen is to continue. If the lid has come off the drum and sufficient damage to the inner container has occurred such that the Cork surrounding the shield is exposed as defined in Section 8.12, then a thermal test will be assessed.

- If the thermal test needed, evaluate the condition of the specimen to determine the orientation for the thermal test to achieve maximum damage and go to section 8.13.

- If, after assessment, it is determined that the thermal test is not needed, then go to section 8.14.

8.12 Second Intermediate Test Inspection

After the puncture test, examine all specimens as follows.

1. Measure and record the damage to each of the test specimens.

2. Measure and record the location of the source from the shipping plug using AEA Technology standard practice.

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

4. Reassemble the package using an 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 the test specimen in accordance with AEA Technology QSA appropriate method.

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

7. Review all results and decide whether a thermal test is needed.

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

The thermal test specified in 10 CFR 71.73(c)(4).

The oven is to be pre-heated to a temperature of no less than 810°C prior to the test commencing.

The specimen may comprise just an inner container or a 976 Transport Drum with inner container within.

Thermocouples are to be placed around and inside the specimen such that the temperature; on all external surfaces of the specimen placed in the oven and the center of the shield adjacent to the source, as a minimum is monitored. Other thermocouples may be positioned subject to the damage caused by the impact.

The thermocouples shall be positively fixed to their surfaces and the external ones shall be shielded from radiation from the furnace such that they measure the surface temperature of the specimen.

When the oven has been pre-heated the package is placed inside and positioned centrally within the oven. When the temperature at the surface of the specimen has risen to no less than 810°C the test will start. This temperature, above the required 800°C, includes an allowance for measurement uncertainty.

The package will remain in the oven for a period of 30 minutes after this point.

The test environment is an oven operating up to 900°C. There will be sufficient airflow to allow combustion.

If the specimen is burning when it is removed, the unit shall be allowed to extinguish by itself and then cool naturally. Appropriate measures should be taken to avoid the radiological risks associated with this hazard. The final evaluation of the package is performed when the specimen reaches ambient temperature.

8.13.1 Test Specimen Orientation

The selected orientation should be based on an assessment of the test specimen condition immediately after the puncture test. Record, justify and approve the orientation for this test in accordance with AEA Technology QSA appropriate method.

8.13.2 Thermal Test

To perform the thermal test:

1. Attach thermocouples to the specimen's internal and external measurement locations.

2. Heat the oven to no less than 810°C.

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

4. When the temperature of all surfaces of the specimen are at or above 810° C, start a 30-minute timer.

5. Throughout the test (5-min. intervals) measure and record the oven temperature, test specimen internal and external temperatures. Record whether there is any combustion.

6. Remove the test specimen from the oven. WARNING if the package is burning, appropriate safety measures must be in place to avoid the risks associated with burning polyurethane foam, cork and/or depleted uranium. Consult with the oven operator.

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

8. Record the damage to the package and make a photographic record / X-ray or radiograph.

8.13.3 Thermal 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.

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

8.14 Final Test Inspection

Perform the following inspections after completion of all required testing:

- Measure and record any damage to each test specimen.
- Measure and record the location of the sources using AEA Technology standard practice method.
- Remove and assess the condition of the simulated sources.
- Reassemble the packages using an active source, making sure that the source position and the package configuration are the same as they were immediately after the puncture test.
- Measure and record a radiation profile of each test specimen in accordance with AEA Technology QSA Standard practice method.
- Assess the significance of any change in radiation at the surface or at one meter from each package.
- Remove the active sources.
- Determine whether it is necessary to dismantle any of the test specimens for inspection of hidden component damage or failure.
- If it is decided to proceed with the inspection, record and photograph the process of removing any component.
- Measure and record any damage or failure found in the process of dismantling the test specimens.

Engineering, Regulatory Affairs, and **Quality Assurance** team members will make a final assessment of each test specimen and jointly determine whether the specimen meets the requirements of 10 CFR 71.73.

Section 9 Checklists

Use the following checklists for executing these tests. There are two checklists for each test: an equipment list and a test procedure checklist.

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

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

Note:

Equipment list 6 and Checklist 7 will only be required if it is determined that damage to a specimen is sufficient to warrant a Thermal Test.

Checklist 0: Specimen *Preparation and Inspection*

Step	TP90(A)	TP90(B)	TP90(C)	TP90(D)	TP90(E)	TP90(F)	TP90(G)
1. Record serial number of Device.							
2. Record device weight.							
3. Record Drum weight.							
4. Record total package weight.							
5. Are all fabrication and inspection records documented in accordance with the AEA TECHNOLOGY QSA INC Q.A. Program (at the time of manufacture)?							
4. Does the test unit comply with the requirements of Drawing?							
5. Has the radiation profile been recorded in accordance with AEA TECHNOLOGY QSA INC. Standard practice method?							
6. Is the package prepared for transport?							

Witnessed and verified by: Print Name: Date:

Engineering:

Regulatory Affairs:

Q.A.:

Equipment List 1: *Compression Test Equipment*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		
Signature	Print Name	Date
Completed by:		

Checklist 1: *Compression Test*

Step	**Test Specimen TP90(A)**			
1. Position the specimen as noted.				
2. Record the ambient temperature:				
3. Record the test weight:				
4. Measure and record reference dimensions pre-test.	A.	B.		
5. Place the test weights onto the test specimen and leave for 24 hours.				
6. Measure and record reference dimensions post-test.	A.	B.		
7. Record any damage to the test specimen.				

Test witnessed by: Signature:	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Equipment List 2: *Penetration Test Equipment*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		

Signature	Print Name	Date
Completed by:		

Checklist 2: *Penetration Test*

Step	Test Specimen TP(A)
1. Chill the test specimen to a temperature at or below -40°C.	
2. Record the test specimen temperature.	
3. Record the ambient temperature.	
4. Position the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the bar height.	Figure 8.7.2.1
5. Release the penetration bar. Check to ensure that the penetration bar hit the specified area.	
6. Record damage to the test specimen.	
7. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the 1.2m (4-foot) drop test to achieve maximum damage.	

Test witnessed by: Signature:	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Equipment List 3: *1.2m (4 foot) Drop Equipment List*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		
Signature **Completed by:**	Print Name	Date

Checklist 3: *1.2m (4 foot) Drop Test*

Step	**Test Specimen TP90(A)**			
1. Chill the test specimen to a temperature at or below -40°C.				
2. Measure and record the ambient temperature.				
3. Record thermocouple readings:	1.	2.	3.	4.
4 Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.8.2.1			
5. Release the test specimen.				
6. Record thermocouple readings:	1.	2.	3.	4.
7. Record any damage to the test specimen.				
8. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the 9m (30-foot) drop test to achieve maximum damage.				
Test witnessed by: Signature	Print Name	Date		
Engineering:				
Regulatory Affairs:				
Quality Assurance:				

Data Sheet 3: *1.2m (4 ft) Drop Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP90(A)**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 4: *9m (30 foot) Drop Test Equipment List*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		
Signature	Print Name	Date
Completed by:		

Checklist 4: *9m (30 foot) Drop Test*

Step	**Test Specimen TP90( )**			
1. Chill the test specimen to a temperature at or below -40°C.				
2. Record thermocouple readings:	1.	2.	3.	4.
3. Measure and record the ambient temperature.				
4. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.10.2.1			
5. Release the test specimen.				
6. Record thermocouple readings:	1.	2.	3.	4.
7. Record any damage to the test specimen.				
8. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test to achieve maximum damage.				

Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 4: *9m (30 ft) Drop Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP90( )**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ______________ Regulatory: ______________ QA: ______________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 5:*Puncture Test Equipment*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		
Signature **Completed by:**	Print Name	Date

Checklist 5: *Puncture Test*

Step	Test Specimen TP90( )			
1. Chill the test specimen to a temperature at or below -40°C.				
2. Record thermocouple readings:	1.	2.	3.	4.
3. Measure and record the ambient temperature.				
4. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	~~Figure 5~~ 8.11.1.1			
5. Record thermocouple readings:	1.	2.	3.	4.
6. Release the test specimen.				
7. Record any damage to the test specimen.				
8. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.				

Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 5: *Puncture Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP90( )**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 6: *Thermal Test Equipment*

(Attach inspection report or calibration certificate for all equipment)

Description	Model Number	Serial Number
Ambient Thermometer.		
Thermocouple surface probe.		
Thermocouple surface probe.		
Thermocouple surface probe.		
Thermocouple recording device.		
Oven		
Oven thermostat.		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
	Signature	Date
Completed by:		
Verified by:		

Checklist 6: *Thermal Test*

Test Location:

Step	Specimen TP90(B)
1. Pre-heat the oven to a minimum of 810°C.	
2. Attach the thermocouple(s) to the specimen. Note locations on Data Sheet.	
3. Place the package in the oven and close the door. Record time.	
4. When all surfaces of the specimen exceed 810°C, Start the 30-min test time. Record time.	
5. Continually measure the oven temperature and the specimen's temperatures.	
6. Monitor the specimen's temperatures throughout the 30-minute period to ensure that they are above 810°C.	
7. At the end of the 30-minute period, remove specimen from oven. Record Time.	
8. Describe combustion when door is opened to remove specimen.	
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.	
9. Continue to monitor the specimen's temperature during cool down. Allow cooling to ambient.	
10. Measure and record the ambient temperature.	
11. Photograph the test specimen and any subsequent damage.	
12. Record the damage to test specimen on a separate sheet and attach.	
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on Data Sheet 4	

Test Witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 6: *Thermal Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP90(B)**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ______________ Regulatory: ______________ QA: ______________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

NOTES ON	TEST	
Prepared by:	**Date:**	**Sheet**

Department	Signature	Print Name	Date
Engineering			
Regulatory			
Quality Assurance			

Section 10 Drawing Reference

Section 13. APPENDIX F – NYCOMED AMERSHAM PLC TEST NUMBER 1835

Test Number 1835 by Nycomed Amersham plc in the United Kingdom

Submitted to the USDOT as part of the Type B(U)-85 Approval Application for Package Design Number 3605B.
Reference: USDOT Competent Authority Certificate USA/0592/B(U)-85.

Commercial - in - confidence

AMERSHAM INTERNATIONAL plc

PACKAGING DESIGN GROUP

IAEA Type B package test sequence

Container design number 3605B

Contents

Part A: Specification of test assemblies

A1 Design description: Container design number 3605B

A2 Design drawings: To drawing list DL25068 issue 1

A3 Quality Assurance:

Item	Drawing	Batch / serial number Assembly A	Batch / serial number Assembly B
Drum body & lid	A21716 issue M	10/90	10/90
Clamp	A24793 issue A	Prototype	Prototype
Cork insert, P027	3A21703 issue D	04/93	04/93
Cork spacer, P028	3A21714 issue C	04/93	04/93
Lead pot, P500	3A23165 issue C) 2A22484 issue D)	P500/0952	P500/950
Pot lid, P523	2A21523 issue B	-	-
Insert, P524	BRC21524 issue C	I15/1003	I15/--
Tube cap nuts	ARC21525 issue A		

Clamp band closure torque 7 lbf.ft (9.1 kgf.m)

Measurements were made of a wide variety of features to enable before and after comparisons to be made. Manual records are dated 2 June 1994 in project lab record book.

A4 Variations from design specification:

The test unit was confirmed by inspection to be to specification

A5 Serial number: Test assembly A used outer drum serial number 3605/14
Test assembly B used outer drum serial number 3605/15

A6 Package contents:

Both assemblies contained Orion Components 'Tinytalk-Temp' miniature temperature loggers in addition to a large number of temperature sensitive strips covering the range 50°C - 193°C.

A7 Package weight: 54 kg

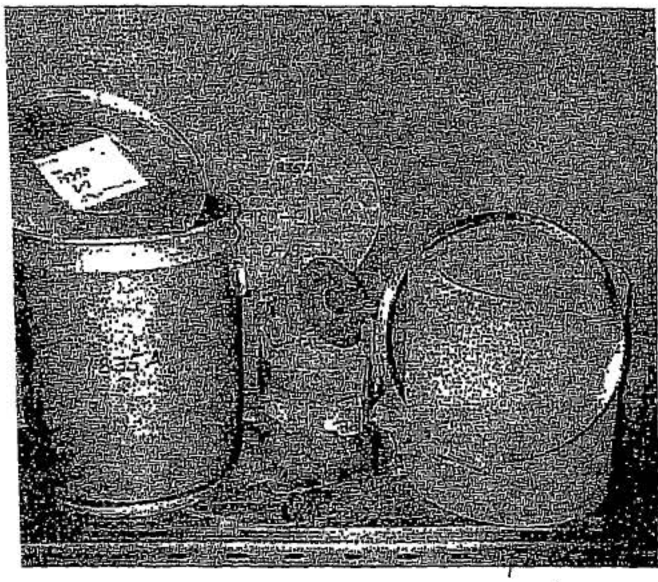

Figure 1
Assembly A components

Figure 2
Pot A orientation in drum

Figure 3
Assembly B components

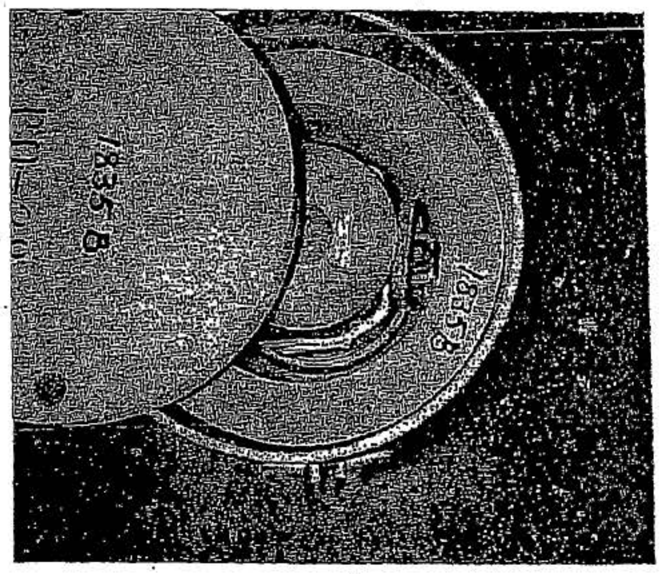

Figure 4
Pot B orientation in drum

Part B: Tests and test procedures

B1 Regulatory description

i) IAEA Safety Series 6 paragraph 622 - 1.2m free drop test

ii) IAEA Safety Series 6 paragraph 627a - Drop I - 9m free drop

iii) IAEA Safety Series 6 paragraph 627b - Drop II - 1m punch test

iv) IAEA Safety Series 6 paragraph 628 - Thermal test (Furnace)

B2 Standard procedures

i) Packaging Group Procedure PGP15 issue 4. A quick release shackle will be used in place of the parachute release shown in PGP15. The operator will stand on a strong platform to measure the 1.2m drop height and to release the package.

ii) Packaging Group Procedure PGP15 issue 4, amended as above and with a drop height of 9m. A 'steady' cord may be attached to the hoist or the package as an aid to eliminating swing at height.

iii) No standard procedure has been written for the Drop II (punch) test. The following procedure will be followed:

Safety As location of impact is as important as orientation in the punch test, it is not practical for the shackle release operator to evacuate the test compound. To ensure his safety and to provide a well controlled access to the release mechanism to ensure impact as planned, he should stand on a suitable strong platform (an 0924 drum is ideal).

Follow PGP15 (as B2(i)), excepting paragraphs 4.3 - 4.6

While ensuring that there is no chance of an unintentional release, hoist the package sufficiently to set punch and package in the intended location and orientation of impact.

Attach a piece of weighted string, 1m long, to the position on the package it is intended to impact the punch.

Hoist the package until the plumb bob weight hangs on the punch at the intended impact position. Do not remove the plumb line.

Ensuring the set alignment remains true by means of the plumb line, gently twist the release lever of the shackle.

iv) IPM108 issue 1

B3 Maintenance

No maintenance will be carried out on the packages between tests.

B4 Drop test facility

Drawing 3A24849 shows a schematic layout of the Amersham Laboratory site drop test target. PGP15 shows a schematic view of the superstructure. The punch is a six inch diameter bar, fifteen inches high as described in IAEA SS6 paragraph 627(b), welded vertically on a base plate 445 x 445 x 12mm.

B5 Recording and instrumentation

The tests will be recorded on video tape and by Polariod photographs. The tape will be available for viewing and used for analysing the impact orientations, although only the photographs will be appended to this report. Photographs will be identified on site by date plus a reference number. Each test package contains a Tinytalk temperature logger, set to record the last two days temperatures, fresh data overwriting previous data. No mechanical instrumentation is installed.

B6 Impact attitudes

Assembly A

i) 1.2m free drop test	1835/1	Centre of gravity above the lid corner at the closure bolt
ii) Drop I (9m free drop)	1835/2	Onto the base at about 5° from flat
iii) Drop II (Punch test)	1835/3	Inverted with impact by the edge of the punch onto the folded drum side

Assembly B

i) 1.2m free drop test	1835/4	Centre of gravity above the lid corner at the closure bolt
ii) Drop I (9m free drop)	1835/5	Centre of gravity above the lid corner at the closure bolt
iii) Drop II (Punch test)	1835/6	Inverted with impact by the edge of the punch onto the folded drum side

B7 Damage assessment criteria

After each test the container will be examined to review the general level of mechanical damage, particular attention being given to continued security of the drum lid and closure clamp. No attempt will be made to remove the lid between tests.

B8 Pass / fail criteria

i) Following the 1.2m free drop test:

The minimum source to surface distance, established by examination of surface distortion, shall be reduced by not more than 10%.

ii) and iii) Following the 9m free drop test and the punch test:

The drum lid shall be retained on the drum body for at least one half of its circumference

The outer surface of the drum shall be intact to such an extent that the package components are securely retained in the design relationship

The damaged assembly shall be secure enough that it may be transported to the thermal test facility under routine conditions without subsequently failing the above criteria.

iv) Following the thermal test:

The assembly shall be essentially intact with the lead pot located approximately central in the package

The lead pot shall be intact and have risen to a temperature of no greater than 193°C (the maximum temperature strip fitted)

Part C - Mechanical test schedule

Date:	10 June 1994
Condition of test equipment:	Satisfactory
Condition of height plumb lines:	Satisfactory
Indicated condition of video battery:	Charged
Ambient weather conditions:	Light breeze, dry, generally sunny
Persons present:	A R Webster, Department of Transport S T Winfield A Lewis R Campbell-Grieve

Test reference 1835 / 1 (1.2m free drop test, assembly A)

Check	Operation	Notes
✓	Stand package on the drop test target and hoist from a base flange lifting point to achieve a drop onto the clamp bolt	
✓	Attach slings to the quick release shackle and raise the package for photo record of orientation	10/6 1
	Mark test reference 1835/1 on video	
✓	Evacuate the compound of all but the drop operator and secure the gate	
✓	Set the video running	
✓	Raise the package until the 1.2m drop height is confirmed	
✓	Very gently twist the release lever to release the package	
✓	Stop video record. Photo record position of the package as it came to rest	10/6 2
	Set the package to a convenient viewing position and photo record damage	10/6 3
	Figures 5 - 7 refer	

Damage report

No significant damage. Slight distortion of drum rim and clamp band.

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned
Accept. Continue to next test, revised
Fail

Figure 5
1835/1 - Drop test orientation

Figure 6
1835/1 - Immediately post test

Figure 7
1835/1 - Damage

Test reference 1835 / 2 (9m free drop test, assembly A)

Check	Operation	Notes
✓	Stand package on the drop test target and arrange the slings through the drum handles to achieve a base drop at about 5º from flat	1/96 4
✓	Attach slings to the quick release shackle and raise the package for photo record	
✓	Mark test reference 1835/2 on video	
✓	Attach the 9m plumb line to the lowest part of the package, and ensure that it will uncurl without tangling. Place the bob weight close to the impact point and lay the withdrawing string and shackle operating string out to the compound gate	
✓	Set video running, evacuate the compound and secure the gate	
✓	Raise the package until the bob weight is just clear of the target. Pull the plumb line clear of the package and the target	
✓	Very gently increase tension in the release string to release the package. Ensure that the package is stationary immediately prior to release	
✓	Stop video record. Photo record position of the package as it came to rest	10/6 5
✓	Set the package to a convenient viewing position and photo record damage	10/6 6 10/6 7
✓	Figures 8 # 11 refer	

Damage report

Impact took place as planned. Three of the four base segments showed evidence of shearing of the drum base sheet around the reinforcement bars. Rust marks showed contact between the base sheet and the target face, a distortion of 19mm

Analysis of damage against criteria of B8

Accept. Continue to next test as planned
✓ Accept. Continue to next test, revised
Fail

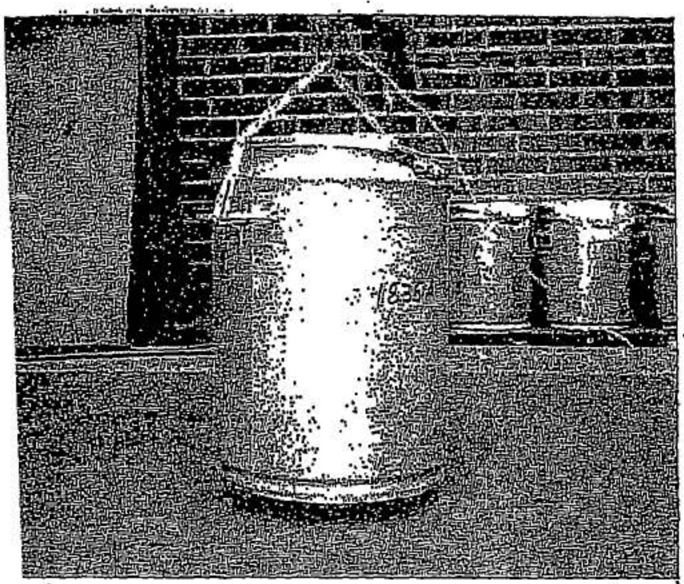

Figure 8
1835/3 - Drop test orientation

Figure 9
1835/3 - Immediately post test

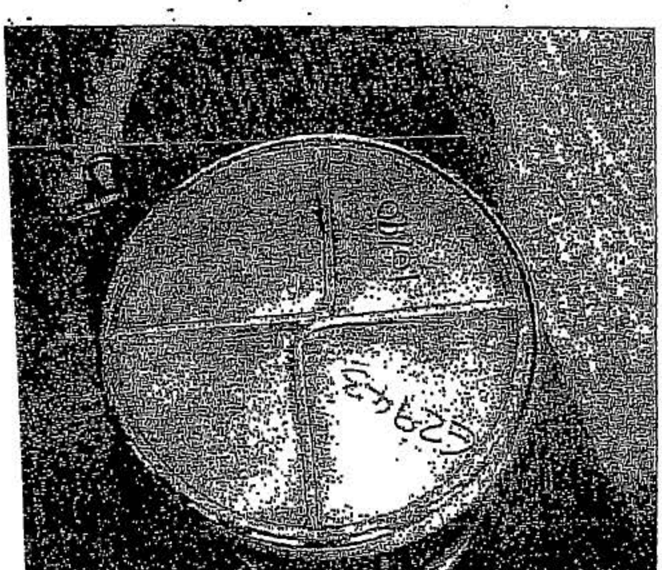

Figure 10
1835/3 - Damage

Figure 11
1835/3 - Damage

Test reference 1835 / 3 (1m free drop onto punch, assembly A)

Check	Operation	Notes
✓	Fit slings to the drum handles to achieve a flat centre base drop onto the punch	10/6 (8)
✓	Mark test reference 1835/3 on video. Leave video running	
✓	Raise the package until a clearance of 1m between drum base and punch top is confirmed	
✓	Very gently rotate the release lever to achieve release.	
✓	Set the package to a convenient viewing position and photo record damage	10/6 (9)

Figures 12 - 13 refer

Damage report

No noticeable additional damage

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned

Fail

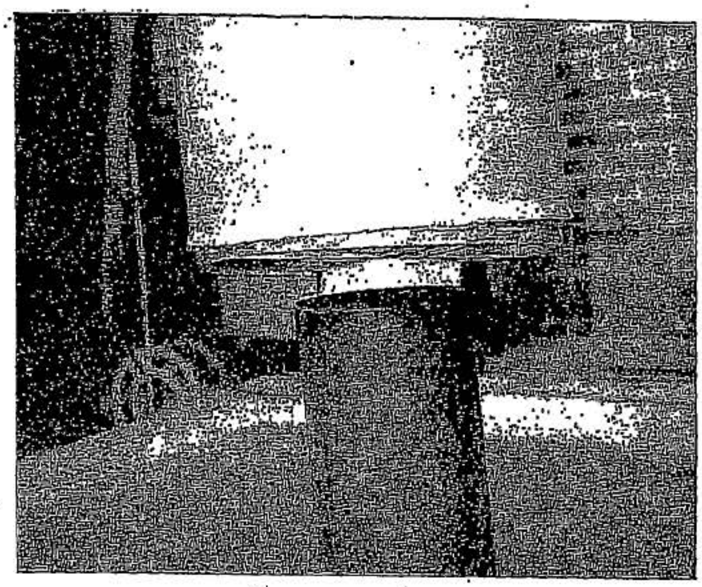

Figure 12
1835/3 - Drop test location and orientation

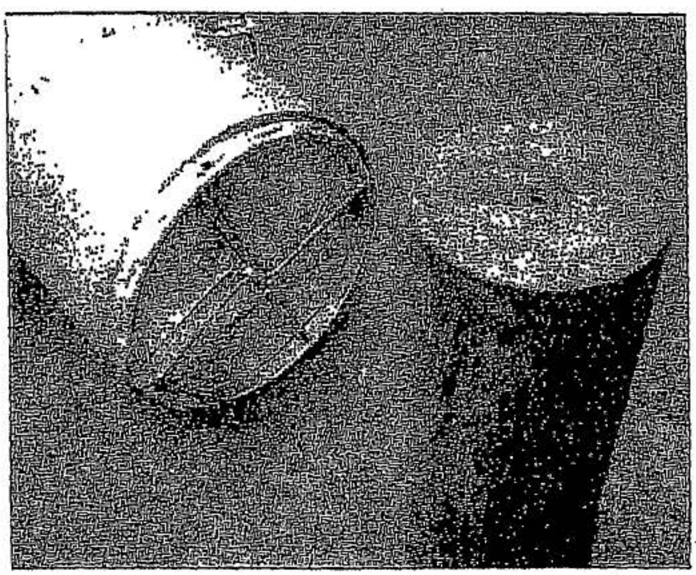

Figure 13
1835/3 - Damage

Test reference 1835 / 4 (1.2m free drop test, assembly B)

Check	Operation	Notes
✓	Stand package on the drop test target and hoist from a base flange lifting point to achieve a drop onto the clamp bolt	
✓	Attach slings to the quick release shackle and raise the package for photo record of orientation	10/6 10
✓	Mark test reference 1835/4 on video	
✓	Evacuate the compound of all but the drop operator and secure the gate	
✓	Set the video running	
✓	Raise the package until the 1.2m drop height is confirmed.	
✓	Very gently twist the release lever to release the package	
✓	Stop video record. Photo record position of the package as it came to rest	10/6 11
✓	Set the package to a convenient viewing position and photo record damage	12 9/6

Figures 14 - 16 refer

Damage report

No significant damage. Slight distortion of drum rim and clamp band.

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned
Accept. Continue to next test, revised
Fail

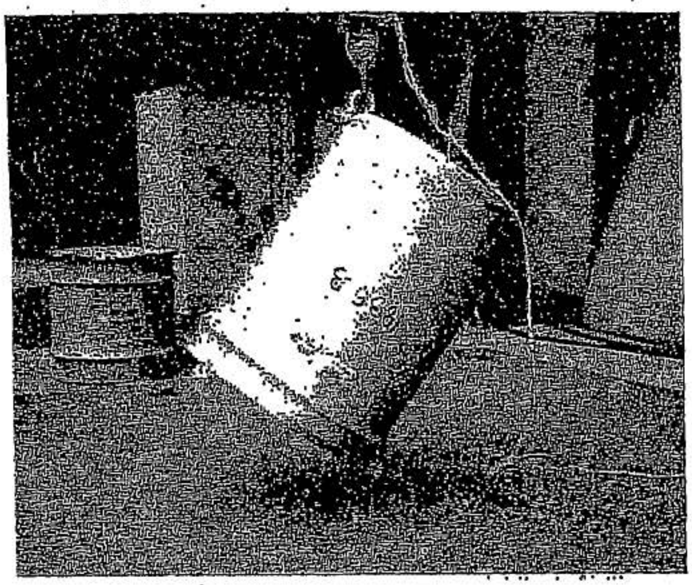

Figure 14
1835/4 - Drop test orientation

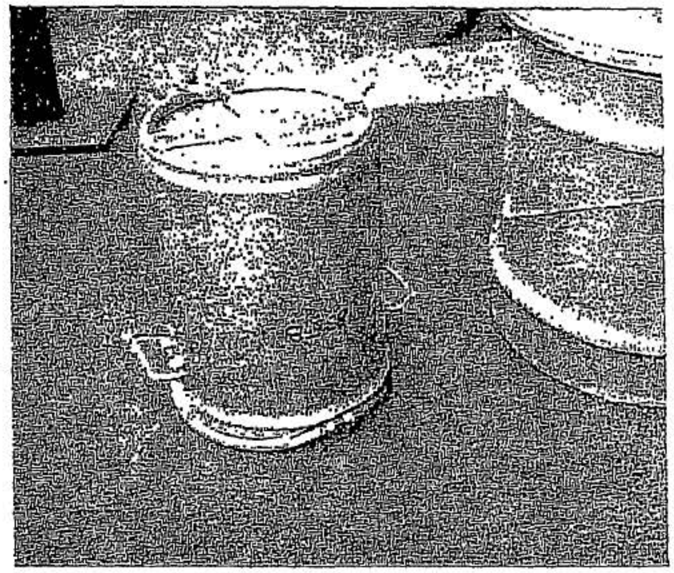

Figure 15
1835/4 - Immediately post test

Figure 16
1835/4 - Damage

Test reference 1835 / 5 (9m free drop test, assembly B)

Check	Operation	Notes
✓	Stand package on the drop test target and hoist from a base flange lifting point to achieve a drop onto the clamp bolt	
✓	Attach slings to the quick release shackle and raise the package for photo record	13 9/6
✓	Mark test reference 1835/5 on video	
✓	Attach the 9m plumb line to the lowest part of the package, and ensure that it will uncurl without tangling. Place the bob weight close to the impact point and lay the withdrawing string and shackle operating string out to the compound gate	
✓	Set video running, evacuate the compound and secure the gate	
✓	Raise the package until the bob weight is just clear of the target. Pull the plumb line clear of the package and the target	
✓	Very gently increase tension in the release string, to release the package. Ensure that the package is stationary immediately prior to release	
✓	Stop video record. Photo record position of the package as it came to rest	14 9/6
✓	Set the package to a convenient viewing position and photo record damage	15 9/6

Figures 17 - 19 refer

Damage report

Extensive distortion of the drum and clamp at the point of impact, but the clamp and lid remained fully retained on the drum body.

Analysis of damage against criteria of B8

Accept. Continue to next test as planned
✓ Accept. Continue to next test, revised
Fail

Test reference 1835 / 6 (1m free drop onto punch, assembly B)

Check	Operation	Notes
✓	Invert the package and arrange the slings to achieve a drop onto the edge of the punch by clamp closure bolt. Photo record	10/6 (16)
✓	Attach a 1m plumb line to the required point of impact on the drum	
✓	Mark test reference 1835/6 on video. Leave video running	
✓	Raise the package until the bob weight is just clear of the punch	
✓	While keeping the bob weight at the desired point of impact on the punch, very gently rotate the release lever to achieve release	
✓	Set the package to a convenient viewing position and photo record damage	10/6 (17)

Figures 20 - 21 refer

Damage report

Clear evidence of impact as planned. No additional damage observed.

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned
Fail

Figure 20
1835/6 - Drop test location and orientation

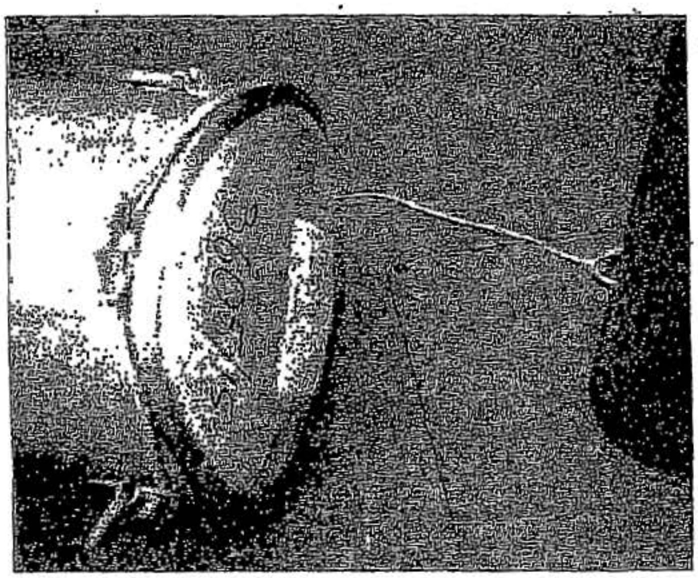

Figure 21
1835/6 - D

Part D - Thermal test schedule

Date: 15 June 1994

Test site: Warrington Fire Research Centre

Persons present: A R Webster, Department of Transport
D Williams, Warrington Fire Research Centre
S T Winfield

Test reference 1835 / 7 (Thermal test, assembly A)

Check	Operation	Notes
✓	Position support blocks and ambient thermocouples in the furnace	
✓	Organise lifting equipment to allow access for the package through the furnace roof	
✓	Light the furnace burners and allow the furnace to achieve a steady temperature of 820°C	
✓	Open the furnace roof and insert the package. Replace the roof section with the minimum of delay, and start the test timer when the ambient temperature shows a minimum of 800°C	
✓	Observe progress of the test with intermittent video records of the drum state and the ambient thermocouples output. Maintain an ambient of 800 - 820°C	
✓	After a test duration of 30 minutes, remove the package from the furnace and place on the laboratory floor to cool	15/6 2 16/1 1
✓	After not less than 18 hours, open the package and check the indication on the temperature sensor strips. Photo record the components and the strips	
	Figures 22 - 23 refer	
	Confirm some of the temperature strips' records by heating until the next higher indicator position changes.	

Test commentary

The furnace temperature dropped back to 650°C, returning to 800°C after one minute. Copious flaming observed throughout test, reducing as the test progressed. Minor flaming still in evidence from the base as the drum was lowered to the lab floor.

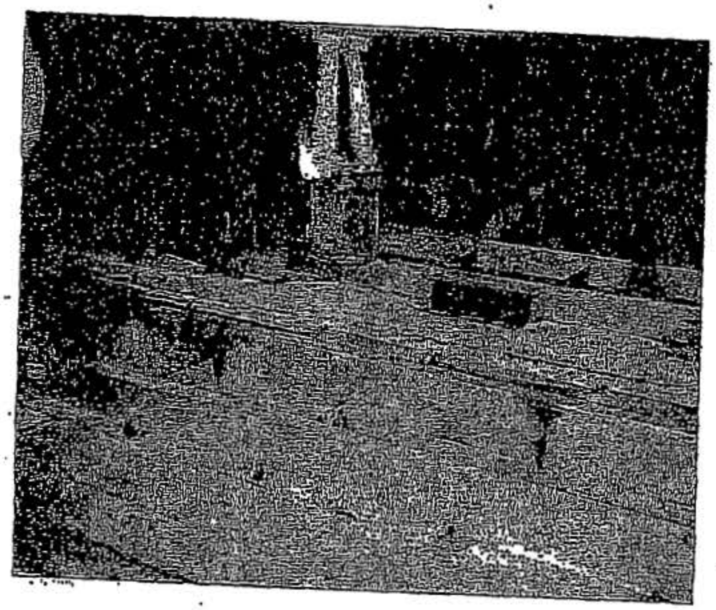

Figure 22
1835/7 - Assembly A removal from furnace

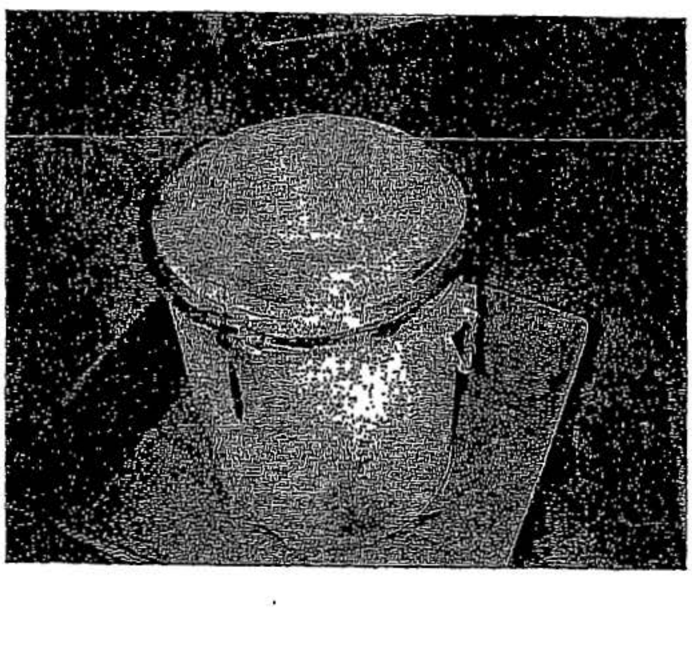

Figure 23
1835/7 - Assembly A exterior post-thermal test

Test reference 1835 / 8 (Thermal test, assembly B)

Check	Operation	Notes
✓	Allow the furnace to achieve a steady temperature of 820°C	
✓	Open the furnace roof and insert the package. Replace the roof section with the minimum of delay, and start the test timer when the ambient temperature shows a minimum of 800°C	
✓	Observe progress of the test with intermittent video records of the drum state and the ambient thermocouples output. Maintain an ambient of 800 - 820°C	
✓	After a test duration of 30 minutes, remove the package from the furnace and place on the laboratory floor to cool	15/6 (4) 16/6 (2)
✓	After not less than 18 hours, open the package and check the indication on the temperature sensor strips. Photo record the components and the strips	
	Figures 24 - 25 refer	
	Confirm some of the temperature strips' records by heating until the next higher indicator position changes.	

Test commentary

The furnace temperature dropped back to 685°C, returning to 800°C after less than one minute. Copious flaming observed throughout test, reducing as the test progressed. Minor flaming still in evidence as the drum was lowered to the lab floor.

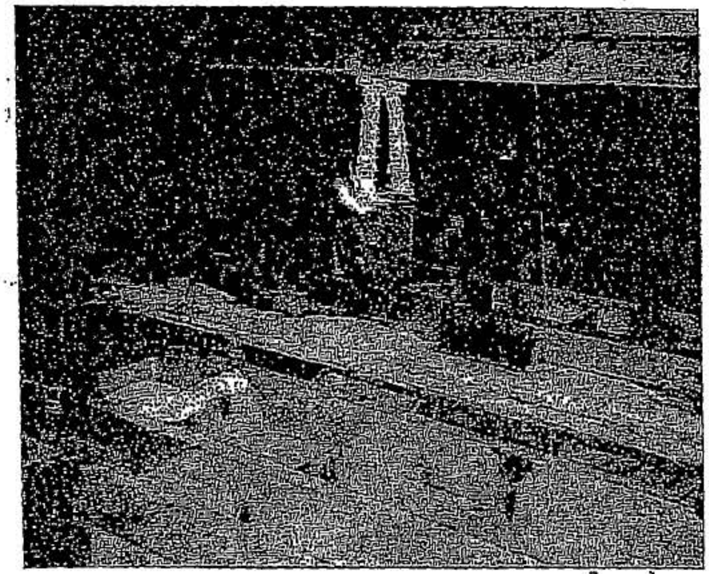

Figure 24
1835/8 - Assembly B removal from furnace

Figure 25
1835/8 - Assembly B exterior post thermal test

Approvals

Test Quality Plan comprises Parts A and B and the 'Operation' column of Parts C and D

Quality Plan prepared by S J Winfield, Packaging Design Group

Quality Plan agreed by

Part E - Dismantling and discussion

Both assembly A and assembly B were dismantled on 16 June at Amersham Labs.

E1 Assembly A (Figures 26 - 31 refer)

The clamp bolt sheared despite its being oiled before unscrewing. The cork spacer showed charring to 22mm depth (using a flat ended probe 10x1mm). The upper edge of the cork insert had 26mm of thickness remaining intact, indicating a char depth of 17mm. The bottom of the cork cavity was cracked around the circumference and across diagonals in line with the drum reinforcement bars; there were clear marks from impact by the pot cradle straps. The sides of the cork cavity were sooty, but less so than the base. The lead pot was essentially undamaged with resin condensate and soot extending down to the cradle body band. Temperature record strips on top of the lead insert showed a maximum temperature of between 60°C and 82°C (the intervening three indicators were unclear as to whether they had changed fully). Two sets of indicators within the pot body on the insert showed a maximum temperature of between 65°C and 82°C. The Tiny-talk recorder had failed.

E2 Assembly B (Figures 32 - 37 refer)

The clamp bolt unscrewed without breaking. The lid cork showed a char depth of 25mm (using a flat ended probe 10x1mm). The upper edge of the cork insert showed 26mm intact indicating a char depth of 17mm. The cork cavity was sootier than assembly A. The pot was generally undamaged, although one insert tube nut was bent but unbroken. The was a higher degree of condensate and soot on the pot than assembly A. The temperature strip on the top of the insert indicated a maximum temperature of between 77°C and 82°C. Strips on the insert within the pot cavity showed maxima of between 71°C and 82°C (upper portion of pot cavity) and between 77°C and 82°C (lower portion of pot cavity). All the strips were in good condition and easily read. The Tiny-talk recorder had failed.

Figure 26
1835/7 - Under drum lid

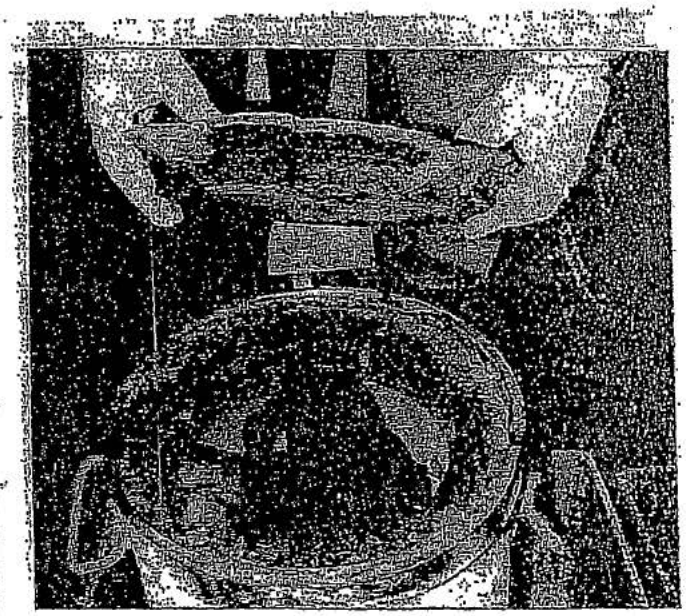

Figure 27
1835/7 - Char damage to spacer

Figure 28
1835/7 - Damage to lead pot

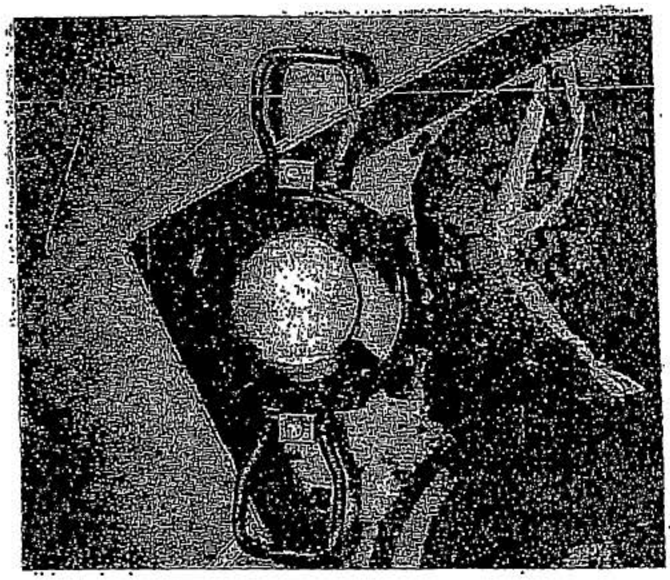

Figure 29
1835/7 - Lead pot, cover removed

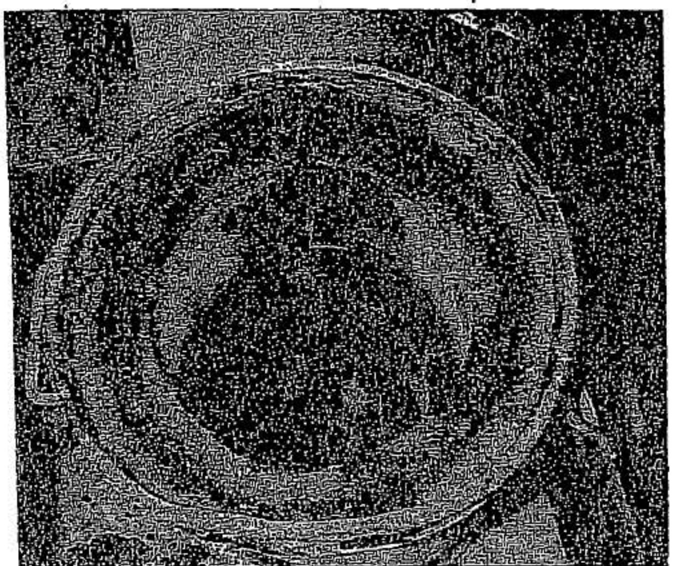

Figure 30
1835/7 - Cork cavity

Illustration
deliberately
omitted

Figure 31
1835/7 - Cork section

Figure 32
1835/8 - Under drum lid

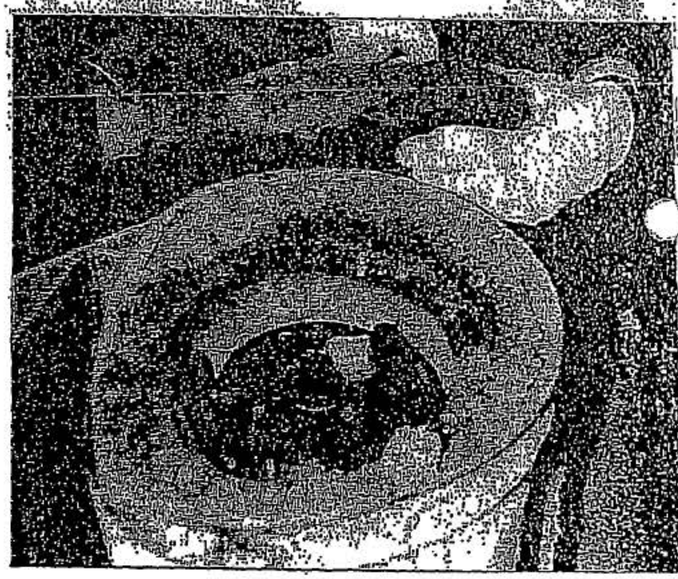

Figure 33
1835/8 - Char damage to spacer

Figure 34
1835/8 - Damage to lead pot

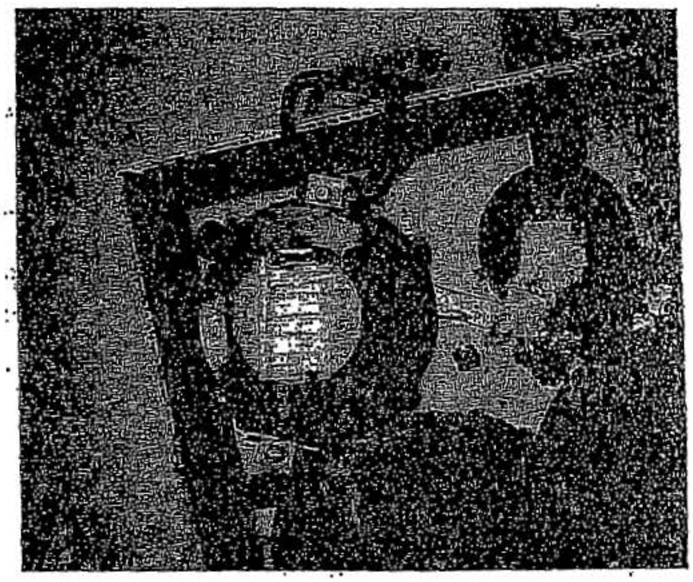

Figure 35
1835/8 - Lead pot, cover removed

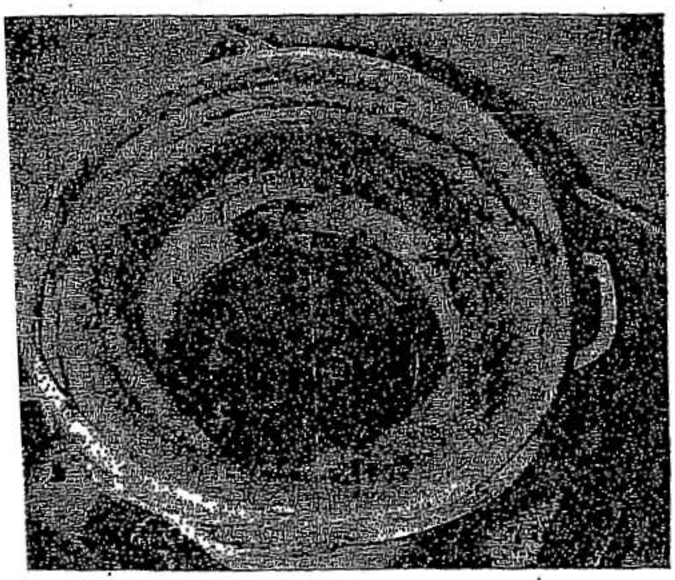

Figure 36
1835/8 - Cork cavity

Illustration
deliberately
omitted
21/5/96

Figure 37
1835/8 - Cork section

E3. Discussion

Both assemblies passed the specified test sequence with a clear margin of safety. Assembly B showed marginally more vulnerability to the thermal test in regard to smoke damage, although the temperature strips showed similar results. Both lead pots were substantially undamaged and would have continued to provide adequate radiation shielding for any source in the tubes. A maximum temperature of less than 82°C is considerably less than the solidus point of the 4% antimonial lead of the pot construction (252°C). The drum assemblies remained intact and could be handled with safety.

Part F - Conclusions

Package design number 3605B has been shown to comply with the requirements of IAEA Safety Series 6 in regard to drop test sequences, in two opposing orientations, comprising a 1.2m free drop test (paragraph 622), a Drop I (9m free drop) test (paragraph 627 (a)) and a Drop II (1m punch) test (paragraph 627 (b)). These mechanical tests were followed by thermal tests (paragraph 628) in which the packages remained essentially undamaged.

Test carried out by S T Winfield

S Winfield 11 Feb/ 1994

Witnessed by

A. Lees 13/7/94

Section 14. APPENDIX G – TYPE A CHECK LIST

AEA TECHNOLOGY QSA

Rev. 0 March, 2004
AEA 976 Series Type A Packages

TYPE A Package Evaluation Checklist

Use this checklist as a guide for evaluating a device or package to the following Type A regulations:

(1) USDOT, 49 CFR Part 171, et al., dated Thursday, September 28, 1995.

(2) USNRC, 10 CFR Part 71, dated Thursday, September 28, 1995.

(3) IAEA, Regulations for the Safe Transport of Radioactive Material No. TS-R-1, 1996 Edition (Revised).

Product Model/Description: Model 976 Series Packages

Package Specifications/Limitations: 976 Series Packages, consists of a source shield inside of cork inserts, inside of a stainless steel barrel. The barrel is closed with a clamp band tightened with a stainless steel M8 x 1.25 – 130 mm Long bolt and a tamper evident seal wire. One of 5 different source shield models will be shipped in each package. They are:

- **Model 855 (maximum weight 225 lbs).**
- **Model 3015 (maximum weight 104 lbs).**
- **Model 3018 (maximum weight 104 lbs).**
- **Model 3056 (maximum weight 104 lbs).**
- **Model 3078 (maximum weight 126 lbs).**

Special Form Source Assemblies Authorized for Transport

Type A Approved Activity (Max.)[1]	Isotope	Source Assembly Model Number
27 Ci	Ir-192	Various, special form. Minimum ANSI pressure classification of 3.
81 Ci	Se-75	Sources in the Model 855, 3018 and 3056 must be attached to flexible source wire assemblies compatible with the shield assemblies.

References: TP Report 90; Type B SAR Model 976 Series package;
DWG's R976A Rev. A; R976B Rev. A; R976C Rev. A; R976D Rev. A; R976E Rev. A; R97608 Rev. A; RCLM009 Rev. A; R97615 Rev. A; R97616 Rev. A; R97623 Rev. A; R97637 Rev. A; R85590 Rev. A; R3015 Rev. A; R3018 Rev. A; R3056 Rev. A; R3078 Rev. A;

Max Weight of Package 280 lbs

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

L. Padillo	7 Mar 04	Stephen Foste	07 MAR 2004
Regulatory Signature	Date	Engineering Signature	Date

1. General Requirements.

1-1. Handling:

The package must be easily handled and properly secured in or on a conveyance during transport.
* USDOT, 49 CFR 173.410 (a)
* IAEA TS-R-1, para. 606

Barrel is cylindrical and can be secured and handled using standard transportation techniques.

1-2. Lifting Attachment:

Each lifting attachment that is a structural part of the package must be designed with a minimum safety factor of three (3) against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting attachment under excessive load would not impair the ability of the package to meet other requirements. Any other structural part of the package which could be used to lift the package must be capable of being rendered inoperable for lifting during transport or must be designed with strength equivalent to that required for lifting attachments.
* USDOT, 49 CFR 173.410 (b)
* USNRC, 10 CFR 71.45 (a)
* IAEA TS-R-1, para. 607, 608

The Model 976 Series packages are designed to be lifted by the base using a hand truck or other suitable mechanical means. For this analysis, the base is assumed to be a flat, circular plate 19 ¾ inches (502 mm) in diameter and 0.06 inches (1.5 mm) thick, supported about its outer edge. We take the supporting cylinder (the walls and bottom welded rim of the drum) to be essentially ridged for the magnitude of stresses encountered here. Any lifting would span all edges of the drum and thus allow the bottom to be supported and suspended by the edges. As such, the maximum stress on the base is:

$$\sigma_{max} = k\, wr^2/t^2$$

Where:

w	=	The weight of the transport package 127 kg (280 Ib) taken as a distributed load over the base.
t	=	The thickness of the base plate 1.5 mm (0.06 inches)
r	=	The radius of the base plate 251 mm (9.9 inches)
k	=	A tabulated factor for this case of flat plate. [1]

[1] - Marks Handbook, 9th edition, pp 5-52 – 5-53

Therefore, the stress generated in the base is 20,316 psi. With a Safety Factor of 3 applied, the maximum stress in the drum base is 60,947 psi. This is below the ultimate yield strength of the stainless steel base which is 70,000 psi. Therefore, the lifting device is capable of supporting more than three times the weight of the transport package as required by 10 CFR 71.45(a).

1-3. Tie-down:

See the listed regulatory requirement for full details.
* USNRC, 10 CFR 71.45 (b) (1) (2) (3)

> Not applicable. This package has no tie-down system

1-4. External Surface:

The external surface, as far as practicable, shall be free from protruding features and easily decontaminated.
* USDOT, 49 CFR 173.410 (c)
* IAEA TS-R-1, para. 609

> Comply. External surfaces of this package have no protruding features. Should the barrel become contaminated its smooth stainless steel surfaces can be easily decontaminated.

1-5. Outer Layer:

The outer layer, as far as practicable, shall be free pockets or crevices where water might collect.
* USDOT, 49 CFR 173.410 (d)
* IAEA TS-R-1, para. 610

> Comply. The surfaces of this package are flat or cylindrical and contain no pockets or crevices where water might collect, except for a slight depression in the lid, which has no holes.

1-6. Added Features:

Each feature that is added to the package will not reduce the safety of the package.
* USDOT, 49 CFR 173.410 (e)
* IAEA TS-R-1, para. 611

> Not applicable. There are no added features to this package which would reduce the safety of the package.

1-7. Vibration:

The package will be capable of withstanding the effects of any acceleration, vibration or vibration resonance that may arise under normal conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole and without loosening or unintentionally releasing the nuts, bolts, or other securing devices even after repeated use.
* USDOT, 49 CFR 173.410 (f)
* IAEA TS-R-1, para. 612

> Comply. The shield containers have been used for years as a Type B Package components without any detrimental effect being observed due to vibration changes incurred during shipment. The addition of the cork inserts and the stainless steel barrel overpack will dampen vibration. The Model 3015, 3018, 3056 and 3078 have been shipped for years as Type B Packages inside an overpack similar to the 976, but smaller in height and diameter, without any detrimental effect being observed due to vibration changes incurred during shipment. The thicker cork inserts in the 976 design will dampen vibration better than the previous overpack.

1-8. Seals:

Incorporates a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.

* USDOT, 49 CFR 173.412 (a)
* USNRC, 10 CFR 71.71 (b)
* IAEA TS-R-1, para. 635

Comply. The barrel clamp band is sealed with wire at the time of shipment. Breakage of this wire would be evidence that the package may have been opened by unauthorized persons and would imply the need to initiate special handling precautions to ensure the integrity of the package contents.

1-9 External Radiation Levels:

Each package must be designed so that, under conditions normally incident to transportation, the radiation level does not exceed 200 mR/hr at any point on the external surface of the package and the transport index does not exceed 10, unless shipped exclusive use.

* USNRC, 10 CFR 71.47 (a)
* USDOT, 49 CFR 173.441 (a)
* IAEA TS-R-1, para. 531, 532

Comply. Each package is surveyed before shipment.

2. **Additional Requirements.**

2-1. Overall Size:

Smallest overall dimension must be 4 inches (10 cm) or greater.

* USDOT, 49 CFR 173.412 (b)
* USNRC, 10 CFR 71.43 (a)
* IAEA TS-R-1, para. 634

Comply. The package inner dimensions are Ø19"ID by 21" deep.

2-2. Tie-down:

Tie-down attachment that is a structural part of the package, under both normal and accident conditions, shall not impair the ability of the package to meet other requirements of the governing regulations.

* USDOT, 49 CFR 173.412 (i)
* IAEA TS-R-1, para. 636

Not applicable. There are no tie-down attachments that are a structural part of this package.

2-3. Containment:

Containment and shielding is maintained during transportation and storage in a temperature range of -40°C (-40°F) to 70°C (158°F). The design of the package will take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport. For radioactive material having other dangerous properties, the package design shall take into account those properties.
* USDOT, 49 CFR 173.412 (c)
* IAEA TS-R-1, para. 637, 615, 616

Comply. The primary containment are the welded stainless steel sources. All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 3. They have complied with external temperatures of -40°C (-40°F) to 80°C (176°F). The capsules are shielded within one of the previously mentioned shields, inside the cork inserts inside the stainless steel barrel. This temperature range will have no adverse affect on the integrity of the source or the shielding and package materials, with the exception of the carbon steel jacket on the Model 855 Source Changer. While carbon steel is susceptible to brittle fracture at -40°C, the Model 855 has served for years as a Type B Package on its own without fracture. In TP90, the 976 Package, containing the Model 855 chilled to -40°C was subjected to several drop tests. The Model 855 suffered no damage. See Test Plan/Report TP90

Containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.
* USDOT, 49 CFR 173.412 (d)
* USNRC, 10 CFR 71.43 (c)
* IAEA TS-R-1, para. 639

Comply. The primary containment are the welded stainless steel sources. No pressures will be generated within the sources or the package that could adversely affect the containment system. See Type B SAR Model 976 Series package for further assessment.

If the containment system forms a separate unit of the package, it shall be capable of being securely closed by a positive fastening device which is independent of any other part of the packaging.
* USDOT, 49 CFR 173.412 (d)
* IAEA TS-R-1, para. 641

Comply. The primary containment is the welded stainless steel sources.

Components of the containment system shall take into account, where applicable, the radiolytic decomposition of liquids and other vulnerable materials and the generation of gas by chemical reaction and radiolysis.
* USDOT, 49 CFR 173.412 (e)
* IAEA TS-R-1, para. 642

Not applicable. No reactions known and no liquids.

The containment system shall retain its radioactive contents under a reduction of ambient pressure to 60 kPa (8.6 psi) (25 kPa for USDOT).
* USDOT, 49 CFR 173.412 (f)
• IAEA TS-R-1, para. 643

Comply. The primary containment are the welded stainless steel sources. All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 3. They have complied with external pressure of 25 MN/m^2 abs. (290 lbs/in^2 abs). The rest of the package is unaffected by pressure.

Packages containing liquids will be capable of withstanding, without leakage, an internal pressure that produces a differential of not less than 95 kPa (13.8 lb/in^2).
* USDOT, 49 CFR 173.410 (i)(3)

Not applicable. No liquids.

Packages containing liquids will either provide sufficient absorbent material to absorb twice the volume of the liquid contents or be provided with a containment system composed of primary inner and secondary outer containment components designed to ensure retention of the liquid contents within the secondary containment even if the primary containment leaks.
* IAEA TS-R-1, para. 648(b)

Not applicable. No liquids.

Packages containing liquids will provide for ullage (the amount of liquid within a container that is lost, as by leakage, during shipment or storage) to accommodate variations in the temperature of the contents, dynamic effects and filling dynamics.
* IAEA TS-R-1, para. 647

Not applicable. No liquids.

Packages containing gases (excluding tritium or noble gases) shall prevent loss or dispersal of the radioactive contents when subjected to the tests specified in para 725.
* IAEA TS-R-1, para. 649

Not applicable. No gases.

Any radiation shield that encloses a component of the packaging specified as part of the containment system shall prevent the unintentional release of that component from the shield. Where the radiation shield and such component within it form a separate unit, the radiation shield shall be capable of being securely closed by a positive fastening device which is independent of any other packaging structure.
* USDOT, 49 CFR 173.412 (h)
• IAEA TS-R-1, para. 645

Comply. The primary containment is the welded stainless steel sources, which are separate from the shields.

- The Model 855 Source changer has 8 independent "J" tubes that contain and protect one source each and extend into the depleted uranium radiation shield. The top of each J tube has a stop mechanism, which captures the stop ball or the teleflex cable on the source wire. These stop mechanisms have key activated locks. If these locks should fail, the Model 855 cover plate has a cylinder on the underside of it, that prevents movement of the stop mechanisms when the cover plate is bolted on for transport.
- The Model 3015 Shield has a cavity to contain the sources. This cavity is closed by a shielding plug, which is covered with a cap that bolts to the shield jacket.
- The Model 3018 has 4 independent "J" tubes that contain and protect one source each and extend into the radiation shield. The top of each J tube is closed with a threaded cap.
- The Model 3056 has 10 independent "J" tubes that contain and protect one source each and extend into the radiation shield. The top of each J tube is closed with a threaded cap. These caps are protected by the top cover which is bolted to the shield jacket.
- The Model 3078 Shield has a cavity to contain the sources. This cavity is closed by a shielding plug, which is covered with a cap that bolts to the shield jacket.

2-4. Chemical Reaction:

Materials and construction assures no significant chemical, galvanic, or other reaction among contents and components of package, including possible reaction resulting from in leakage of water. Also consider behavior of materials under irradiation.

* USDOT, 49 CFR 173.410 (g)
* USNRC, 10 CFR 71.43 (d)
* IAEA TS-R-1, para. 613

Comply. Package components are stainless steel, depleted uranium, which is separated from all carbon steel by copper spacers and poured foam, tungsten, lead, cork and carbon steel. Based on the low level of radiation emitted from the shield, no adverse effects to the cork inserts or the stainless steel barrel will occur. These materials will have no significant chemical, galvanic or other reactions among the contents and components of the package.

2-5. Valves:

All valves, other than pressure relief valves, shall be provided with an enclosure to retain any leakage from the valve. If valve failure allows release of radioactive contents, then valve shall have protection from unauthorized operation.

* USDOT, 49 CFR 173.412 (g), 173.410 (h)
* USNRC, 10 CFR 71.43 (e)
* IAEA TS-R-1, para. 614, 644

Not applicable. This package has no valves.

2-6. Integrity:

Package must be designed , constructed, and prepared to ensure; no loss or dispersal of the radioactive contents, no more than a 20% increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging, when evaluated against the performance and test requirements.
* USDOT, 49 CFR 173.412 (j) (1) (2)
* USNRC, 10 CFR 71.43 (f)
* IAEA TS-R-1, para. 646

Comply. See Test Plan/Report TP90.

2-7. No Venting:

A package may not incorporate a feature intended to allow continuous venting during transport.
* USNRC, 10 CFR 71.43 (h)

Not applicable. This package does not incorporate any feature intended to allow continuous venting during transport.

2-8. Air Transport

Package must be designed, constructed, and prepared for transport so that in still air at 38°C (100°F) and in the shade, no accessible surface of a package would have a temperature exceeding 50°C (122°F) in a nonexclusive use shipment, or 85°C (185°F) in an exclusive use shipment.
* USDOT, 49 CFR 173.410 (i) (1)
* USNRC, 10 CFR 71.43 (g), 71.71 (c)(1)
* IAEA TS-R-1, para. 617

Comply. The Specific heat output of Ir-192 is 8.6 mW/Ci. The maximum Type A Ir-192 activity for this container is 62 Ci. (The output activity is corrected by a factor of 2.3 to account for source attenuation and self-absorption). The Specific heat output of Se-75 is 5.1 mW/Ci. The maximum Type A Se-75 activity for this container is 81 Ci. The controlling nuclide heat output is for Ir-192 and equals:

$$8.6 \text{ mW/Ci} \times 62 \text{ Ci} = 533.2 \text{ mW}$$

The radiant energy of the shield without addition of the source at 50°C (122°F) is calculated as follows:

$q = \sigma A\, \varepsilon(T_1^4 - T_2^4)$ Ref. (pg.408)

where: σ= Stefan-Boltzman constant = 5.669×10^{-8} w/m²K⁴ Ref. (pg.14)

A = surface area of the barrel = $\pi dh + \pi d^2/2 = 1.00 m^2$ (d-dia of the pot=0.49m; h-height =0.53m)

ε = emmisivity of the barrel material (stainless steel) = 0.3 Ref. (pg.648)

T_1 = 50°C or 323K

T_2 = 38°C or 311K

Calculating q from the above equation produces the need for a source term of at least 26 W to produce a surface temperature on the surface of the barrel of 50°C. The Ir-192 transported in shield in this package is much less than the minimum energy necessary to increase the temperature of the lead to 50°C and therefore the surface temperature of the package will remain less than 50°C.

The integrity of containment will not be impaired if the package is exposed to ambient temperatures ranging from -40°C (-40°F) to 55°C (131°F).
* USDOT, 49 CFR 173.410 (i)(2)
* USNRC, 10 CFR 71.71 (c)(2)
* IAEA TS-R-1, para. 618

Comply. The primary containment is the welded stainless steel sources. All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 2. The capsules are shielded within the shield containers, inside the cork inserts inside the stainless steel barrel. This temperature range will have no adverse affect on the integrity of the source or the shielding.

Packages containing liquids will be capable of withstanding, without leakage, an internal pressure that produces a differential of not less than 95 kPa (13.8 lb/in^2) (5 kPa for IAEA).
* USDOT, 49 CFR 173.410 (i)(3)
* IAEA TS-R-1, para. 619

Not applicable. No liquids.

2.9 Increased External Pressure

Evaluate the effects of an external pressure of an external pressure of 140 kPa (20 psia) on a package at an initial internal pressure at the minimum normal operating pressure and at a temperature between -20°F and 100°F most unfavorable to the package.
* USNRC, 10 CFR 71.71 (c)(4)

Comply. . All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 3. They have complied with external pressure of 2MN/m^2 abs. (290 lbs/in^2 abs). The rest of the package is unaffected by pressure.

3. **Test Requirements.**

3-1. Water Spray Test:

Subject test specimen to a water spray that simulates exposure to rainfall of approximately 5 cm per hour for at least an hour. The free drop, stacking, and penetration test below are to be preceded in each case by the water spray test. Do not allow test specimen to dry before each test.
* USDOT, 49 CFR 173.465 (b)
* USNRC, 10 CFR 71.71 (c) (6)
* IAEA TS-R-1, para. 721

Comply. The stainless steel barrel is not affected by water and shields the internal components from water. The internal components are not affected by water within the time period of this test. Although the carbon steel jacket on the Model 855 source changer could oxidize over a long period of time; years of experience with this source changer as a standalone transport package have shown no decreased structural integrity. See Test Plan/Report TP90.

3-2. Free Drop Test:

Subject the test specimen to drop onto a hard, flat, horizontal surface so as to suffer maximum damage in respect of the safety features to be tested. The height of the drop measured from the lowest point of the specimen to the upper surface of the target shall not be less than 1.2m (4 ft) for packages less than 5000 kg (11,000 lbs). See additional regulations for fissile and wood materials. Corner drops of 1 ft onto each corner of the package for cardboard packages.

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

Comply. See Test Plan/Report TP90.

3-3. Stacking/Compression Test:

Subject the test specimen to a compressive load equal to 5 times the mass of the actual package for a period of 24 hours.

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

Comply. See Test Plan/Report TP90.

3-4. Penetration Test:

Place the test specimen on a rigid, flat, horizontal surface which will not move significantly while the test is being carried out. Drop a bar, 6 kg (13.25 lb), 3.2 cm (1.26) diameter with hemispherical end, with its longitudinal axis vertical, onto the center of the weakest part of the specimen, so that, if it penetrates sufficiently far, it will hit the containment system. The height of drop measured from the bars lower end to the intended point of impact on the upper surface of the test specimen shall be 1 m (39.37 in).

* USDOT, 49 CFR 173.465 (e)
* USNRC, 10 CFR 71.71 (c) (10)
* IAEA TS-R-1, para. 724

Comply. See Test Plan/Report TP90.

3-5. Tests for Packages Containing Liquids and Gases:

Subject the test specimen to drop onto a hard, flat, horizontal surface so as to suffer maximum damage in respect of the safety features to be tested. The height of the drop measured from the lowest point of the specimen to the upper surface of the target shall not be less than 9 m (30 ft).
* USDOT, 49 CFR 173.466 (a)(1)
* IAEA TS-R-1, para. 725(a)

Not applicable. No liquids or gases.

Place the test specimen on a rigid, flat, horizontal surface which will not move significantly while the test is being carried out. Drop a bar, 6 kg (13.25 lb), 3.2 cm (1.26) diameter with hemispherical end, with its longitudinal axis vertical, onto the center of the weakest part of the specimen, so that, if it penetrates sufficiently far, it will hit the containment system. The height of drop measured from the bars lower end to the intended point of impact on the upper surface of the test specimen shall be 1.7 m (66.93 in).
* USDOT, 49 CFR 173.466 (a)(2)
* IAEA TS-R-1, para. 725(b)

Not applicable. No liquids or gases.

Section 2.12.3 Appendix: Test Plan 163 Report Revision 1 dated April 2005 (minus Appendix C).

TEST PLAN 163 Report
Revision 1

MODEL 976
TYPE B
TRANSPORT PACKAGE

AEA Technology QSA Inc.
40 North Avenue
Burlington
MA 01803

April 2005

Department	Printed Name	Signed Name	Date
Originator	STEPHEN FORASTÉ	Stephen Foraste	14 APRIL 2005
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CONTENTS

Section 1. Purpose

The purpose of this test was to qualify the design of the Model 976 Transport Drum to Type A and Type B transport requirements through testing or analysis, either reasoned or calculated. The samples were subjected to the Hypothetical Accident Conditions in accordance with 10 CFR Part 71 and IAEA-TS-R-1 (current revisions), the drop sequence (9m (30-foot) and 1m (~3-foot) puncture). Assessment of the Model 976 Series packages is based on

- the damage resulting from the testing described in this report,
- the justification for the drop orientations contained in Test Plan 163 (see Appendix E),
- evaluation of untested package configurations to the tested configurations and
- evaluation of thermal testing conducted in the UK to assess the Model 976 Series package response to the thermal portion of the test sequence.

Models 976A specimens TP163(A) and TP163(B), and Model 976F specimen TP163(C) were tested on 22 Oct 2004. Compliance of the Models 976B, 976C, 976D, 976E and two variations of the 976F with different shielding inserts are assessed in this Test Plan Report. No physical testing of these package configurations was performed under this test plan.

Section 2. Scope of Testing

Section 2.1 Normal Conditions of Transport

The tests for Normal Conditions of Transport described in 10 CFR 71.71 are the compression test, penetration test and 1.2m (4-foot) free drop test. These tests were previously completed and documented in Test Plan 90 Report using test specimen TP90A (Model 855). The results of those tests are summarized here along with an assessment of how the addition of the lid closure bolts would have affected the results. The additional lid closure bolt configuration is shown in Figures 1 and 2 and in drawings 20046_LID Rev 1, 20046_DRUM Rev 1 and SCR303 Rev A included in Appendix A.

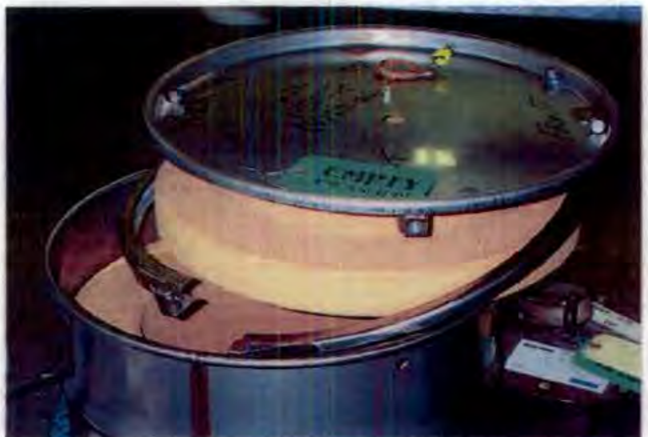


FIGURE 1. DRUM/LID CLOSURE MODIFICATION

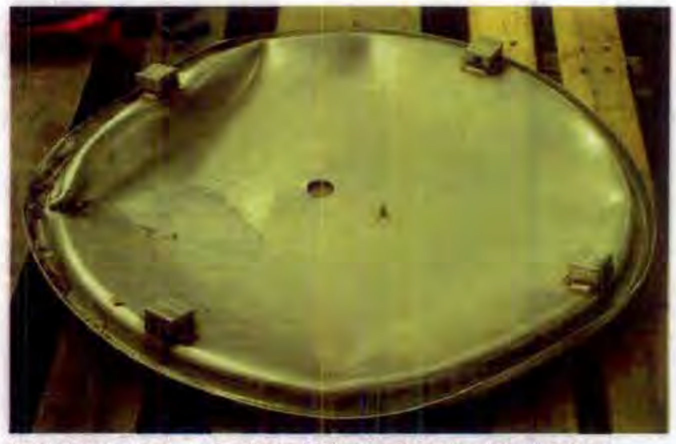


FIGURE 2. LID CLOSURE MODIFICATION (NOTE FOUR BLOCKS WELDED ON THREE SIDES TO BOTTOM OF LID – LID SHOWN IS AFTER TESTING)

Section 2.1.1 Compression Test – Assessed Based on Test Plan 90 Report

The test specimen was subjected to a weight of 1,465 lbs. for more than 24 hours. This was 5.3 times the maximum weight of the package as described in TP 90, and accounted for any tolerance stack-up in the scales used. No damage was noted to the test specimen. The test specimen was profiled prior to testing and at the end of the Hypothetical Accident Transport sequence of tests with no significant change in the profile measurements after testing.

The lid closure bolt modification has no adverse affect on these results. In compression, a sufficient load could produce drum deformation which could eventually create a shear load on the lid closure bolts from the drum clearance holes. In actual testing described in Test Plan 90 Report, the lid and drum did not deform during the compression test.

Under Test Plan 163, the maximum package weight was increased from 280 lbs to 300 lbs. The Test Plan 90 compression test was performed with a compressive load of 1,465 lbs. This represents 4.88 times the new maximum package weight of 300 lbs. as evaluated under Test Plan 163. Since test specimen TP90(A) exhibited no deformation during the compression test, the addition of 35 lbs. in compressive load to produce 5 times the total package weight is only a 2.3% increase. Additionally, the 4 holes drilled for the lid closure bolts reduce the cross sectional area of the drum

wall from 3.43 sq" to 3.31 sq". The compressive stress in the drum side wall, tabulated in Figure 3, will increase from 405 psi to 453 psi, both negligible compared to the yield strength of stainless steel (30,000 psi). The 976 packages with the modified lid closure bolts and the increased package weight will comply with the compression requirements of 10 CFR 71.71(c)(9).

Test Specimen	Shield Container Model and Serial Number	Shield Container plus added lead weights	Package Weight with Overpack	Package Weight with Overpack multiplied by 5	Compressive Stress in Drum Side Wall.
TP90(A)	Model 855 sn 9	207 lbs.	278 lbs.	1390 lbs.	405psi
TP163(A)	Model 855 sn 8	224 lbs.	298 lbs.	1490 lbs.	450 psi
TP163(B)	Model 855 sn 9	226 lbs.	300 lbs.	1500 lbs.	453 psi
TP163(C)	Model 1911 sn 13	184 lbs.	263 lbs.	1315 lbs.	397 psi

FIGURE 3: COMPRESSION ASSESSMENT TABLE

Section 2.1.2 Penetration Test – Assessed Based on Test Plan 90 Report

In Test Plan 90 testing, the penetration bar impacted as intended. The bar bent the lid clamp band closure bolt slightly and left a slight impression on the threads. No other damage was noted. There was no effect to the integrity of the package.

Addition of the lid closure bolts will have no adverse affect on these results. The lid closure bolts are inserted into the clearance holes in the drum, with only the hex heads exposed. As described later in this TP Report, the lid closure bolts were subjected to the hypothetical accident test impact force without any failures, so no failures will occur based on the force imparted during the penetration test. The 976 packages with the modified lid closure bolts will comply with the penetration requirements of 10 CFR 71.71(c)(10).

Section 2.1.3 1.2m (4-foot) Free Drop Test – Assessed Based on Test Plan 90 Report

In Test Plan 90 testing, the specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the cork and its binder resin, as well as any water resident in the cork may exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel drum components.

The test specimen impacted the test pad as intended. Very little damage to the drum was noted. The bottom of the drum was scuffed and slightly bowed out. Upon disassembly, the cork liner had fractured and separated at the base. The Model 855 was undamaged. The Model 855 was released for use in Specimen TP90B, for Hypothetical Accident testing.

Survey results of TP90B were taken after completion of the hypothetical accident testing. Surveys were taken with the Model 855 outside of the drum and cork assembly. This produced dose rates higher than would have occurred with the Model 855 placed inside the test drum and cork assembly. Using only the inner shield resulted is a more conservative assessment of the Model 976A package performance as the presence of the drum/cork assembly would have increased the survey distance and resulted in even lower package survey results than were used for acceptance of the package containment after testing. Profile results of the Model 855 after testing were within expected tolerances of the initial shield profile results taken on 7 Mar 96 (See Appendix C for the initial shield profile results which are part of the shield manufacturing records.)

The addition of the lid closure bolts will have no affect on these results. A possible form of damage would be for the drum to deform enough for the clearance holes in the drum to create a shear load on the lid closure bolts. As described later in this report, the lid closure bolts were subjected to the hypothetical accident test impact force (9 m free drop) without any failures, so no failures will occur based on the force imparted during the 1.2 m free drop test.

Under Test Plan 163, the maximum package weight was increased from 280 lbs to 300 lbs. This means that the free drop test specimen under Test Plan 90 at 278 lbs., weighed 22 lbs. less than the 300 lbs. test unit TP163(B) tested for the hypothetical accident drop test configurations in Test Plan 163. Test Plan 90 Report results showed very little damage. As described later in this report, the heaviest transport package (976A) was subjected to the 9 m free drop test under the hypothetical accident conditions testing without any failures and a maximum package radiation dose rate increase of only 27%. Based on the Hypothetical Accident Condition testing, subjecting these packages to the less destructive 1.2 m drop testing will cause no significant increase in dose rates as a result of the testing. After testing the radiation dose rates still remained within the regulatory limits specified in 10 CFR 71.47. The addition of 22 lbs., a 7.9% increase in the test specimen weight will not adversely affect the results of the package performance during the 1.2 m Free Drop Test. The 976 packages with the modified lid closure bolts and increased package weight will comply with the free drop requirements of 10 CFR 71.71(c)(7).

Test Specimen	Shield Container	Shield Container and added lead weight	Package Weight with Overpack	Weight difference with TP90(A)
TP90(A)	Model 855 sn 9	207 lbs.	278 lbs.	NA
TP163(A)	Model 855 sn 8	224 lbs.	298 lbs.	+20 lbs.
TP163(B)	Model 855 sn 9	226 lbs.	300 lbs.	+22 lbs.
TP163(C)	Model 1911 sn 13	184 lbs.	263 lbs.	-15 lbs.

FIGURE 4: NORMAL TRANSPORT 1.2 m FREE DROP SHIELD CONTAINER COMPARISON TABLE

FIGURE 5. NORMAL CONDITIONS DRUM DAMAGE: SPECIMEN TP90A (NOTE: Package as shown above does not reflect the package configuration immediately after testing. This package had been

disassembled and inspected, then the components re-assembled without engagement of the clamp band bolt at the time this photograph was obtained.)

FIGURE 6. NORMAL CONDITIONS CORK DAMAGE: SPECIMEN TP90A

Section 2.1.4 The Water Spray Preconditioning

Not necessary as the Model 976 Transport Drum, in all its configurations, is constructed of waterproof materials throughout. The water spray would not contribute to any degradation in structural integrity.

Section 2.1.5 General Package Performance Requirements

Compliance of the Model 976 Series packages to the general package requirements in 10 CFR 71.43, 71.45 and 71.47 as well as 49 CFR and IAEA TS-R-1 is contained in the Type A Evaluation included in Appendix G of this report.

Section 2.1.6 Normal Condition Transport Summary

Based on evaluations in Sections 2.1.1-2.1.5, the Model 976 package configurations comply with the requirements for Normal Conditions of Transport as specified in 10 CFR 71.71, 49 CFR and IAEA TS-R-1.

Section 2.2 Hypothetical Accident Conditions

The Hypothetical Accident Tests described in 10 CFR 71.73 are the 9m (30-foot) drop, the 1m (~3-foot) puncture drop and thermal test.

The crush test described in 10 CFR 71.73(c)(2) does not apply and therefore was not performed. Items transported in the drum are sources qualified as Special-Form radioactive material or empty devices with depleted uranium, lead or tungsten shielding.

Section 2.2.1 9m (30-foot) Drop Test

Three (3) tests were performed. The tests are described in Section 5.0.

Section 2.2.2 1m (~3-foot) Puncture Trop Tests

Four (4) tests were performed (one specimen was dropped twice). The tests are described in Section 5.0.

Section 2.2.3 Thermal Test

The response of the package, in its various configurations, to the thermal test of 10 CFR 71.73(c)(4) is assessed in Section 5.5. This assessment is based on the testing performed on the Model 3605B transport container. The Model 3605B is a stainless steel drum of similar size which utilizes cork insulation in the same manner as the Model 976 packages.

Section 2.2.4 Package Assessments

Compliance for the Model 976 Series packages containing shield container Models 3056, 3078, 3015 and 3018 are assessed in Sections 5.4 and 5.5. No physical testing was performed on these package configurations under this test plan.

The shield container Models 3056, 3078, 3015 and 3018 have been used in the field for over twenty (20) years without incident or problem as part of USDOT Type B endorsements of Great Britain Type B(U) approved packages. The Model 855 has been used in the field for over twenty (20) years without incident or problem as part of a USNRC and USDOT Type B approval. These containers and their associated Type B endorsement certifications are listed in Figure 5.

Inner Shield Container	USNRC Type B(U) Certificate	USDOT Type B(U) Endorsed Certificate	Great Britain Type B(U) Certificate	Intended Model 976 Package Designation
855	USA/9165/B(U)	USA/9165/B(U)	None	976A
3015	None	USA/0590/B(U)-85	GB/3605A/B(U)-85	976B
3018	None	USA/0592/B(U)-85	GB/3605B/B(U)-85	976D
3056	None	USA/0316/B(U)	GB/0924BZ/B(U)	976C
3078	None	USA/0250/B(U)	GB/0924BP/B(U)	976E

FIGURE 7 – CROSS REFERENCE TABLE OF INNER SHIELD CONTAINER TRANSPORT APPROVAL HISTORY

Section 3. Test specimen Descriptions

Section 3.1 General Information

All specimens were prepared per Test Plan 163 (See Figure 8). Test specimens were fabricated and designed using the same materials, methods and quality assurance as the ones to be used in the transportation package. Route cards in Appendix C document the materials and methods of fabrication/acceptance of package components. All test specimens were subjected to the same design and quality assurance requirements as are required for approved Type B packaging under AEA Technology QSA, Inc. U.S.N.R.C. Quality Assurance Program Number 0040. Any discrepancies from the criteria specified in Test Plan 163 are listed below in the sections specific to the specimens.

Test Specimen	Drawings Referenced	Test Condition	Comments	Source Assemblies in Test Specimen During Hypothetical Test Conditions[1]
TP163 (A)	R976A Rev 1 R85590 Rev C R42409 Rev C 20046_LID Rev 1 20046_DRUM Rev 1 SCR303 Rev A	Hypothetical Accident	Inner Shield Model 855 Sn. 8	Eight, Inactive Model 424-9 source wire assemblies.
TP163 (B)	R976A Rev 1 R85590 Rev C R42409 Rev C 20046_LID Rev 1 20046_DRUM Rev 1 SCR303 Rev A	Hypothetical Accident	Inner Shield Model 855 Sn. 9	Eight, Inactive Model 424-9 source wire assemblies.
TP163 (C)	R976F Rev 1 20046M Rev A 87555 Rev D 20046_LID Rev 1 20046_DRUM Rev 1 SCR303 Rev A	Hypothetical Accident	Inner Shield Model 1911 Sn. 013	Two, inactive Model 87555 source capsules. Source capsules were loose in the shield cavity without bracing to produce the worst case condition where the maximum source movement during impact testing was allowed.

[1]Note: Active radiation sources contained in the test specimens during the pre and post testing radiation profiles are identified in Section 6.0 of this report. Inactive sources contained in the test specimens during physical testing comply with the applicable source drawings referenced above, however, the sources were manufactured without the addition of Ir-192.

FIGURE 8. TABLE OF SPECIMEN CONSTRUCTION DATA

The Model 855's have been in service for over twenty (20) years as a Type B(U) package without an overpack. The Model 855s have been maintained based on the procedures approved under USA/9165/B(U). The design has been improved for use in the Model 976 package by replacing the carbon steel cover bolts with stainless steel bolts. The 855's used in the Model 976 test specimens were not otherwise modified.

The Model 1911 has been in service for over twenty (20) years as the inner shield container under Great Britain approval GB/0924W/B(U). The Model 1911 has received standard shipping maintenance (cleaning, replacing worn hardware, etc.). The Model 1911 used in this test has the lead shield encased in a stainless steel jacket. When used in the Model 976 Type B package, all Model 1911 shield containers will be encased in stainless steel jackets.

All test specimens were dropped without labels and seal wires. The labels would have no effect on the packages ability to withstand the hypothetical accident condition drop testing. Labels that are to be installed are of a standard design, which has been shown to pass all physical and thermal testing. Holes drilled in the drums to attach the label would perform in a manner similar to the larger holes drilled in the test specimens for the thermocouple wires. The omission of the seal wire is a worst case scenario. If installed, the wire would only help to hold the lid clamp band together.

Two (2) thermocouples were attached to each Specimen: one internal to the inner shield container and one to the outside of the drum. The drum thermocouple was attached with a small screw threaded into the lid. A hole was cut in the lid of the drums to allow access to the internal thermocouple. Any material removed, or holes cut into the device will only serve to exacerbate the stresses induced during impact and would constitute a worse case scenario for the package. Production packages will not have these holes.

Section 3.2 Test Specimen TP163(A)

This test specimen was subjected to the Hypothetical Accidental condition testing (30-ft and puncture drops only). It was dropped with the lid oriented down at approximately a 45° angle, with the lid clamp band closure bolt down. The lid clamp band closure bolt was also oriented directly above one of the four lid closure bolts.

The test specimen was tested with eight (8) inactive 424-9 style sources. These sources simulate the maximum carrying capacity and are representative of the source wire assembly designs transported in this container. TP Report 90 tested the 855 container with two source assembly designs and both variations of the lock hold down block assemblies. As was seen in Test Plan 90 Report, there was no source displacement or damage to the source assemblies or lock mechanisms of the 855 in the testing. Based on the similarity of function of the source/lock block assemblies, and the protection provided to the lock assemblies within the Model 976 package, the 855 containers used in this test were configured using the standard lock block assemblies and 424-9 inactive source assemblies. This configuration is representative of the various sources transported in the 855 so long as no damage to the cover of the 855 is sustained which could be translated to the inner lock mechanisms.

An additional 20 lbs. of lead was added to bring the gross weight of the Model 976 Specimen TP163 (A) up to 298 lbs. The lead was added to increase the package weight only to compensate for any variance in weight that might exist in the existing shield containers and this lead was not present when the device was profiled before and after testing. Lead sheet was added between the inside cover of the 855 and the outside of the lock block mechanisms. Drawings may be found in Appendix A.

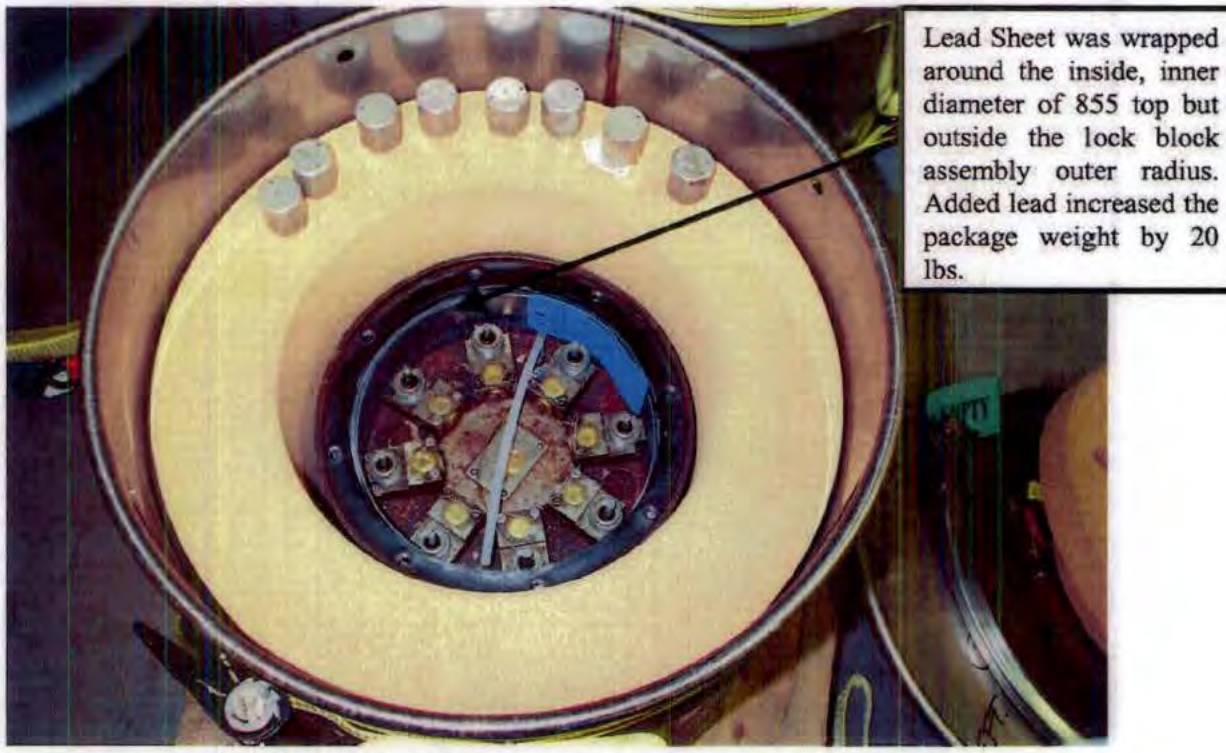


FIGURE 9. MODEL 855 IN MODEL 976 OUTER DRUM WITH ADDED LEAD

Section 3.3 Test Specimen TP163 (B)

This test specimen was subjected to the Hypothetical Accidental condition testing (30-ft and puncture drops only). It was dropped with the lid oriented down at approximately a 17.5° angle, with the lid clamp band closure bolt up. The impact point was directly in between two of the four lid closure bolts.

The test specimen was tested with eight (8) inactive 424-9 style sources. These sources were used to simulate the maximum carrying capacity and the varied type of sources transported as was described for test specimen TP163(A). An additional 20 lbs. of lead was added to bring the gross weight of the Model 976 Specimen TP163 (B) up to 300 lbs. The lead was added to increase the package weight only to compensate for any variance in weight that might exist in the existing shield containers and this lead was not present when the device was profiled before and after testing. Drawings may be found in Appendix A.

Section 3.4 Test Specimen TP163 (C)

This test specimen was subjected to the Hypothetical Accidental condition testing (30-ft and puncture drops only). It was dropped with the lid oriented down at approximately a 17.5° angle, with the lid clamp band closure bolt up. The lid clamp band closure bolt was also oriented directly above one of the four lid closure bolts. The test specimen was tested with two (2) inactive 87555 style source capsules. These sources simulate the maximum carrying capacity and the minimum mechanically protective configuration of sources transported.

An additional 16 lbs. of lead in the form of lead discs was added to bring the gross weight of the Model 976 Specimen TP163 (C) up to 263 lbs. (see Figure 10). The lead was added to increase the package weight only to compensate for any variance in weight that might exist in the existing shield containers and this lead was not present when the device was profiled before and after testing. The lead discs were placed directly above the 1911 container (after removal of the eyebolt) and replaced two of the four cork rings that are used in this shipping configuration. This modification provides a worst case test unit as the lead discs increased the package weight and provided less shock absorption than would be provided if all four cork rings had been used. Drawings may be found in Appendix A.

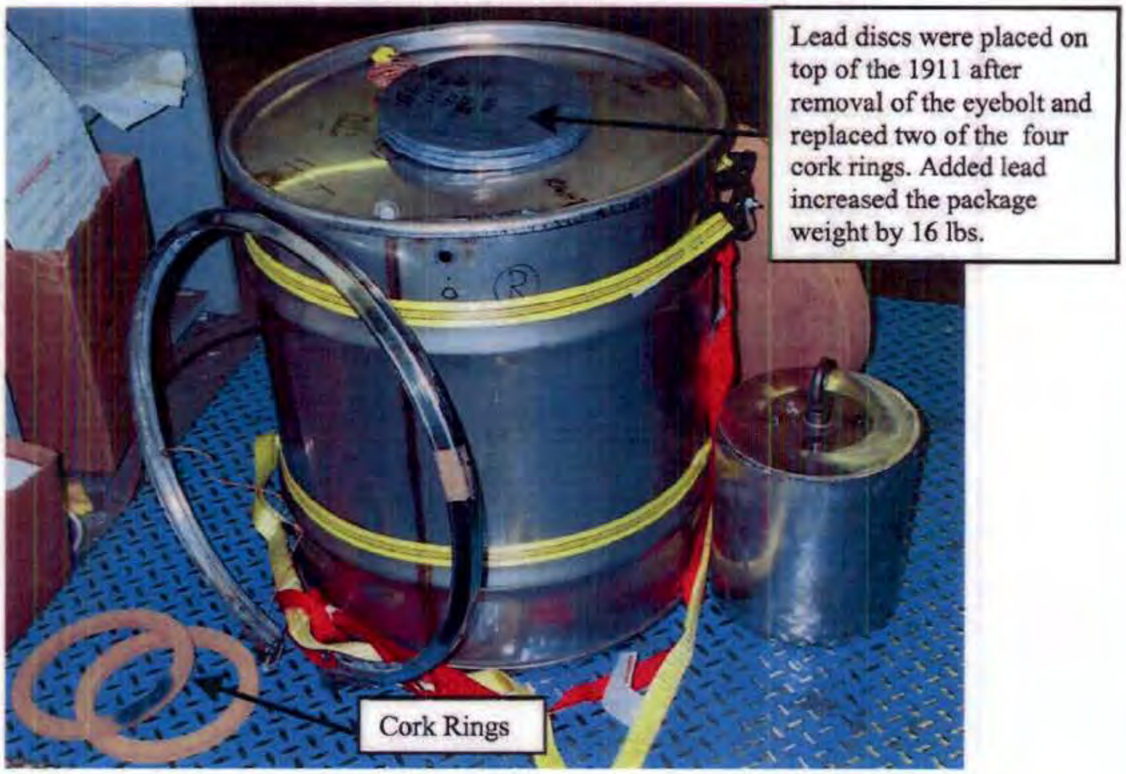


FIGURE 10. TP163(C) TEST UNIT COMPONENTS PRIOR TO ASSEMBLY

Section 4. Changes to Test Conditions or Orientations

Section 4.1 Hypothetical Accident Conditions (71.51(a))

TP163 (A)

a. 9m (30-foot) Drop - No variations from plan.
One lid closure bolt from TP163(C), which was dropped before TP163(A), was reused on TP163(A).

b. Puncture Drop - No variations from plan.

TP163 (B)

a. 9m (30-foot) Drop - No variations from plan.

b. Puncture Drop - No variations from plan.

TP163 (C)

a. 9m (30-foot) Drop - No variations from plan.

b. Puncture Drop - No variations from plan.

Section 5. Test Specimen Results

Section 5.1 Specimen TP163(A)

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the cork and its binder resin, as well as any water resident in the cork may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.1.1 30-ft Drop

The test specimen impacted the test pad as intended. The closure bolt assembly was crushed, shearing the clamp band closure bolt. The 4 lid closure bolts remained intact. The drum lid and top rim of the drum side were crimped together and folded under the bolt assembly. This was caused by the primary impact.

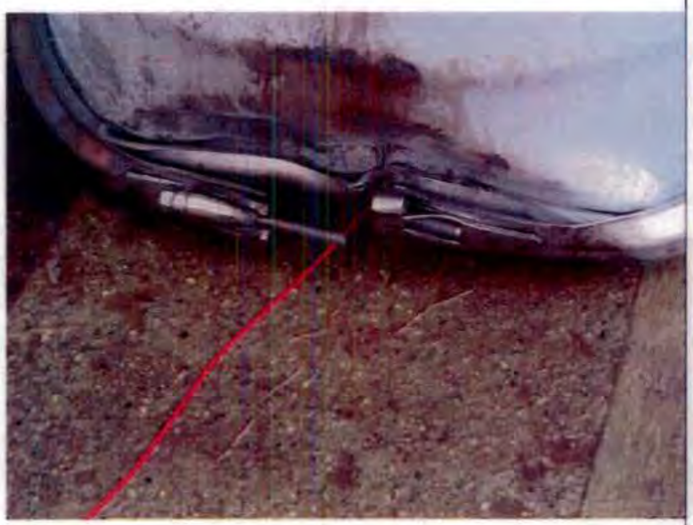


FIGURE 11. PRIMARY IMPACT DAMAGE: SPECIMEN TP163(A) CLAMP/LID BOLT

FIGURE 12. PRIMARY IMPACT DAMAGE: SPECIMEN TP163(A) DRUM FLATTENING

Secondary impact, the slap down, caused the side of the drum to be slightly flattened and the bottom ring weld to be dented. No rips or tears were noted in the steel. The four (4) lid closure bolts were intact. The lid and lid clamp band, although damaged, did not separate from the drum even when inverted. The 855 was retained within the drum.

5.1.2 Puncture Test

Based on the damage to the clamp band bolt in the 30-ft drop test, it was decided to attempt to remove the lid clamp band and lid with the puncture test. The test specimen was angled at approximately 45° and dropped to impact on the opposite, undamaged side of the closure bolt.

The test specimen impacted the puncture bar as intended. Upon impact, the lid clamp band came off the drum and the puncture bar further dented the side of the drum. The four (4) lid closure bolts remained intact and the lid remained attached to the drum. As before, the Model 855 was retained within the drum, even when inverted.

FIGURE 13. SPECIMEN TP163(A) DRUM DAMAGE AFTER PUNCTURE TEST

5.1.3 Post Test Examination

The lid closure bolts were removed with a normal socket wrench. The lid was then pried from the drum. The closure bolts were intact after removal with no shearing or signs of fracturing. The threaded blocks on the lid were intact with no weld cracking evident.

The top cork was cracked into several pieces. Due to the angle of the cracks, however, the first few pieces of cork had to be pried out before others could be removed. The bottom cork insert sides were fractured into two halves.

The Model 855 was undamaged. After examination it was determined that the locks were still all engaged and the sources had not moved.

FIGURE 14. SHEARED LID CLAMP BAND BOLT: SPECIMEN TP163(A)

FIGURE 15. TOP CORK DAMAGE: SPECIMEN TP163(A)

FIGURE 16. SIDE CORK DAMAGE: SPECIMEN TP163(A)

FIGURE 17. MODEL 855 WITH COVER REMOVED, SOURCE CAPS ON AND LOCKS ENGAGED: SPECIMEN TP163(A)

FIGURE 18. MODEL 855 WITH CAPS OFF, SOURCES SHOWN: SPECIMEN TP163(A)

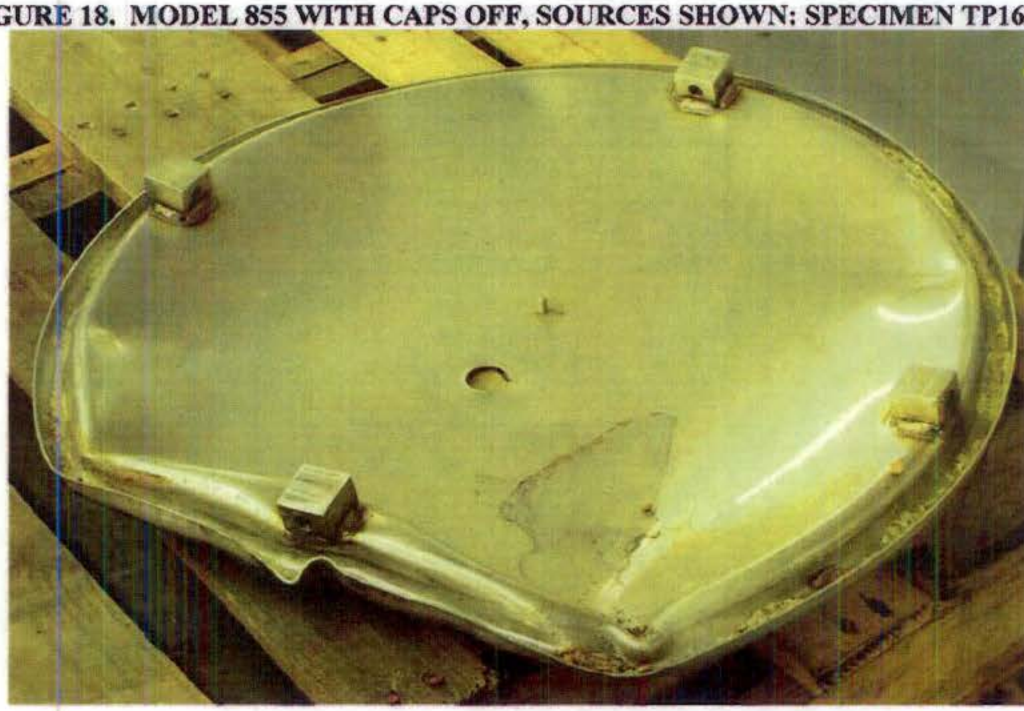


FIGURE 19. SPECIMEN TP163(A) LID CLOSURE BLOCKS

Section 5.2 Specimen TP163(B)

The specimen was chilled to at least -40°C as the Model 855, being constructed of carbon steel, is susceptible to brittle fracture upon shock loading. In addition, the cork and its binder resin, as well as any water resident in the cork may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.2.1 30-ft Drop

The test specimen impacted the test pad as intended. The top edge of the drum was deformed similar to TP163(A), but to a lesser extent. This was attributed to the shallower angle of impact (17.5° versus 45°) transferring less energy directly upon impact. The lid clamp band was deformed, but intact and held the lid on the drum. The four (4) lid closure bolts were intact. The lid and top rim of the drum were folded and crimped, as with TP163(A). This damage was caused by the primary impact.

The secondary, slap down impact caused the side of the drum to be flattened and the lower corner of the drum to be deformed along the angle of impact. Although folded over, the lower flange did not tear or split. No rips or tears were noted in the steel. The lid and lid clamp band did not separate from the drum and the Model 855 remained within the drum even when inverted.

FIGURE 20. PRIMARY AND SECONDARY IMPACT DAMAGE: SPECIMEN TP163(B)

5.2.2 Puncture Test

Based on the damage to the lid clamp band in the 30-ft drop test, it was decided to attempt to remove the lid clamp band and lid with the puncture test. The test specimen was impacted at approximately 17.5° on the opposite side of the lid from the 9m impact.

On the first puncture test drop the lid clamp band just missed the puncture bar and the side of the drum impacted the puncture bar instead. The specimen was then hoisted again and the crane boom was moved laterally.

On the second puncture drop the lid clamp band impacted the puncture bar as intended. The lid clamp band bolt assembly was deformed, but both the lid clamp band and the lid remained secure. The four (4) lid closure bolts remained intact. The puncture bar slightly dented the side of the drum. The Model 855 was retained within the drum, even when inverted.

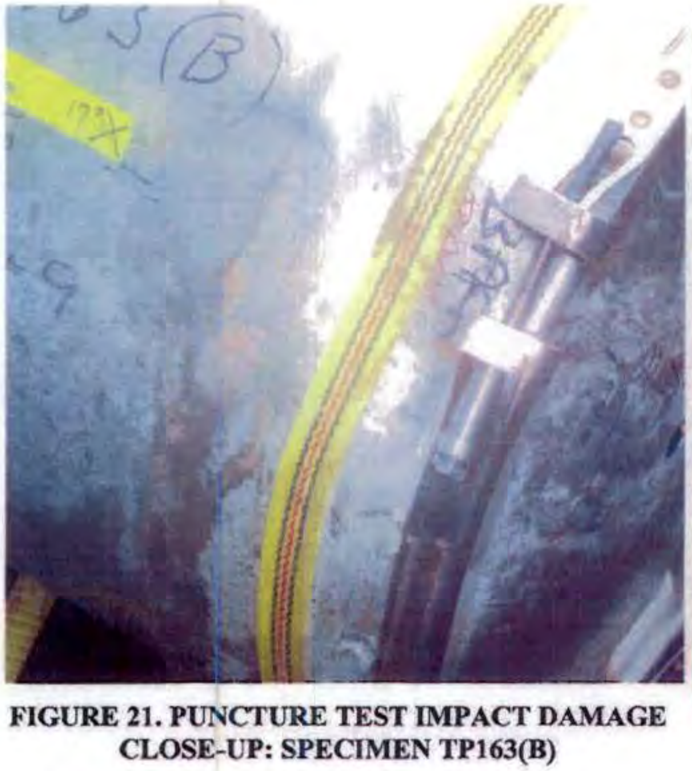


FIGURE 21. PUNCTURE TEST IMPACT DAMAGE CLOSE-UP: SPECIMEN TP163(B)

FIGURE 22. PUNCTURE TEST IMPACT DAMAGE SIDE: SPECIMEN TP163(B)

5.2.3 Post Test Examination

The lid clamp band and the lid closure bolts were removed with normal socket wrenches. The lid was then pried from the drum. The lid closure bolts were intact after removal with no shearing or signs of fracturing. The threaded blocks on the lid were intact with no weld cracking evident.

The top cork was cracked into several pieces. Due to the angle of the cracks, however, the first few pieces of cork had to be pried out before others could be removed. The bottom cork was fractured into a few pieces. The side cork insert was fractured. The damage from the three drops (one 9m and two puncture) drops looked to be slightly less than in TP163A. This was attributed to the shallower angle of impact in the drops (17.5° versus 45°).

The Model 855 was undamaged. After examination it was determined that the locks were still all engaged and the sources had not moved.

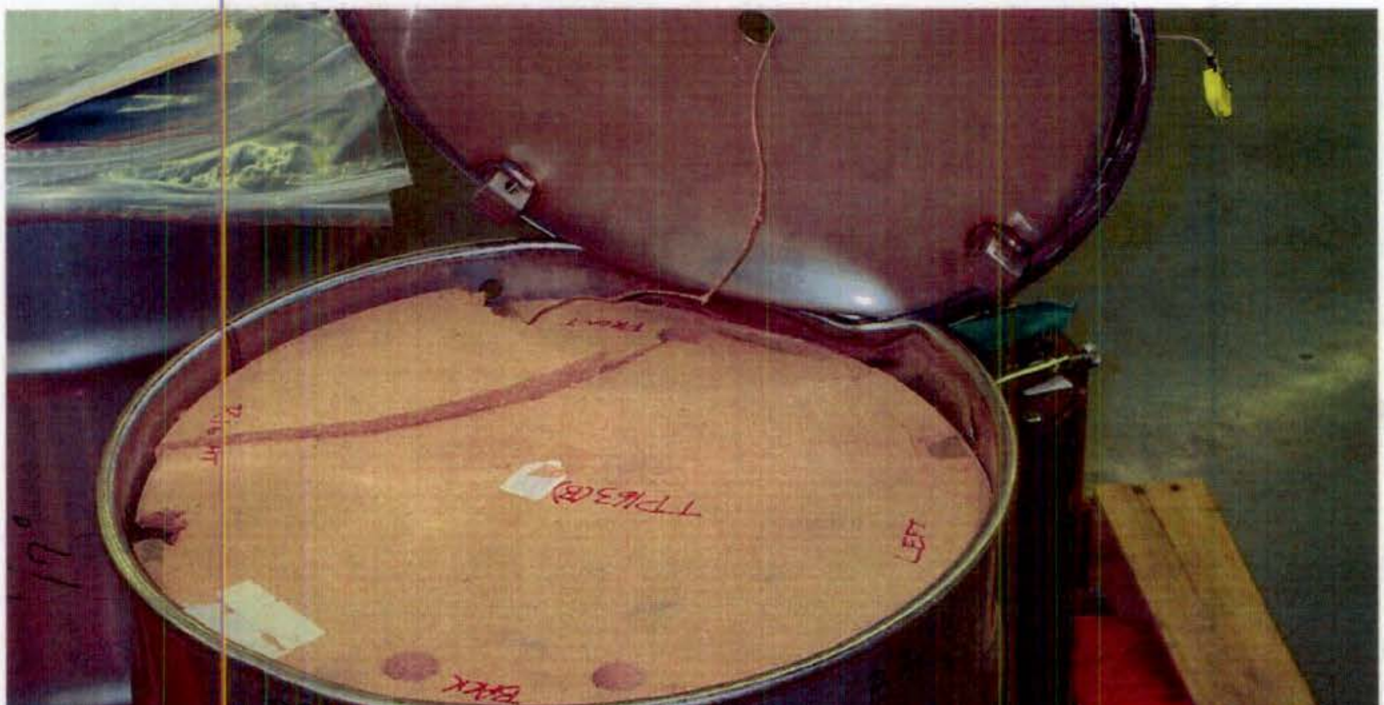


FIGURE 23. TOP CORK DAMAGE: SPECIMEN TP163 (B)

FIGURE 24. SIDE CORK DAMAGE: SPECIMEN TP163 (B)

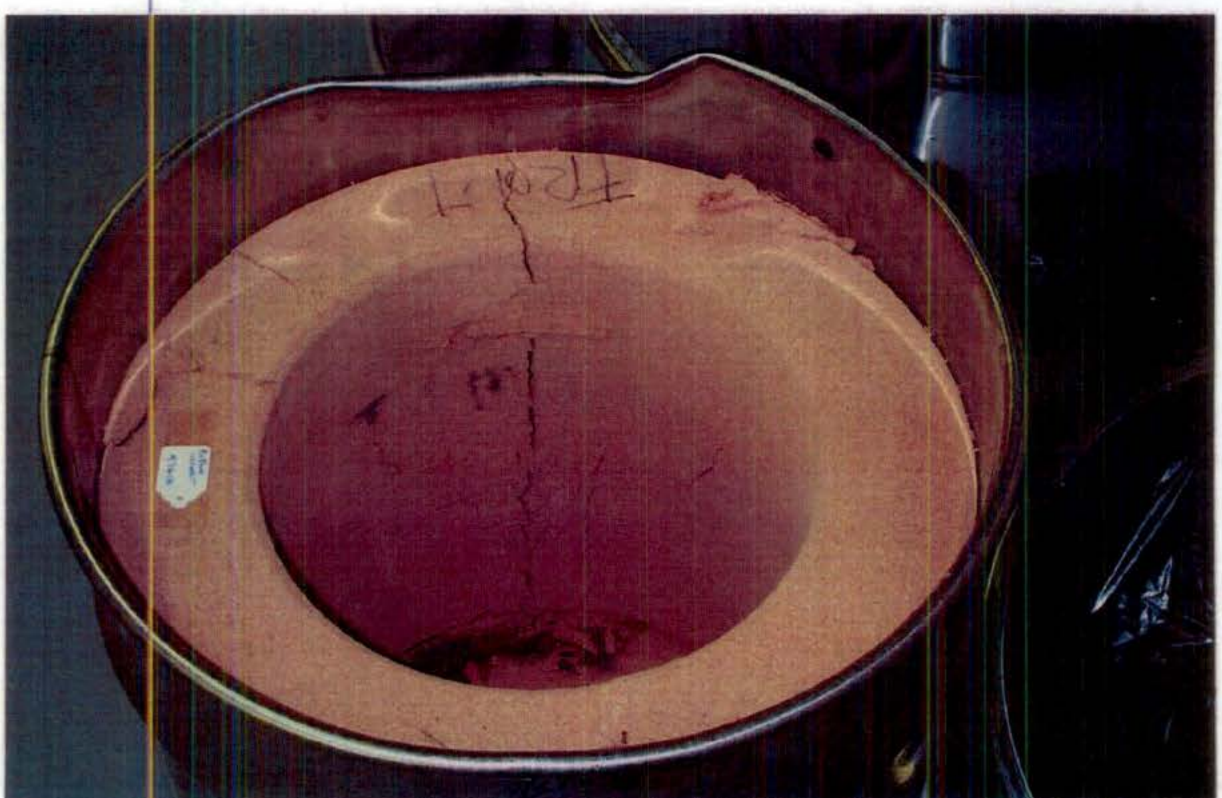


FIGURE 25. SIDE CORK DAMAGE: SPECIMEN TP163 (B)

FIGURE 26. SPECIMEN TP163(B) LID CLOSURE BLOCKS

Section 5.3 Specimen TP163(C)

The specimen was chilled to at least -40°C. The Model 1911, being constructed of lead and stainless steel, is not particularly susceptible to brittle fracture upon shock loading. The cork and its binder resin, as well as any water resident in the cork may tend to exhibit brittle characteristics at lower temperatures. The temperatures within the test range (-40°C to 100°C) would have a negligible effect on the properties of the stainless steel outer drum.

5.3.1 30-ft Drop

The test specimen impacted the test pad as intended. The top corner of the drum was deformed very similar to TP163(B), but to a somewhat lesser extent. The closure bolt assembly was bent, but intact and held the lid on the drum. The lid and top rim of the drum were folded and crimped, as with TP163(B). This damage was caused by the primary impact.

Secondary impact, the slap down, caused the side of the drum to be flattened and the lower corner of the drum to be deformed along the angle of impact. Although folded over, the lower flange did not tear or split. No rips or tears were noted in the steel. The four (4) lid closure bolts remained intact. The lid and lid clamp band did not separate from the drum even when inverted. The Model 1911 was retained within the drum.

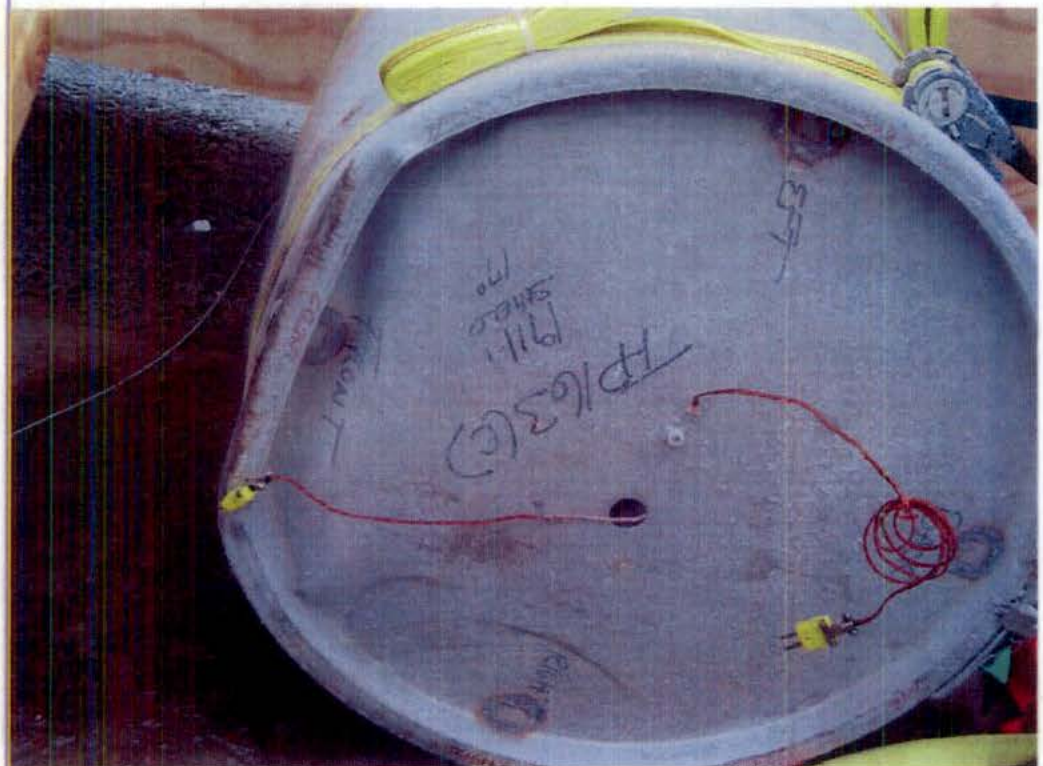


FIGURE 27. PRIMARY IMPACT DAMAGE: SPECIMEN TP163 (C)

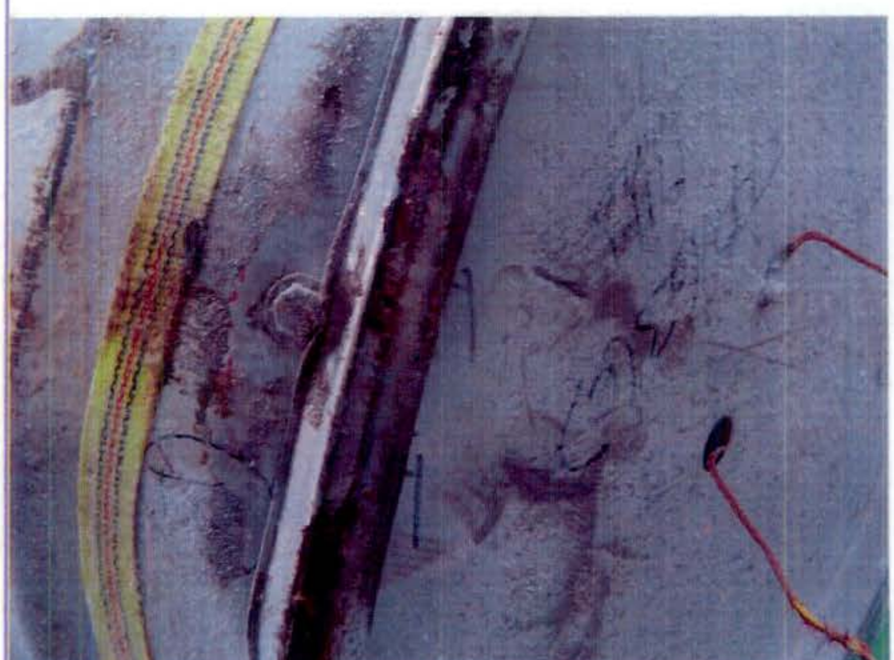


FIGURE 28. PRIMARY IMPACT DAMAGE: SPECIMEN TP163 (C)

5.3.2 Puncture Test

Based on the damage to the clamp band in the 30-ft drop test, it was decided to attempt to remove the lid clamp band and lid with the puncture test. The test specimen was impacted at approximately 17.5° on the same side point on the lid as the 9m impact. Both the lid clamp band and the lid remained secure. The four (4) lid closure bolts remained intact. The puncture bar slightly dented the side of the drum. The Model 1911 was retained within the drum, even when inverted.

FIGURE 29. PUNCTURE IMPACT DAMAGE: SPECIMEN TP163 (C)

5.3.3 Post Test Examination

The lid clamp band and the lid closure bolts were removed with normal socket wrenches, then the lid was pried from the drum. The lid closure bolts were intact after removal with no shearing or signs of fracturing. The threaded blocks on the lid were intact with no weld cracking evident.

The top cork was cracked into several pieces. Due to the angle of the cracks, however, the first few pieces of cork had to be pried out before others could be removed. The bottom cork was cracked into a few pieces. The cork spacer rings and the inner cork insert were cracked. The damage from the two drops (one 9m and one puncture) drops looked to be slightly less than in TP163(B). This was attributed to the lower weight (263 lbs. versus 300 lbs.) and the thicker cork liner on the sides to absorb the impact (4 5/8" versus 3 ¾").

Since test specimen TP163(C) contained a smaller shield container surrounded by more cork, it was theorized that the additional drum deformation allowed by the thicker cork liner might allow the lid clamp band to separate from the drum. However, the lid clamp band remained intact after testing.

The Model 1911 was undamaged. After examination it was determined that there was no damage to the shield, lid, lid bolts, inserts or sources.

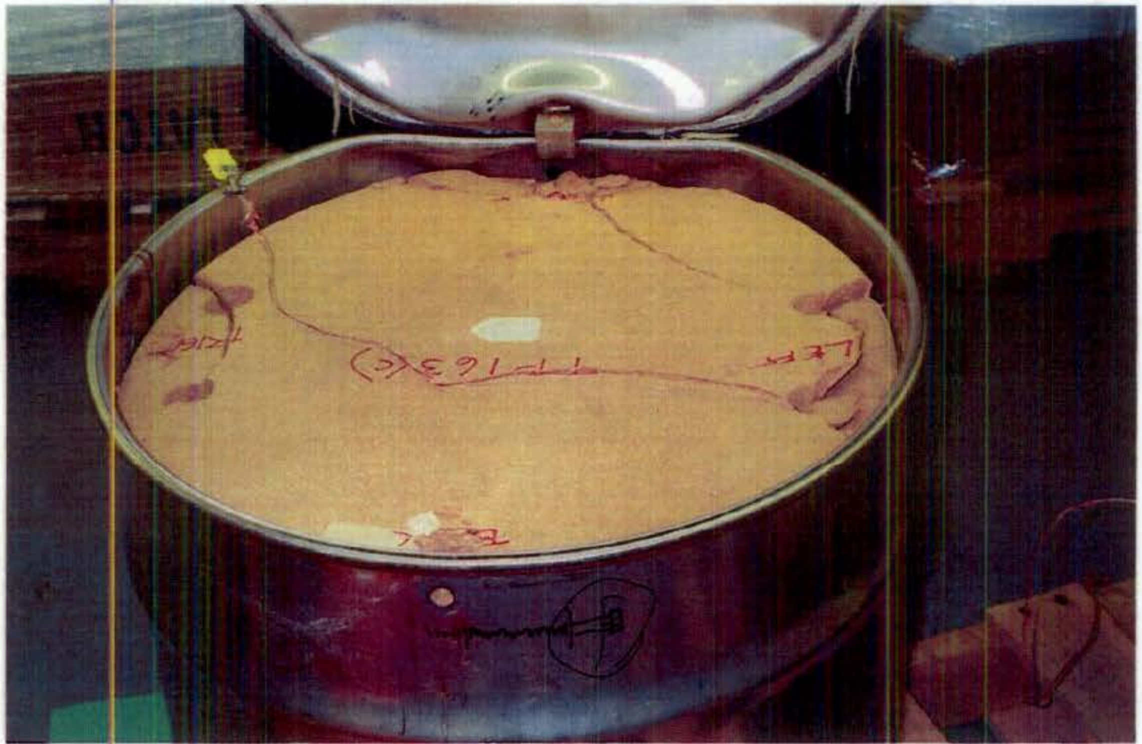


FIGURE 30. TOP CORK DAMAGE: SPECIMEN TP163(C)

FIGURE 31. SIDE AND INSERT CORK DAMAGE: SPECIMEN TP163(C)

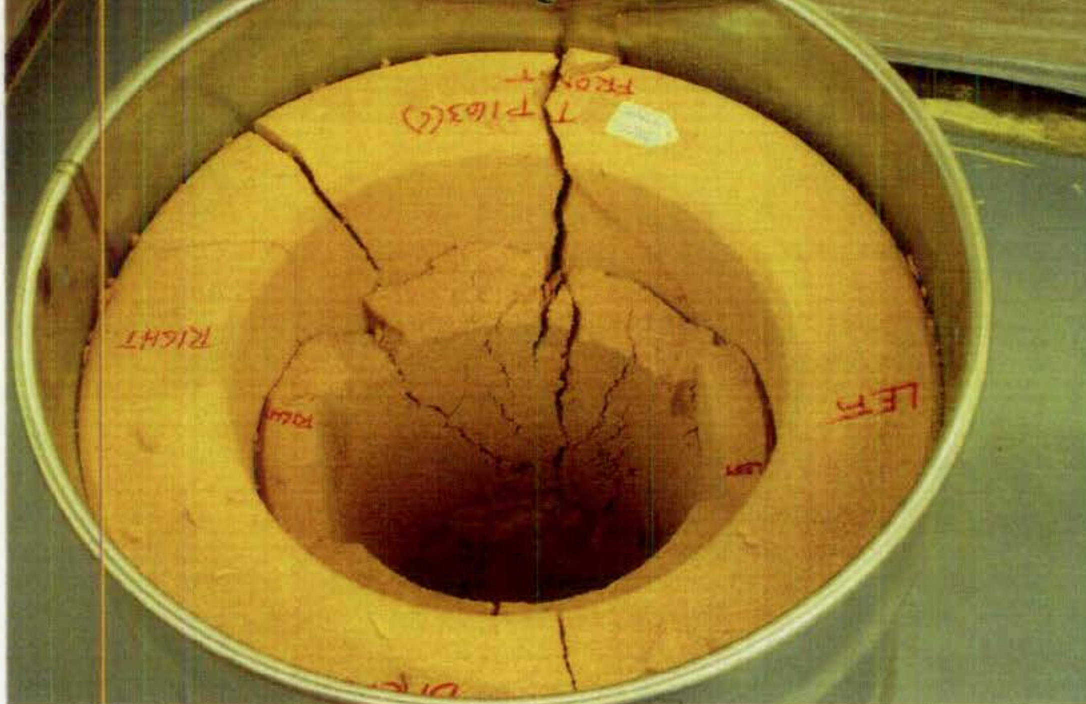


FIGURE 32. SIDE CORK DAMAGE: SPECIMEN TP163(C)

FIGURE 32. MODEL 1911 SOURCES INTACT: SPECIMEN TP163(C)

Section 5.4 9M and Puncture Test Assessments

The shield containers used in the Model 976 drum assembly are of two general types: (1) those which use depleted uranium for their primary shielding (e.g., 855 and 3078), and (2) those that use lead for their primary shielding with supplemental materials as part of the inner assembly shielding design (e.g., 3015, 3018, 3056 and 1911). Securing mechanisms for these containers are one or more of the following:

- Bolted cover lid or protective cover (Models 855, 3078, 1911, 3056, 3018, 3015, 1911)
- Source Wire lock assemblies (Models 855, 3056)
- Source Wire Protective Caps (Models 855, 3056, 3018, 1911)
- Shielding Cavity Plug (Model 3078, 3015)

Based on the modification of the drum/lid securing mechanism (addition of four (4) bolts securing the lid to the drum base) results of the Model 855 and Model 1911 can be used to justify that the lighter package contents will comply with the 9M and Puncture test performance requirements. As seen in the Test Plan 90 Report comparisons, and also seen in the test specimens under this test plan, none of the tested shield containers experienced any damage from the drop testing which adversely affected the source containment. In all cases the source securing mechanisms were not observably changed after testing and the shield containers were protected from any external damage by the cushioning provided by the cork drum liners. Since the Model 855 and Model 1911 are representative of the heaviest package configurations tested it is reasonable to assess that damage induced to these shield containers will be more extensive than would be produced in drop testing any of the lighter shield containers.

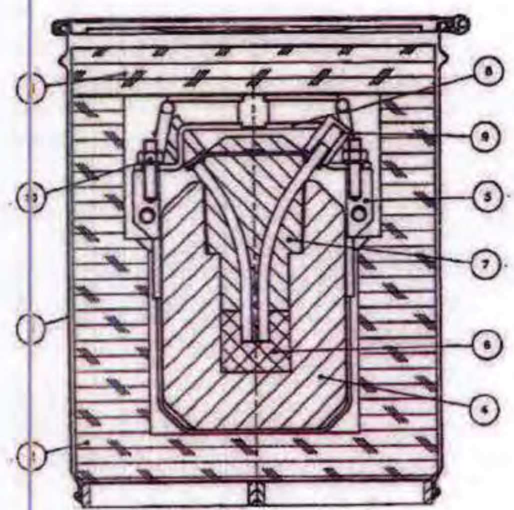
Based on the added lid securing bolts, none of the tested shield containers caused a failure to any of the four (4) lid securing bolts and none of the test units exited the drum. The tested drums were impacted at 45° and 17.5° angles to assess configurations of greatest impact force and slapdown effects at shallow angles. Using these test units as representative of the worst case extremes for this package design, then testing of these package designs with inner shield containers of lesser mass will not induce greater damage than was observed with the Test Specimens.

From a comparison of the pre and post testing radiation measurements, there was no significant change in the packages tested. With no appreciable damage to the source securing mechanisms, no observable damage to the externals of the shield containers and the similarities of the comparison shield containers to previously tested containers under Test Plan 90 and this test plan, it is determined that the Models 3015, 3018, 3056 and 3078 will perform as well if not better than the tested units under Test Plan 163 Report (e.g., 855 and 1911). Damage induced in the test units was insufficient to adversely affect the source containment and therefore the 976 package containing either the Model 3015, 3018, 30156 or 3078 will perform as well if not better than the test specimens when subjected to the 9M and Puncture tests.

By assessment, the Model 976B (with 3015) package design, the Model 976D (with 3018) package design, the Model 976C (with 3056) package design, and the Model 976E (with 3078) package design would perform as well if not better than the Model 976A (with 855) and the Model 976F (with 1911) package designs under the 9 m and puncture test requirements.

Section 5.5 Thermal Assessments

Thermal testing was performed for a similar, but smaller, drum design to support approval of a Type B container in Great Britain (See Figure 33). The tested drum measured 32.5 cm in diameter by 40.5 cm tall with minimum cork thickness on the bottom of 4 cm, on the top of 4.5 cm and on the sides of 5 cm. In contrast the Model 976 package measures 50 cm in diameter by 54 cm tall. The Model 976 Series packages have a minimum cork thickness, which is based on the Model 976A configuration containing the least cork material, of 5 cm on the bottom, 12.7 cm on the top and 8.3 cm on the sides.



Item	Description	Material	No. off
1	DRUM	STEEL	1
2	PACKING INSERT	CORK	1
3	PACKING SPACER	CORK	1
4	LEAD POT	LEAD	1
5	POT CRADLE	CARBON STEEL	1
6	CORE SHIELD	TUNGSTEN ALLOY / DEPLETED URANIUM	1
7	SHIELDING INSERT	LEAD	1
8	RETAINING STRAP	CARBON STEEL	1
9	TUBE CAP	BRASS	4
10	M10 COMB NUT	STAINLESS STEEL	2

FIGURE 33 – TEST SPECIMEN CONFIGURATION FOR TEST NUMBER 1835

Test Number 1835 (see Appendix F) documents testing of a Model 3018 inner shield container (lead shielded device) inside of a cork lined steel drum assembly. The cork used in these test units was purchased to the same specification as the cork used for the test specimens under this Test Plan Report, however, the overall cork thickness is greater in the Model 976 style packages than was used in the specimens tested under Test Number 1835.

Testing included 9 m drop tests and puncture tests in similar orientations as were performed for the test specimens under this test plan report. The test specimens under Test Number 1835 were tested at ambient temperature and were not cooled to -40°C prior to the 9 m and puncture drop tests.

As was seen with the Model 976 style test specimens, the test units described under Test Number 1835 also experienced drum deformation but no loss of the lid from the drum base. Though cracking of the cork was not specifically referenced on the sides of the cork liners in the test units from Test Number 1835, cracking of the bottom cork inserts was noted. The bottom of the cork cavity was cracked around the circumference and across diagonals in line with the drum reinforcement bars.

Thermal testing of the specimens under Test Number 1835 placed the specimens into a furnace maintained at an ambient temperature between 800°C - 820°C for a period of 30 minutes. The test specimens did not contain any radioactive contents during the thermal testing performed under Test Number 1835. The test specimens were allowed to cool for at least 18 hours before disassembly and evaluation.

Upon evaluation it was found that the top cork inserts exhibited slight charring (e.g. 22-25 mm depth) with a 26 mm thickness of the insert remaining intact. In both cases the lead shield container was undamage, exhibiting only the

presence of a resin condensate and soot on the lead pot exterior. For both test specimens, the maximum temperature recorded by temperature strips on the exterior surface of the lead pot was 82°C. This temperature rise was less than 1/4 of that necessary to reach the melting point of the lead pot (300°C). Therefore no melting or slumping of the lead shielding occurred.

Upon inspection of the test specimens under this test plan it was observed that TP163(C) exhibited the largest cork cracking on the side inserts. This test unit contained jagged cracks up to ¼" in width in the sides of the cork inserts (see Figures 28 and 29). The presence of these cracks introduces the possibility of a different result in the thermal test if performed. The three thermal transport mechanisms are conduction, convection and radiation. Each will be addressed in the following assessment.

The shield containers used in the Model 976 drum assembly are of two general types: (1) those which use depleted uranium for their primary shielding (e.g., 855 and 3078), and (2) those that use lead for their primary shielding with supplemental materials as part of the inner assembly shielding design (e.g., 3015, 3018, 3056 and 1911). All shield container exteriors are a steel weldment which does not melt below 1,427 °C. The melting point of depleted uranium is 1,130°C.

Section 5.5.1 Conduction Contribution

A calculation of the worst case, steady state conduction through the cork insulation that could be created in TP163(C) is as follows:

$$Q_X = \frac{k\,A(T_1 - T_2)}{L}$$

(Reference Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and Dewitt, page 5.)

Where: Q_x = the heat transfer rate in Watts
k = coefficient of thermal conductivity, 0.0314 W/m K for air at 370°K; 0.039 W/ m K for cork[1]
A = cross sectional area of material (~2 cracks, ¼" wide = 0.00635 m, each 0.5 m long) = 0.00635 m^2
T_1 = Drum Wall Temperature (assumed to be thermal test temperature = 800°C or 1,027°K)
T_2 = Shield Container Initial External Temperature (assumed to be = 97°C or 370°K from 5.5.3)
L = minimum thickness of the outer and inner cork liners (located on the sides) = 0.08m + 0.04m = 0.12 m

Reference 1: Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and DeWitt, Appendix A.

For the thermal test, regardless of the cork condition, A, T_2, T_1 and L will be the same. The only difference will be the variation in the coefficient of thermal conductivity between air and cork. As indicated above, the coefficient for air is less than the coefficient for cork, therefore the heat transfer rate in air through the crack will be less than is experienced through the cork.

Calculation of the maximum conduction through the solid cork is based on the maximum outer area divided by the minimum cork thickness. The drum outer surface is 0.52 m in diameter and 0.54 m high for a maximum cross sectional area of 1.31 m^2. The minimum cork thickness at the bottom of the drum is 0.08 m. Therefore the maximum heat transfer rate is 420 Watts.

Section 5.5.2 Convection Contribution

There is a limited air gap between the cork and the inner surface of the drum. As such, movement of the air around the cork inside the drum to produce convection heating will be insignificant when compared to the conductive heat transferred directing from the drum to the cork. If the crack in the cork is approximated as a solid air volume between the inner drum surface and the outer shield container, then a worst case approximation of the conductive heat transfer

can be made in this limited air volume. Similar to steady state conduction, the under steady state conditions, the local heat transfer rate can be calculated as follows:

$$q_X = (T_1 - T_2) \int h \, dA_s$$

(Reference Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and Dewitt, page 327.)

Where: q_x = the heat transfer rate in Watts
h = convection coefficient for air = 10 Watts/m^2 °K (Reference IAEA TS-G-1.1 (ST-2))
dA_s = cross sectional area of material (~1 cracks, ¼" wide = 0.00635 m, each 0.5 m long)
T_1 = Drum Wall Temperature (assumed to be thermal test temperature = 800°C or 1,027°K)
T_2 = Shield Container Initial External Temperature (assumed to be = 97°C or 370°K from Section 5.5.3)

Estimating the air volume between the inner drum wall and outer shield surface as a vertical cylinder produces the following equation

$$q_X = h \, 2 \pi \, r \, l (T_1 - T_2)$$

Where: r = the radius of the cylinder (crack) = 0.0032 m
l = length of the crack = 0.305 m

Solving for q_x produces a worst case heat transfer rate from convection of 43 Watts along the inner surface of the cork crack.

Section 5.5.3 Radiant Heat Contribution

The jagged path of the crack through the cork prevents any radiation from the drum wall directly contacting the shield container. Without direct contact, the radiative heat transfer to the shield container surface will be insignificant in comparison to the other heat transfer contributions.

Assuming heat contribution to the inner shield from the radioactive contents produces a worst case transfer rate as follows:

The Specific heat output of Ir-192 is 8.6 mW/Ci assuming a decay energy of 1.46 MeV/decay and that 100% of the radioactive decay is transferred to thermal energy. The maximum source content for the package is 1,000 Ci. Actual content to output activity varies based on the capsule configuration as well as variations in isotope self-absorption. A factor of 2.3 was used to convert output activity to content activity as this factor reflects the worst case variation for Ir-192 sources transported in these packages. Therefore the total content activity would be 2,300 Ci and the total heat output assuming a conservative 100% decay during the thermal test is:

8.6 mW/Ci x 2,300 Ci = 19,780 mW = 19.78 Watts

Even assuming complete decay of the Ir-192 during the thermal test produces a heat transfer rate that is insignificant when compared with heat transfer from conduction.

Calculation for the Model 1911 inner shield (smallest shield diameter/wall thickness and largest source term) based on a thermal analysis from "Fundamentals of Heat and Mass Transfer", F.P. Incropera, 5th Edition, 2002 is as follows:

$$Q_{in} = Q_{radiated} = Q_{decay} = 19.78 \; watts$$

Where:

$Q_{radiated}$ = heat radiated = B E A_{ts} [$(T_w + 273)^4 - (T_m + 273)^4$]

(This equation assumes no conduction or convection from all surfaces and radiative heat losses from the top and side surfaces only).

A_{ts} = Area of the top and sides = 0.174 m^2 based on:

$$A_{ts} = \left(\left[\frac{diameter}{2}\right]^2 \pi\right) + (diameter)(height)\pi$$

T_a = ambient temperature = 20°C
T_w = shield maximum equilibrium temperature
T_m = shield median temperature = $(T_a + T_w)/2$
B = Stefan Boltzmann Constant = 5.670×10^{-8}
E = emissivity for rough stainless steel surface between 300 and 400°K = 0.3

Iteration for T_w balancing the heat in to the heat radiated produces a value of 97°C for the maximum temperature at the surface of the inner shield prior to the start of the thermal test.

Section 5.5.4 Thermal Contribution Summary

To raise the temperature of the 1911 lead shield container to the melting point of lead would require a significant amount of energy. The specific heat of lead, C_p = 0.15 kJ/kg-°K. From this relation, calculation of the required heat transfer rate is as follows:

$$Q_{Input} = C_p M (T_2 - T_1)$$

Where Q_{Input} = Minimum heat input to melt the lightest lead container (Model3015)
C_p = Specific Heat of Lead
M = Mass of the shield container = 104 lbs or 47 kg for the Model 3015
T_2 = Melting temperature of lead = 573°K (or 300°C, Smithells, Colin J. Smithells Metals Reference Book, Seventh Edition, Butterworth-Heinemann Ltd, Oxford 1992)
T_1 = Ambient shield temperature = 370°K (see section 5.5.3)

Therefore the required heat transfer rate to cause lead melting in the shield is 1,431 kJ or 1.43×10^6 Watts/sec. To achieve this in the 30 minutes (1,800 sec) of the thermal test requires a heat input of 795 Watts. Even when combining all the worst case thermal contribution factors, the required heat input in the most vulnerable area along the cork crack is less than 60% of the actual heat input that would melt the lead shield and will therefore be insufficient to degrade the lead shielding.

Section 5.5.5 Additional Factors for Consideration

In the case of the depleted uranium shield containers, there was no breach or weld cracking of the shield container which would allow oxygen to reach the inner depleted uranium shield. Without the presence of a continuing source of oxygen, these shields will remain intact during the thermal test. As seen in testing performed on the Model 650L (Reference USNRC CoC USA/9269/B(U)-85, Test Plan 80 Report Revision 1) thermal testing of this device where cracking to allow air to the shield had occurred resulted in production of only a small amount of depleted uranium oxide. With an air path and air circulation during the thermal test, the radiation dose rate at one meter from this unit increases by approximately 10% remaining less than 3% of the regulatory limit.

Without sufficient oxygen provided to the interior of the depleted uranium shield containers (e.g., welds intact) there will be no appreciable oxidation of the depleted uranium shield inside the steel container housings, and the 800°C temperature is well below the melting point of depleted uranium (1,130°C) therefore the shield will retain its original shape throughout the thermal test.

The thermal test will not adversely effect the structural integrity of the shield containers. The Model 855 and Model 1911 containers were physically undamaged after the 9 m and puncture drop testing. The other shield containers (e.g., Models 3015, 3018, 3056 and 3078) are lighter than the Models 855 and 1911 and would therefore be expected to sustain less damage in the drop configurations than was seen for these package assemblies. For shield containers incorporating lead, again the exterior shield temperature will not exceed 82°C. The testing performed under Test Number 1835 took drum assemblies at ambient temperature prior to subjecting them to the thermal test condition. In actual practice the 976 package assemblies would have been thermally tested immediately after the puncture test and would still have been at a temperature below 0°C introducing a further temperature difference to be overcome before the shield container would be susceptible to a melting temperature.

For the Model 976 Series packages, performance of the thermal test would not produce a condition sufficient to reduce the shielding efficiency or containment efficiency of the shield containers within the 976 drum assembly. In addition the temperature increase in the shield container surfaces will be well below the melting temperature of the lead which will preclude any shielding configuration change or lead slumping in the shield containers. By assessment, the Model 976 Series package designs would therefore meet the thermal test requirements.

Section 6. PROFILE RESULTS AND COMPARISON ASSESSMENT

The following table in Figure 35 shows pre and post testing profile results for the test units, along with the amount of testing each shield was subjected to and which specimens the shields were used in. Figure 37 includes profile measurements for alternate shielding variations for the Model 1911 shield container which were not directly tested as well as for other Model 976 package configurations which were not directly tested under this test plan. This information is provided to support activity capacities for these alternate package configurations.

Radiation measurements included in the Figures 35 and 37 were adjusted to the maximum activity capacity for the package (e.g., activity correction factor) and the surface measurements were also adjusted to correct for off-set of the survey meter probe from the true surface of the package.

Activity correction factors (CF_A) were obtained by using the following relationship:

$$CF_A = \frac{MaximumPackageActivityCapacity\ (A_C)}{ActualPRofileActivity\ (A_P)}$$

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

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

Therefore, in this example, all original surface and 1 meter profile measurements would be multiplied by a factor of 1.2 prior to listing the results in the tables.

Radiation measurements at the surface of the container included in Figures 35 and 37 were also adjusted to compensate for the off-set of the survey meter probe center from the surface of the package.

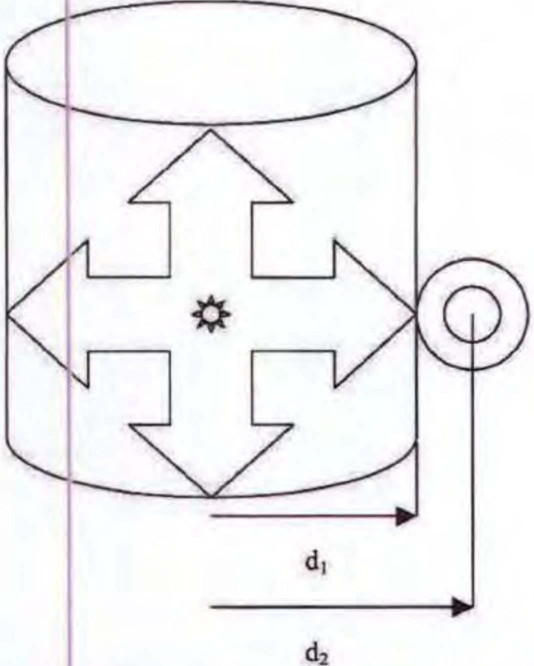
Surface correction factors (SCF) were obtained by using the following relationship:

$$SCF = \frac{d_2}{d_1}\ where\ d_1\ and\ d_2\ are\ determined\ as\ shown\ in\ Figure\ 34.$$

$$For Example,\ if\ d_1 = 9\,inches\ and\ d_2 = 9.5\,inches,\ then$$

$$SCF = \frac{9.5\,inches}{9\,inches} = 1.06$$

Therefore in the example shown, all original surface profile measurements located along the side of the drum would be multiplied by a factor of 1.06 prior to listing the result in applicable table. Different SCF's would be calculated for the any dimension of the container where the minimum distance from the center of the activity to the center of the radiation probe is different.



d_1 =	distance from activity center to surface of container.
d_2 =	distance from activity center to surface of container plus radius of the survey meter probe.

FIGURE 34. SAMPLE SURFACE CORRECTION FACTOR DISTANCE CRITERIA

The radiation profile data showed no increase in radiation dose after testing beyond normal measurement variations. All test specimens met the regulatory requirements.

Figure 35 shows profile results pre and post testing. Figure 36 shows the source information for the pre and post testing radiation profiles for the test specimens. The various 976 Type B package specimens are listed along with the shield containers they contained, along with the amount of testing each specimen was subjected to. The data will show, save for normal measurement variations, no increase in dose post-test. All units passed.

Figure 37 shows profile results for each Model 976 Series package configuration rated to the maximum activity to be transported under that configuration. For the Model 976F package, results are included for the three different types of shield inserts which can be used in this shield container (e.g., depleted uranium, tungsten and lead). The profile results in Figure 37 demonstrate compliance with package survey requirements of 10 CFR. 71.47.

Radiation profiles were obtained using either an AN/PDR-27T, sn SM392401 or an ND-500P sn 42363, or sn 42365. Both instruments have Geiger-Mueller detectors that meet the requirements of ANSI N432-1980.

976 Type B Package Model and Capacity	Shield Model	Used in Test Specimen	Testing Endured	PRE-TEST @ SURFACE (millirem/hour) PRE-TEST @ 1 m (millirem/hour)						Post-TEST @ SURFACE (millirem/hour) Post-TEST @ 1 m (millirem/hour)					
				TOP	RIGNT	FRONT	LEFT	REAR	BOTTOM	TOP	RIGNT	FRONT	LEFT	REAR	BOTTOM
Profile Sheet Identification for 976 Configuration following:				855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan Report 90 and Pre-Test Results under Test Plan Report 163 (855 Serial Number 8)						855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan Report 163 (855 Serial Number 8)					
976A (1000 Ci)	Model 855 Sn # 8[2] (1,000 Ci)	TP163(A)	Hypothetical Accident Conditions: (1) 30-ft Drops (1) Puncture Drop	141	38	32	32	38	62	179	33	37	40	40	83
				1.9	0.3	0.3	0.3	0.3	0.6	2.1	0.6	0.6	0.6	0.6	2.9
Profile Sheet Identification for 976 Configuration following:				855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan Report 90 and Pre-Test Results under Test Plan Report 163 (855 Serial Number 9)						855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan Report 163 (855 Serial Number 9)					
976A (1000 Ci)	Model 855 Sn # 9[1] (1,000 Ci)	TP163(B)	Hypothetical Accident Conditions: (1) 30-ft Drops (2) Puncture Drops	141	32	32	32	38	75	179	43	37	37	46	83
				1.9	0.3	0.3	0.3	0.3	0.8	2.8	0.6	0.6	0.6	0.6	1.1
Profile Sheet Identification for 976 Configuration following:				976F (1911 w/Depleted Uranium Insert Device Capacity Profile with 976 drum/cork overpack) Performed Before Testing Under Test Plan 163 – Test Specimen TP163(C)						976F (1911 w/Depleted Uranium Insert Device Capacity Profile with 976 drum/cork overpack) Performed After Testing Under Test Plan 163 – Test Specimen TP163(C)					
976F (1,000 Ci)	Model 1911 Sn # 013 (1,000 Ci)	TP163©	Hypothetical Accident Conditions: (2) 30-ft Drops (1) Puncture Drops	11	49	47	47	48	18	9	43	44	43	44	21
				0.7	1.1	1.1	1.1	1.1	0.7	0.6	1.5	1.5	1.5	1.5	0.6

[1] - Model 855 shields, Sn 8 and 9 were profiled outside of the 976 overpack assembly (drum and cork) during the profiles.

FIGURE 35. TABLE OF PACKAGE RADIATION PROFILES

976 Type B Package Model and Capacity	Shield Model	Used in Test Specimen	Pre-Testing Radiation Profile Sources[1,2,3]		Post-Testing Radiation Profile Sources[1,2,3]	
976A (1,000 Ci)	Model 855 Sn # 8	TP163(A)	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 914.4 Ci on 29 Apr 02. Source serial numbers and individual activities as follows:		Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 895.4 Ci on 12 Nov 04. Source serial numbers and individual activities as follows:	
			Source Serial Number	Source Activity (Ci)	Source Serial Number	Source Activity (Ci)
			04256B	114.5	18098B	112.9
			04257B	114.5	18097B	111.4
			04258B	114.3	18094B	108.8
			04259B	116.4	18093B	111.3
			04260B	116.7	18090B	116.3
			04261B	117.2	18091B	117.3
			04262B	110.7	18096B	108.4
			04263B	110.1	18092B	109.0
976A (1,000 Ci)	Model 855 Sn # 9	TP163(B)	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 914.4 Ci on 29 Apr 02. Source serial numbers and individual activities as follows:		Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 895.4 Ci on 12 Nov 04. Source serial numbers and individual activities as follows:	
			Source Serial Number	Source Activity (Ci)	Source Serial Number	Source Activity (Ci)
			04256B	114.5	18098B	112.9
			04257B	114.5	18097B	111.4
			04258B	114.3	18094B	108.8
			04259B	116.4	18093B	111.3
			04260B	116.7	18090B	116.3
			04261B	117.2	18091B	117.3
			04262B	110.7	18096B	108.4
			04263B	110.1	18092B	109.0
976F (1,000 Ci)	Model 1911 Sn #013	TP163(C)	Seven Model 87555 Sources. Total activity of all seven sources equaled 761.0 Ci on 19 Jul 04. Source serial numbers and individual activities as follows:		Seven Model 87555 Sources. Total activity of all seven sources equaled 826.8 Ci on 16 Nov 04. Source serial numbers and individual activities as follows:	
			Source Serial Number	Source Activity (Ci)	Source Serial Number	Source Activity (Ci)
			5686SB	108.2	6650SB	117.7
			5693SB	108.9	6663SB	116.5
			5688SB	108.6	6651SB	116.8
			5689SB	108.8	6669SB	118.0
			5690SB	109.4	6668SB	117.7
			5691SB	108.5	6666SB	121.6
			5692SB	108.6	6664SB	118.5

[1]Decay of Ir-192 calculated based on $A_t = A_0 e^{-(0.693/74\ d)\ t}$ where t = time in days since initial activity. This equates to a decay rate of 1% per day.

[2]The Model 424-9 radioactive source assemblies comply with the specifications of drawing R42409 Rev C. The Model 87555 source capsules comply with the specifications of drawing 87555 Rev D. The Ir-192 in the sources is a metal.

[3] Model 855 shields, Sn 8 and 9 were profiled outside of the 976 overpack assembly (drum and cork) during the profiles.

[4] The Model 87555 sources in the Model 1911 shield container were placed loosely into the shield insert cavity. This is representative of the loading configuration for this container and as was seen in Figure 32, radiation dose rates when loaded to capacity are 25% or less than the transportation limits in 10 CFR 71.47.

FIGURE 36. TABLE OF RADIATION SOURCES USED IN PROFILES

976 Type B Package Model and Capacity	Shield Model	Profile Sheet Identification	Radiation Profile Sources[1,2]	Capacity Results @ SURFACE (millirem/hour)[1] Capacity Results @ 1 m (millirem/hour)					
				TOP	RIGNT	FRONT	LEFT	REAR	BOTTOM
976A (1000 Ci)	Model 855 Sn # 9	976A (855 Device Profile with 976 drum/cork overpack)	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 874.3 Ci on 30 Jan 02. Source serial numbers and individual activities as specified on the referenced profile sheet.	29	9	7	6	10	22
				1.1	0.3	0.2	0.2	0.3	0.5
976B (350 Ci)	Model 3015 Sn # P500/2128	976B (3015 Device Capacity Profile with 976 drum/cork overpack)	Three Model 87555 Source Capsules. Total activity of all three sources equaled 336.1 Ci on 04 Mar 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	11	186	186	186	186	60
				0.5	6.2	6.7	6.2	5.7	1.4
976C (800 Ci)	Model 3056 Sn #P0745-060	976C (3056 Device Capacity Profile with 976 drum/cork overpack) – Performed Prior to Testing under Test Plan 90 – Test Specimen TP90G	Eight Model 424-9 Source Wire Assemblies. Total activity of all eight sources equaled 874.3 Ci on 30 Jan 02. Source serial numbers and individual activities as specified on the referenced profile sheet.	72	93	65	56	93	182
				3.7	3.3	2.2	1.9	3.1	3.5
976D (500 Ci)	Model 3018 Sn #P500/2057	976D (3018 Device Capacity Profile With 976 drum/cork overpack)	Three Model 424-9 Source Wire Assemblies. Total activity of all three sources equaled 331.6 Ci on 26 Feb 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	45	151	134	134	134	191
				1.5	3.6	3.5	3.6	3.6	3.6
976E (1,000 Ci)	Model 3078 Sn #3078.04	976E (3078 Device Capacity Profile with 976 drum/cork overpack)	Nine Model 87555 Source Capsules. Total activity of all nine sources equaled 1,025 Ci on 03 Mar 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	63	15	15	15	15	18
				6.4	0.5	0.5	0.5	0.5	0.5
976F (1,000 Ci)	Model 1911 Sn #013 with depleted uranium insert	976F (1911 w/Depleted Uranium Insert Device Capacity Profile with 976 drum/cork overpack) Performed Before Testing Under Test Plan 163 – Test Specimen TP163(C)	Seven Model 87555 Sources. Total activity of all seven sources equaled 761.0 Ci on 19 Jul 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	11	49	47	47	48	18
				0.7	1.1	1.1	1.1	1.1	0.7
976F (1,000 Ci)	Model 1911 Sn #013 with tungsten insert	976F (1911 w/Tungsten Insert Device Capacity Profile with 976 drum/cork overpack)	Seven Model 87555 Sources. Total activity of all seven sources equaled 791.1 Ci on 06 Dec 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	63	62	59	59	60	42
				4.5	2.0	2.1	2.3	2.0	1.3
976F (1,000 Ci)	Model 1911 Sn #013 with lead insert	976F (1911 w/Lead Insert Device Capacity Profile with 976 drum/cork overpack)	Three Model 87555 Sources. Total activity of all three sources equaled 349.2Ci on 17 Nov 04. Source serial numbers and individual activities as specified on the referenced profile sheet.	73	127	127	127	127	112
				3.4	5.2	5.2	5.2	5.2	3.4

[1]Decay of Ir-192 calculated based on $A_t = A_0 e^{-(0.693/74\ d)\, t}$ where t = time in days since initial activity. This equates to a decay rate of 1% per day.
[2]The Model 424-9 radioactive source assemblies comply with the specifications of drawing R42409 Rev C where the Model 87501 capsule assembly contains Ir-192 as a metal. The Model 87555 radioactive capsules comply with the specifications of drawing 875 Inner Rev A where the Model 87555 capsules contain Ir-192 as a metal.
[3] The Model 87555 sources in the Model 1911 shield container were placed loosely into the shield insert cavity. This is representative of the loading configuration for this container. Radiation dose rates when loaded to capacity are 65% or less than the transportation limits in 10 CFR 71.47

FIGURE 37. TABLE OF 976 SERIES CONFIGURATION CAPACITY PROFILES

Section 7. Summary and Conclusions

The package performed very well in all testing. None of the test orientations inflicted even minor damage to the shield containers within the drum assemblies. All test specimens retained the sources and passed final profile.

The results of test specimens TP163(A) and TP163(B) were not in agreement with the results demonstrated by Lawrence Livermore National Laboratory (NUREG/CR-6818; UCRL-ID-149067). In our testing, the lid clamp band was only able to be removed from the drum when the maximum impact energy was located with the center of gravity above the impact point (e.g. the drum at a 45° orientation). In the Lawrence Livermore National Laboratory testing, the lid clamp band was most likely to separate from a drum at shallow impact angles due to the differences in deformation between the lid clamp band and the drum.

Since test specimen TP163(C) contained a smaller shield container surrounded by more cork, it was theorized that the additional drum deformation allowed by the thicker cork liner might allow the lid clamp band to separate from the drum. In actual testing, the lid clamp band remained intact and the bolts which secured the lid to the drum body remained intact as well.

The reason for the discrepancy between our results and those obtained by Lawrence Livermore appears to be that our drum deformed less than those tested by Lawrence Livermore. This may be due to differences in cork density, drum strength, and/or the increased rigidity created by the interface between our four (4) lid closure bolts, the welded lid blocks and the drum wall.

The shield containers Models 855 and 1911 were obtained from the population of our existing shipment fleet, providing worst case scenarios. All passed testing without damage. Each test specimen could be returned to field service without repair or modification.

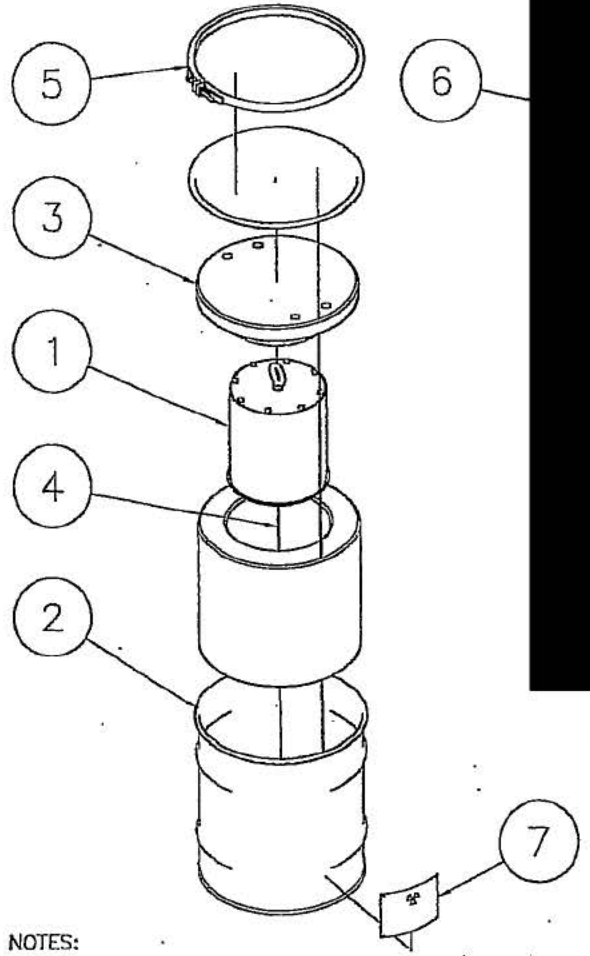
The Model 976 packaging was assessed for compliance to the Type A requirements of 10 CFR 71 and IAEA TS-R-1. This assessment is included in Appendix G.

From the test data, and the analysis contained within this report, we conclude that the Model 976 with shield Model 855, Model 3056, Model 3015, Model 3018, Model 3078 or Model 1911 (all three insert variations):

1. Complies with the requirements for the Normal Conditions of Transport.
2. Complies with the requirements for the Hypothetical Accident Conditions of Transport.

Section 8. APPENDIX A – DRAWINGS

5	4	3	2	1



[redacted]

PROTOTYPE

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS

ENG SPF DATE 21 OCT 2004

20046-LID

ITEM · NO.	DRWNG NO.	QTY.	DESCRIPTION
8	SCR 303	4	SCREW, SS
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	~~R97608~~	1	20 GAL, 16GA SS BARREL
1	R85590	1	MODEL 855 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75−1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT − 300 lbs.

APPROVALS	DATE

AEA TECHNOLOGY QSA

40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

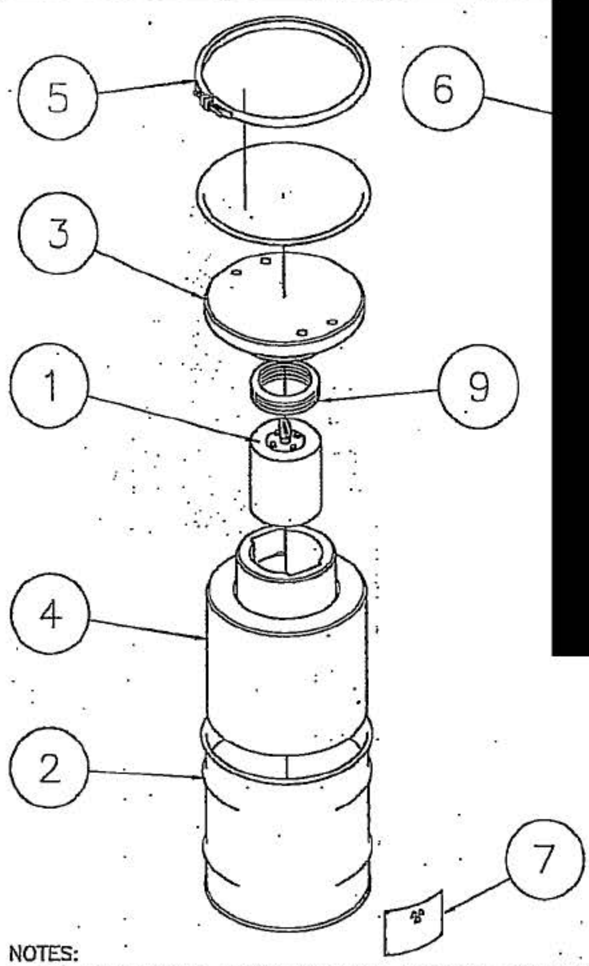
TITLE 976A TYPE B PACKAGE WITH 855 SHIELD CONTAINER

ERF# 843

SIZE B | DWG. NO. R976A | REV 1

SCALE: NONE | SHEET 1 OF 1

5	4	3	2	1



[redacted]

B

PROTOTYPE

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS

ENG. SPF DATE 21 OCT 2004

ITEM NO.	DRWNG NO.	QTY.	DESCRIPTION
10	SCR303	4	SCREW, SS
9	R97637	~~4~~ 2	TOP INNER CORK SPACER
8	R97623A	1	BOTTOM INNER CORK INSERT
7	NA	1	STEEL FIREPROOF TYPE B LABEL
6	NA	1	SEAL WIRE
5	RCLM009	1	CLAMP, SS BAND
4	R97616	1	BOTTOM OUTER CORK INSERT
3	R97615	1	TOP OUTER CORK INSERT
2	20046_LID	1	20 GAL, 16GA SS BARREL
1	R20046M	1	MODEL 1911 SHIELD CONTAINER

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS WELDING CODE OR EQUIVALENT INTERNATIONAL STANDARD CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. TORQUE CLAMP BOLT TO 10FT*LBS (+2/−0). THIS IS EQUIVALENT TO A .75–1.25" GAP BETWEEN THE CLAMP BAND SIDES.
4. MAXIMUM PACKAGE WEIGHT − 300 lbs.

APPROVALS	DATE

AEA TECHNOLOGY QSA
10 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

ERF# 843

TITLE 976F TYPE B PACKAGE WITH 1911 SHIELD CONTAINER

SIZE B | DWG. NO. R976F | REV 1

SCALE: NONE | SHEET 1 OF 1

REVISIONS			
EV.	ERF #	DESCRIPTION	APPROVALS	DATE
1	843	INITIAL RELEASE	SEE TITLE BLOCK	

[redacted]

PROCESS IN ACCORDANCE WITH
ENGINEERING INSTRUCTIONS

ENG [illegible] DATE [illegible]

ATERIALS: ST. STEEL

ROTECTIVE FINISH:

NLESS OTHERWISE SPECIFIED;
DIMENSIONS ARE IN INCHES.
MIN SURFACE TEXTURE: 63
DIMENSIONS APPLY AFTER FINISH.
REMOVE BURRS AND SHARP EDGES.
DO NOT SCALE DRAWING.
TOLERANCES: .X ± 0.1
FRACTIONS ± 1/64 .XX ± 0.01
ANGLES ± 1° .XXX ± 0.005

DRAWN	
CHECKED	NA
APPR.	

THIRD ANGLE PROJECTION

QUALITY CLASS NA

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODIFIED LID FOR 1911

SIZE A DWG. NO. 20046_LID REV 1

SCALE: NTS SHEET 1 OF 1

		REVISIONS		
V.	ERF #	DESCRIPTION	APPROVALS	DATE
	843	INITIAL RELEASE	SEE TITLE	BLOCK

[redacted]

:RIALS: PER DWG 97608 REV.A

TECTIVE FINISH:

ESS OTHERWISE SPECIFIED;
ENSIONS ARE IN INCHES.
SURFACE TEXTURE: 63
ENSIONS APPLY AFTER FINISH.
IOVE BURRS AND SHARP EDGES.
NOT SCALE DRAWING.
ERANCES: .X ± 0.1
CTIONS ± 1/64 .XX ± 0.01
LES ± 1° .XXX ± 0.005

DRAWN		
CHECKED	NA	
APPR.		

THIRD ANGLE PROJECTION

QUALITY CLASS NA

AEA TECHNOLOGY QSA

40 NORTH AVE, BURLINGTON, MA 01803

TITLE: MODIFIED DRUM MODEL 1911

SIZE	DWG. NO.	REV
A	20046_DRUM	1

SCALE: NTS SHEET 1 OF 1

REVISIONS				
EV.	ECO/TGR #	DESCRIPTION	APPROVALS	DATE
\	843	INITIAL RELEASE	SEE TITLE	BLOCK

[redacted]

[redacted]

TERIALS: SEE NOTES.

OTECTIVE FINISH: CLEAN

ILESS OTHERWISE SPECIFIED;
IMENSIONS ARE IN INCHES.
IIN SURFACE TEXTURE: 125
OLERANCES APPLY AFTER PLATING.
EMOVE BURRS AND SHARP EDGES.
O NOT SCALE DRAWING.
OLERANCES: .X ± 0.1
RACTIONS ± 1/64 .XX ± 0.01
ACHINED ANGLES ± 1° .XXX ± 0.005

USED ON: 1911

DRAWN		
CHECKED		
APPR.		

THIRD ANGLE

SAFETY CLASS C

AEA TECHNOLOGY QSA

40 NORTH AVE, BURLINGTON, MA 01803

TITLE: HEX HEAD BOLT, SS 3/8-16 3/4 LG

SIZE	DWG. NO.	REV
A	SCR303	A

[redacted]

NOTES:
1. ALL PERSONNEL QUALIFICATIONS, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE AWS STRUCTURAL WELDING CODE (OR EQUIVALENT INTERNATIONAL STANDARDS) CURRENT AT THE TIME OF FABRICATION AND INSPECTION.
2. NOTES APPLY TO ALL PAGES.
3. SEE SHEET 2 of 2 FOR DETAILS OF ITEMS 1,3,4 AND 5.

ITEM	QTY.	DESCRIPTION

APPROVALS	DATE
[illegible]	9Mar04
[illegible]	9Mar04

UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

ERF# 809

AEATECHNOLOGY
QSA
40 NORTH AVE. BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE CLAMP, BAND

SIZE	DWG. NO.	REV
B	RCLM009	B

SCALE: NA | SHEET 1 OF 2

[redacted]

AEA TECHNOLOGY QSA 40 NORTH AVE, BURLINGTON, MA 01803	DESCRIPTIVE DRAWING	
TITLE	CLAMP, BAND	
SIZE B	DWG. NO. RCLM009	REV B
	SCALE: NA	SHEET 2 OF 2

A

1

[redacted]

NOTES:
1. MATERIAL: 16 GAUGE (.06) STAINLESS STEEL.

APPROVALS	DATE
[illegible]	[illegible]
C. [illegible]	[illegible]

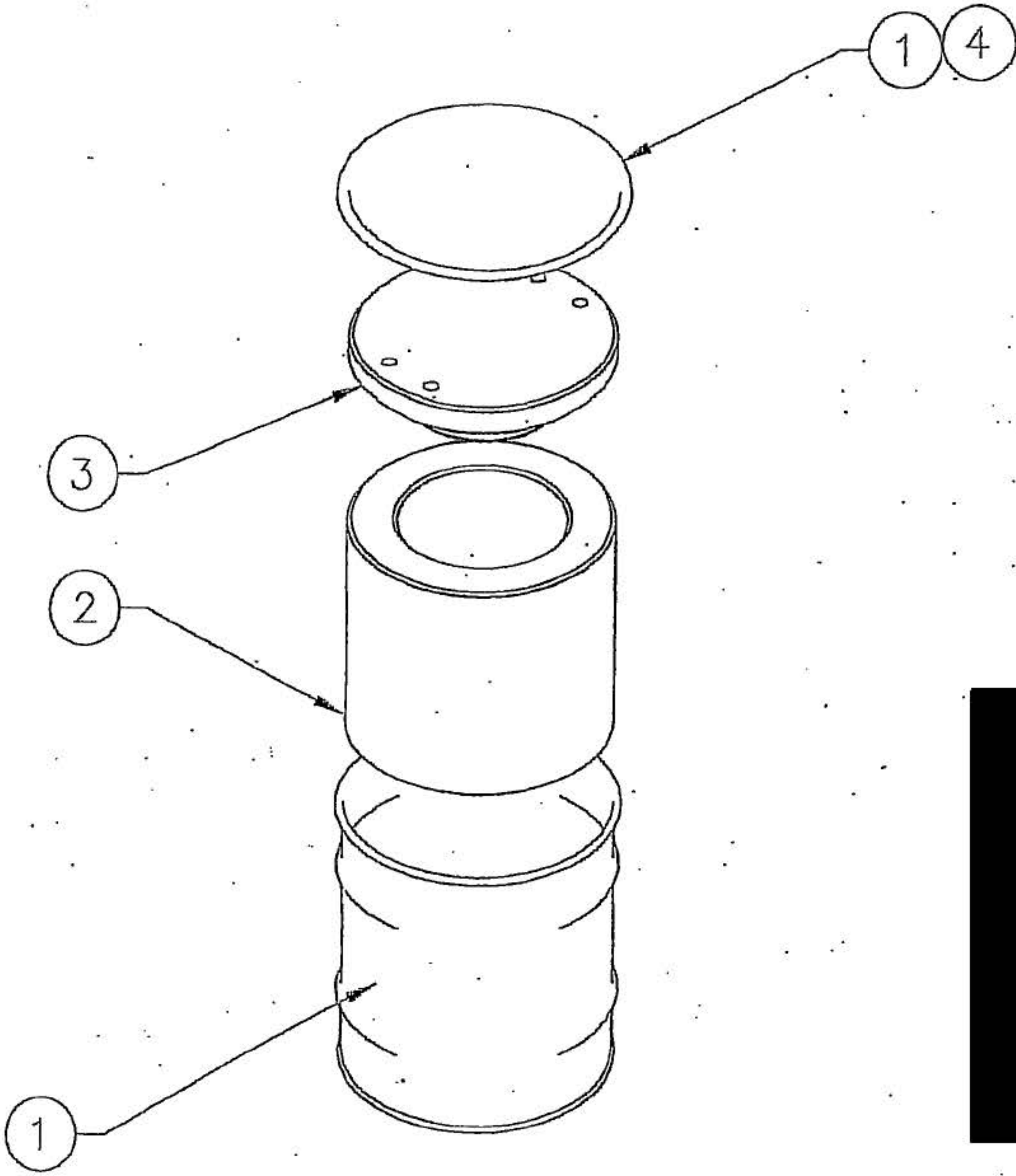
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/2
X.X ± 0.12
X.XX ± 0.05
X.XXX ± 0.020

AEATECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE: 20 GALLON DRUM MODEL 976

ERF#	SIZE	DWG. NO.	SCALE	SHEET	REV
809	B	R97608	NONE	1 OF 1	B



[redacted]

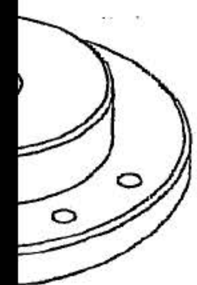
AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE	OVERPACK ASSY, MODEL 855			
SIZE	DWG. NO. R97610			REV
A	SCALE: NONE	SHEET 1 OF 1		A

DDCO 41	INITIAL RELEASE	LR/ [illegible]	20 OCT 99	A
	DESCRIPTION	APPROVALS	DATE	LTR
	REVISIONS			

[redacted]



UREAFORMALDEHYDE RESIN
BINDER, DENSITY
17±2 LBS./CU FT

DESCRIPTION

APPROVALS	DATE
NKlazoulo	9MAL04
C. Kolfridy	9MAR04

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

AEATECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

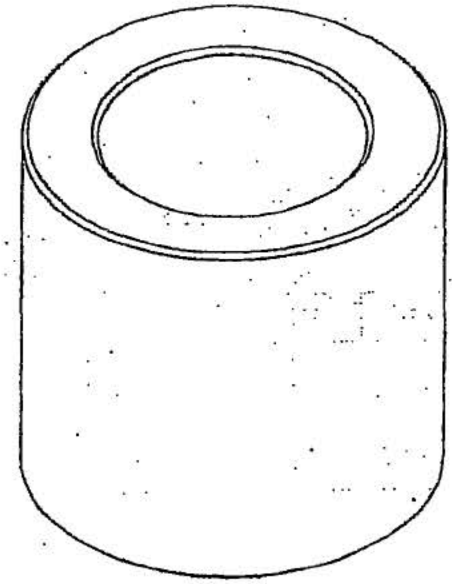
DESCRIPTIVE DRAWING

TITLE TOP OUTER CORK INSERT

ERF #	808

SIZE	DWG. NO.		REV
A	R97615		B
	SCALE: NONE	SHEET 1 OF 1	

[redacted]



CORK		UREA FORMALDEHYDE RESIN BINDER, DENSITY 17±2 LBS./CU FT
PART NAME	QTY.	DESCRIPTION

ROVALS | DATE

SS OTHERWISE SPECIFIED
NSIONS IN INCHES
RANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

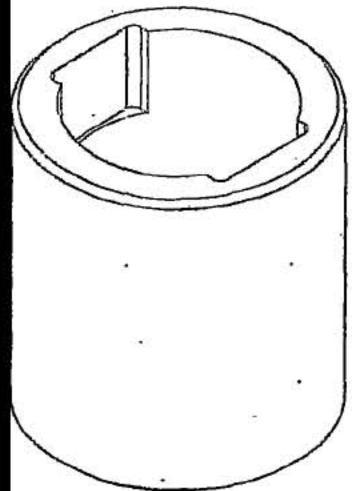
TITLE
BOTTOM OUTER CORK INSERT

SIZE	DWG. NO.	REV
A	R97616	B
	SCALE: NONE — SHEET 1 OF 1	

ERF # 808

1	843	INITIAL RELEASE	SEE TITLE	BLOCK

[redacted]



NOTES:
1. FOR INSPECTION OF INSERT USE A FUNCTION FIT TEST.

PROTOTYPE

PROCESS IN ACCORDANCE WITH ENGINEERING INSTRUCTIONS

ENG [signature] DATE 6/22/04

MATERIALS: SEE DWG.97623

PROTECTIVE FINISH: NONE

UNLESS OTHERWISE SPECIFIED;
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE 125
3. TOLERANCES APPLY AFTER PLATING.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: FRACTIONS ± 1/64, MACHINED ANGLES ± 1°, .X ± 0.1, .XX ± 0.01, .XXX ± 0.005

USED ON: NA

DRAWN

CHECKED

APPR.

THIRD ANGLE PROJECTION

SAFETY CLASS B

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: BOTTOM CORK INSERT, MODEL 911

SIZE B | DWG. NO. 97623A | REV 1

SCALE: 1:4 | SHEET 1 OF 1

D C B A

5 4 3 2 1

D

B

A

[redacted]TERIAL: CORK
UREA FORMALDEHYDE
RESIN BINDER
DENSITY – 17±2 LBS./ CU. FT.

APPROVALS	DATE
[illegible]	9 MAR 04
C. [illegible]	4 mar 04

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
XX ± 0.12
X.XX ± 0.08
X.XXX ± 0.020

AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE BOTTOM INNER CORK INSERT

SIZE	DWG. NO.	REV
B	R97623	A

SCALE: NONE SHEET 1 OF 1

808

5 4 3 2 1

[redacted]

MATERIAL; CORK, UREA FORMALDEHYDE RESIN
DENSITY — 17±2 LBS./CU. FT.

APPROVALS	DATE
[illegible]	9MAR04
C. [illegible]	9mar04

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

ERF# 808

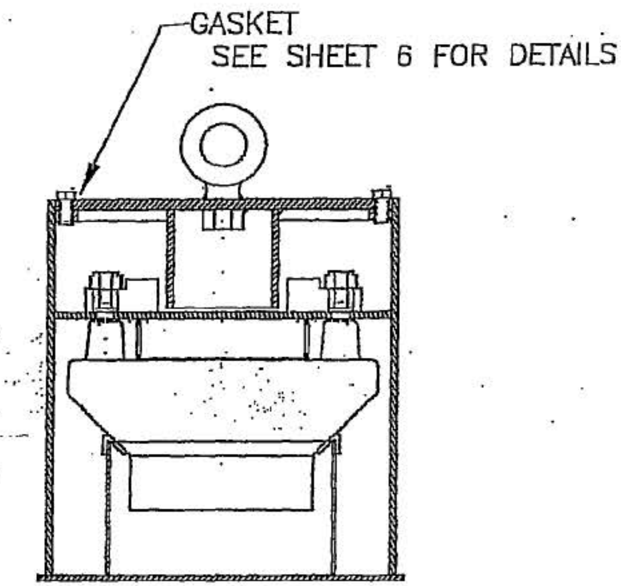
AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE CORK SPACER TOP INNER

SIZE	DWG. NO.	REV
B	R97637	A
	SCALE: NONE SHEET 1 OF 1	

[redacted]



PART NAME	QTY	MATERIAL	DESCRIPTION
HOUSING WELDMENT	1	SEE SHEET #3	SEE SHEET #3
COVER	1	SEE SHEET #2	SEE SHEET #2
EYEBOLT	1	SEE SHEET #2	SEE SHEET #2
NAMEPLATE	1	STAIN. STEEL	
RIVET	4	STAIN. STEEL	1/8 D POP RIVET
COVER SCREW	8	STAIN. STEEL	3/8–16 x3/4 LG

2. ALL PERSONNEL QUALIFICATION, WELDING AND EXAMINATION PROCEDURES ARE IN ACCORDANCE WITH THE REQUIREMENTS OF THE WELDING CODE CURRENT AT THE TIME OF FABRICATION AND INSPECTION. NEW FABRICATIONS WILL BE IN ACCORDANCE WITH THE AWS WELDING CODE.

ERF #	798

APPROVALS	
[illegible]	[illegible]
C. [illegible]	[illegible]

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 855 SOURCE CHANGER

SIZE	DWG. NO.		REV
A	R85590		C
	SCALE: NONE	SHEET 1 OF 6	

[redacted]

BURLINGTON, MA 01803

DESCRIPTIVE
DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

ERF #	798		
TITLE	MODEL 855 SOURCE CHANGER		
SIZE	DWG. NO. R85590		REV
A	SCALE: NONE	SHEET 2 OF 6	C

[redacted]

AEA TECHNOLOGY
QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE	MODEL 855 SOURCE CHANGER		
SIZE A	DWG. NO. R85590		REV C
	SCALE: NONE	SHEET 3 OF 6	

[redacted]

SHIELD

STANDARD
LOCK ASSEMBLY

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE
DRAWING

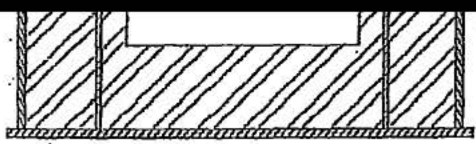
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

ERF #	798

TITLE MODEL 855 SOURCE CHANGER

SIZE	DWG. NO. R85590		REV
A	SCALE: NONE	SHEET 4 OF 6	C

[redacted]



AEATECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

ERF #	798	DIMENSIONS IN INCHES TOLERANCES: FRACTIONS ±1/8 X ± 0.1 XX ± 0.05 XXX ± 0.005	TITLE MODEL 855 SOURCE CHANGER SIZE A	DWG. NO. R85590	REV C SCALE: NONE	SHEET 5 OF 6

[redacted]

AEA TECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/8
X ± 0.1
XX ± 0.05
XXX ± 0.005

ERF #	798

TITLE MODEL 855 SOURCE CHANGER

SIZE	DWG. NO.	R85590		REV
A	SCALE: NONE		SHEET 6 OF 6	C

[redacted]

D

C

B

A

MATERIALS: SEE BOM

PROTECTIVE FINISH:

UNLESS OTHERWISE SPECIFIED;
1. DIMENSIONS ARE IN INCHES.
2. MIN SURFACE TEXTURE: 63
3. DIMENSIONS APPLY AFTER FINISH.
4. REMOVE BURRS AND SHARP EDGES.
5. DO NOT SCALE DRAWING.
6. TOLERANCES: .X ± 0.1
FRACTIONS ± 1/64 .XX ± 0.01
ANGLES ± 1° .XXX ± 0.005

DRAWN		
CHECKED		
APPR.		

THIRD ANGLE PROJECTION

QUALITY CLASS A

AEATECHNOLOGY QSA
40 NORTH AVE, BURLINGTON, MA 01803

TITLE: LEAD POT DESIGN 1911 IN ST.ST. JACKET

SIZE B | DWG. NO. 20046M | REV A

SCALE: NTS | SHEET 1 OF 1

5 4 3 2 1

AEA TECHNOLOGY QSA

FORM E001 Rev B

Bill of Materials

Part No.: 20046M

Title: LEAD POT DESIGN 1911 IN ST ST JACK

Rev.: A

Rev.	ERF	Date	Ckd	Appvd	Rev.	ERF	Date	Ckd	Appvd	Rev.	ERF	Date	Ckd	Appvd
1	843													

Item	Qty	P/N	Description
1	1	A21042	LEAD POT DESIGN 1911
2	1	20046-3	JACKET BODY
3	1	20046-2	JACKET TOP PLATE
4	1	20046-1	JACKET BOTTOM PLATE

REVISIONS				
EV.	ERF. #	DESCRIPTION	APPROVALS	DATE
1	843	INITIAL RELEASE	SEE TITLE	BLOCK

[redacted]

ATERIALS: DU, steel encased

ROTECTIVE FINISH: 20 oct 14

AEATECHNOLOGY QSA

40 NORTH AVE, BURLINGTON, MA 01803

JNLESS OTHERWISE SPECIFIED;
DIMENSIONS ARE IN INCHES.
MIN SURFACE TEXTURE: 63
DIMENSIONS APPLY AFTER FINISH.
REMOVE BURRS AND SHARP EDGES.
DO NOT SCALE DRAWING.
TOLERANCES: .X ± 0.1
FRACTIONS ± 1/64 .XX ± 0.01
ANGLES ± 1° .XXX ± 0.005

DRAWN		
CHECKED		
APPR.		

THIRD ANGLE

QUALITY CLASS A

TITLE: DU INSERT PLUG
MODEL 1911

SIZE	DWG. NO.	REV
A	20046-10	1

		REVISIONS		
EV.	ERF #	DESCRIPTION	APPROVALS	DATE
	843	INITIAL RELEASE	SEE TITLE	BLOCK

[redacted]

TERIALS: DU, Steel encased

OTECTIVE FINISH:

ILESS OTHERWISE SPECIFIED;
IMENSIONS ARE IN INCHES.
AIN SURFACE TEXTURE: 63
IMENSIONS APPLY AFTER FINISH.
EMOVE BURRS AND SHARP EDGES.
IO NOT SCALE DRAWING.
OLERANCES: .X ± 0.1
RACTIONS ± 1/64 .XX ± 0.01
NGLES ± 1° .XXX ± 0.005

DRAWN		
CHECKED		
APPR.		

THIRD ANGLE PROJECTION

QUALITY CLASS A

AEATECHNOLOGY QSA

40 NORTH AVE, BURLINGTON, MA 01803

TITLE: DU INSERT BOTTOM MODEL 1911

SIZE	DWG. NO.	REV
A	20046-11	1

[redacted]

DRAWN	RC (WHITEGATES)	APPROVAL	MATERIAL	TOLERANCES	SURFACE TEXTURE µm	FINISH	THIRD ANGLE PROJECTION	SCALE	1:1	TITLE POT INSERT ASSEMBLY	©
CHECKED		THIS DRAWING IS NOT TO BE USED FOR MANUFACTURE UNLESS SIGNED AS APPROVED	SEE ITEMS LIST			CLEAN	CONFORMS GENERALLY TO BS 308	ISSUE	A		
QA APPROVED							MODIFICATIONS INDICATED ◇	MOD No.			
QA APPROVED				ISO THREADS: 6H 6g		REMOVE ALL BURRS AND SHARP EDGES	DO NOT SCALE	DATE	26/07/04	USED ON	SHT SIZE A3
			UNLESS OTHERWISE STATED					UNITS	MM	DRG NO. JB018/001	SHT 1 OF 1

ITEM	DESCRIPTION.	MATERIAL	DRAWING NO.	QTY
1	PLUG	95% MIN. PURE LEAD	THIS	1
2	STRAP	BRASS	THIS	1
3	DEE RING	BRASS	THIS	1
4	SCREW – No.2 x 12 LG. PAN HEAD SELF TAP	STAINLESS STEEL	THIS	2

NOTE:

1 ITEMS 2 AND 3 MAY BE OBTAINED FROM:
PARKER (TOGGLES) LTD
PATCH PARK FARM
ONGAR ROAD
ROMFORD
ESSEX RM4 1AA

2 MATERIAL OF ITEMS 2 AND 3 MAY ALSO [redacted]

DRAWN	RC (WHITECATES)	APPROVAL	MATERIAL	TOLERANCES	SURFACE TEXTURE µm	FINISH	THIRD ANGLE PROJECTION	SCALE 1:1
CHECKED		THIS DRAWING IS NOT TO BE USED FOR MANUFACTURE UNLESS SIGNED AS APPROVED	SEE ITEMS LIST	X ±0.5 X.X ±0.1 X.XX ±0.05 ANGLES ±5'	NS/	CLEAN	CONFORMS GENERALLY TO BS 308	ISSUE A
QA APPROVED				ISO THREADS: 6H 5g		REMOVE ALL BURRS AND SHARP EDGES	MODIFICATIONS INDICATED ◇	MOD No.
QA APPROVED			UNLESS OTHERWISE STATED				DO NOT SCALE	DATE 26/07/04
								UNITS MM

TITLE MODIFIED PLUG

© HTSL

USED ON JB018/001 | SHT SIZE A3 | DRG NO. JB018/002 | SHT 1 OF 1

[redacted]

DRAWN	RC (WHITEGATES)	APPROVAL	MATERIAL	TOLERANCES	SURFACE TEXTURE µm	FINISH	THIRD ANGLE PROJECTION	SCALE	1:1
CHECKED		THIS DRAWING IS NOT TO BE USED FOR MANUFACTURE, UNLESS SIGNED AS APPROVED	BRASS	X ±0.5 X.X ±0.1 X.XX ±0.05 ANGLES ±5' ISO THREADS: 6H 6g	0.8/	CLEAN REMOVE ALL BURRS AND SHARP EDGES	CONFORMS GENERALLY TO BS 308	ISSUE	A
QA APPROVED							MODIFICATIONS INDICATED ◇	MOD No.	
QA APPROVED							DO NOT SCALE	DATE	26/07/04
			UNLESS OTHERWISE STATED					UNITS	MM

TITLE SOURCE HOUSING

©

USED ON JB018/001	SHT SIZE A3	DRG No. JB018/003	SHT 1 OF 1

[redacted]

DRAWN	RC (WHITEGATES)	APPROVAL	MATERIAL	TOLERANCES	SURFACE TEXTURE µm	FINISH
CHECKED		THIS DRAWING IS NOT TO BE USED FOR MANUFACTURE UNLESS SIGNED AS APPROVED	LEAD 95% MIN. PURE	X ±0.5 X.X ±0.1 X.XX ±0.05 ANGLES ±5° ISO THREADS: 6H 6g	N6/ ∇	CLEAN REMOVE ALL BURRS AND SHARP EDGES
QA APPROVED						
QA APPROVED			UNLESS OTHERWISE STATED			

THIRD ANGLE PROJECTION
CONFORMS GENERALLY TO BS 308
MODIFICATIONS INDICATED ◇
DO NOT SCALE

SCALE	1:1
ISSUE	A
MOD No.	
DATE	26/07/04
UNITS	MM

TITLE CUP

USED ON JB018/001 | SHT SIZE A3 | DRG NO. JB018/004 | SHT 1 OF 1

[redacted]

APPROVALS

[illegible]	5 May 04
[illegible]	6 May 04

DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ±1/32
X ± 0.1
XX ± 0.05
XXX ± 0.005

AEA TECHNOLOGY
QSA
40 NORTH AVE. BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE MODEL 424–9 SOURCE ASSY

SIZE	DWG. NO.	R42409		REV
A	SCALE:	NONE	SHEET 1 OF 1	C

ERF #	836

[redacted]

NOTES:

1. MATERIAL: 304L STAINLESS STEEL.
2. INTERNAL VOID VOLUME TO BE 0.010 mL OR GREATER.
3. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GUARDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL WITHIN THE CAPSULE MAY BE USED.
4. MINIMUM WALL THICKNESS TO BE 0.019.

UNLESS OTHERWISE SPECIFIED: ALL DIMENSIONS ARE REFERENCE

SENTINEL DESCRIPTIVE DRAWING

Amersham Corporation
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTION	APPROVALS	DATE	LTR
INITIAL RELEASE	[illegible] [illegible]	30 Jan '95 25 Jan 95	A

REVISIONS

TITLE 875 SERIES INNER CAPSULE

SIZE	DWG. NO.		REV
A	R 875 INNER		A
	SCALE: NONE	SHEET 1 OF 1	

Section 9. APPENDIX B – TEST DATA SHEETS

Checklist 0: Specimen *Preparation and Inspection*

Step	TP163(A)	TP163(B)	TP163(C)
1. Record serial number of shield container.	855 SN 8	855 SN 9	1911 SN 013
2. Record serial number of the simulated source(s) 855 SOURCES: CONNECTOR GROOVES INLAND DIMENSIONS FROM TOP OF FUNNEL OUTSIDE OF SOURCE TO TOP OF SOURCE CONNECTOR	8-1 .801 .798 8-2 .746 .746 8-3 .736 .739 8-4 .664 .666 8-5 .785 .791 8-6 .743 .738 8-7 .732 .727 8-8 .745 .747	9-1 .742 .740 9-2 .708 .711 9-3 .777 .777 9-4 .823 .835 9-5 .764 .770 9-6 .741 .747 9-7 .718 .725 9-8 .791 .794	1 2
3. Record shield container weight.	204 lbs	206 lbs	168 lbs
4. Record overpack weight.	74 lbs	74 lbs	79 lbs
5. Record added lead weight.	20 lbs	20 lbs	16 lbs
6. Record total package weight.	298 lbs	300 lbs	263 lbs
7. Are all fabrication and inspection records documented in accordance with the AEAT Q.A. Program (at the time of manufacture)?	YES	YES	YES
8. Does the test unit comply with the requirements of Drawing?	YES	YES	YES
9. Has the radiation profile been recorded in accordance with AEA TECHNOLOGY QSA INC. Standard practice method?	YES	YES	YES
10. Is the package prepared for transport?	YES	YES	YES

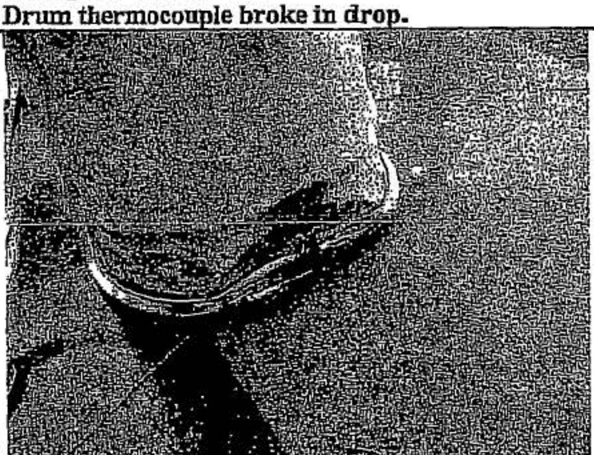
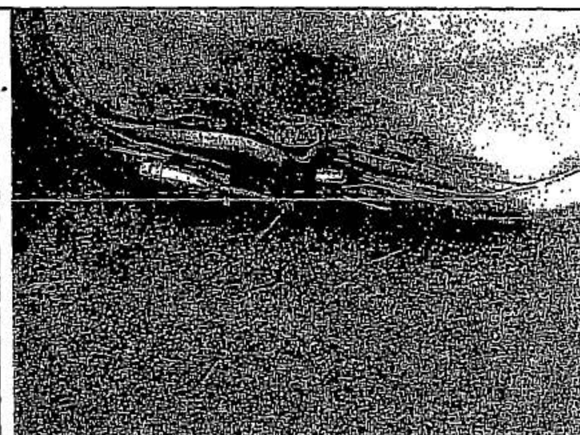
Witnessed and verified by:		Print Name:	Date:
Engineering:	Stephen Forte	STEPHEN FORASTÉ	21 OCT 2004
Regulatory Affairs:	L. P. [illegible]	LORI PODOLAK	21 Oct 04
Q.A.:	C. Roughan	Cathleen Roughan	21 Oct 04

Equipment List 1:*9 m (30 foot) Drop Test Equipment List*

Description	Model Number	Serial Number
1. Scale	DULM IV CAP. 5000#	F116383
2. THERMOCOUPLE METER	OMEGA	ENG-12
3. TORQUE WRENCH (0-20 FT/LBS), 0-250 INCH/LBS	WILLIAMS BTW-1RC	A 202579 SN 182
4.		
5.		
Signature	Print Name	Date
Completed by: Stephen Forte	STEPHEN FORTE	11 JAN 2005

Checklist 1: *9 m (30 foot) Drop Test*

Step	**Test Specimen TP163(A)**	
1. Chill the test specimen to a temperature at or below -40°C.		
2. Measure and record the ambient temperature.	11°C (52°F)	
3. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.6.2.1	
4. Record thermocouple readings: **The outer drum thermocouple reading was above -40°C prior to the drop test. Due to the thin material thickness of the steel it was not possible to keep the outer drum at or below -40°C. The drum, lid clamp and drum bolt components are manufactured from stainless steel (plus a brass component in the lid clamp). These materials are not susceptible to brittle fracture at cold temperatures, therefore the drum temperature above -40°C will not adversely affect the test results.**	Drum: **-23°C**	Shield Container: **-80.6°C**
5. Release the test specimen.		
6. Record any damage to the test specimen. **The drum impacted as intended onto the clamp ring bolt directly above a side bolt. The bolt on the clamp ring broke on impact. The drum lid and bottom rim were crimped together and deformed inward slightly on impact. The drum side bolts were intact. Minor scuffing and flattening of the drum side impacted. Drum thermocouple broke in drop.**		

7. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test to achieve maximum damage.		
Test witnessed by: Signature	Print Name	Date
Engineering: Stephen Forasté	STEPHEN FORASTÉ	11 JAN 2005
Regulatory Affairs: L. Podolak	LORI PODOLAK	22 oct 04
Quality Assurance: J. Beauchamp	JERRY BEAUCHAMP	11 Jan 05

Data Sheet 1: *9 m (30 ft) Drop Test*

Test Unit Model and Serial Number: **855 serial number 8**		Test Specimen No.: **TP163(A)**
Test Date: **22 Oct 04**	Test Time: **~12:15 pm**	Test Location: **Valley Tree, Groveland, MA**

Describe set up:

Package oriented as described in Test Plan. Package orientation 45.5° angle. Impact on lid side. Impact on clamp ring bolt. Clamp ring bolt oriented above lid bolt on the side of the drum marked "Left".

On-site assessment:

The bolt on the clamp ring broke on impact. The drum lid and bottom rim were crimped together and deformed inward slightly on impact. The drum side bolts were intact. Minor scuffing and flattening of the drum side impacted. Drum Thermocouple broke in drop.

Based on damage, determined to impact package on lid side, opposite the clamp bolt for the puncture test. Intent to force the clamp ring off the drum in puncture drop.

Engineering: S. Fote Regulatory: L. P. Lee QA: [signature]

Describe any post-test disassembly and inspection:

Not applicable, no disassembly or inspection beyond visual.

Describe any change in source position: **Not assessed. Package remained intact for Puncture test.**

Describe results of any pre- or post-test radiography: **Not applicable, no interim radiography performed.**

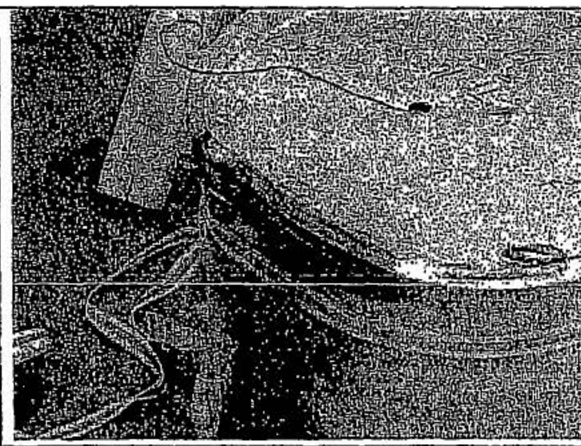
Completed by: Stephen Fote	Date: 11 JAN 2005

Checklist 2: *9 m (30 foot) Drop Test*

Step	Test Specimen TP163(B)	
1. Chill the test specimen to a temperature at or below -40°C.		
2. Measure and record the ambient temperature.	11°C (52°F)	
3. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.6.3.1	
4. Record thermocouple readings:	Drum: -76°C	Shield Container: -88°C
5. Release the test specimen.		
6. Record any damage to the test specimen.		

The drum impacted as intended 180° from clamp ring bolt directly between two of the four side bolts. The drum and clamp ring bolts were intact. Some scuffing and flattening of the drum on the side impacted. Drum Thermocouple broke in drop.

Based on damage, determined to impact package on lid side, on the clamp bolt for the puncture test. Intent to force the clamp ring off the drum in puncture drop.



7. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test to achieve maximum damage.

Test witnessed by: Signature	Print Name	Date
Engineering: S. Forte	STEPHEN FORASTE	11 JAN 2005
Regulatory Affairs: L. Podlak	LORI PODOLAK	22 oct 04
Quality Assurance: J Beauchamp	Jerry Beauchamp	11 Jan 05

Data Sheet 2: *9 m (30 ft) Drop Test*

Test Unit Model and Serial Number: **855 serial number 9**		Test Specimen No.: **TP163(B)**
Test Date: **22 Oct 04**	Test Time: : **~11:15 am**	Test Location: **Valley Tree, Groveland, MA**

Describe set up:

Package oriented as described in Test Plan. Package orientation 17.5° angle. Impact on lid side.

On-site assessment:

The drum impacted as intended. The drum and clamp ring bolts were intact. Some scuffing and flattening of the drum on the side impacted. Drum Thermocouple broke in drop.

Based on damage, determined to impact package on lid side, on the clamp bolt for the puncture test. Intent to force the clamp ring off the drum in puncture drop.

Engineering: S. Forte Regulatory: L. D. Lee QA: G. Beaudry

Describe any post-test disassembly and inspection:

Not applicable, no disassembly or inspection beyond visual.

Describe any change in source position: **Not assessed. Package remained intact for Puncture test.**

Describe results of any pre- or post-test radiography: **Not applicable, no interim radiography performed.**

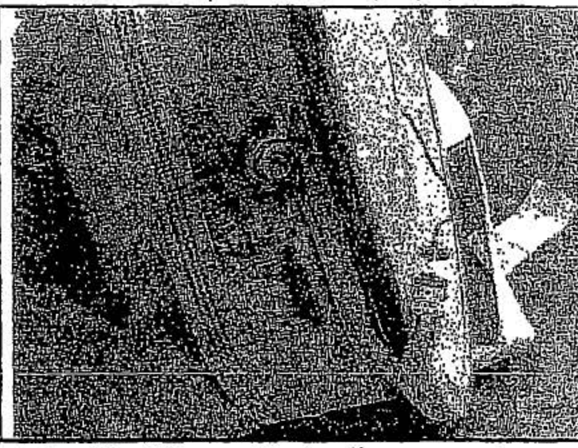
Completed by: Stephen Forte	Date: 11 JAN 2005

Checklist 3: *9 m (30 foot) Drop Test*

Step	Test Specimen TP163(C)	
1. Chill the test specimen to a temperature at or below -40°C.		
2. Measure and record the ambient temperature.	**11°C (52°F)**	
3. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.6.3.1	
4. Record thermocouple readings:	Drum: -72°C	Shield Container: -85°C
5. Release the test specimen.		

6. Record any damage to the test specimen.

The drum impacted as intended 180° from clamp ring bolt directly onto a side bolt. The drum and clamp ring bolts were intact. Some scuffing and flattening of the drum on the side impacted. Drum Thermocouple broke in drop.



7. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test to achieve maximum damage.

Test witnessed by: Signature	Print Name	Date
Engineering: S. Forte	STEPHEN FORASTE	11 JAN 2005
Regulatory Affairs: L. Podolak	LORI PODOLAK	22 Oct 04
Quality Assurance: J. Beauchamp	Jerry Beauchamp	11 Jan 05

Data Sheet 3: *9 m (30 ft) Drop Test*

Test Unit Model and Serial Number: **1911 serial number 013**		Test Specimen No.: **TP163(C)**
Test Date: **22 Oct 04**	Test Time: **~11:45 am**	Test Location: **Valley Tree, Groveland, MA**
Describe set up: **Package oriented as described in Test Plan. Package orientation 17.5° angle. Impact on lid side.**		
On-site assessment: **The drum impacted as intended. The drum and clamp ring bolts were intact. Some scuffing and flattening of the drum and clamp band on the side impacted.** **Based on damage, determined to impact package on lid side, on the clamp bolt for the puncture test. Intent to force the clamp ring off the drum in puncture drop.** Engineering: S. Forte Regulatory: L. Pohle QA: B. Beauchamp		
Describe any post-test disassembly and inspection: **Not applicable, no disassembly or inspection beyond visual.**		
Describe any change in source position: **Not assessed. Package remained intact for Puncture test.**		
Describe results of any pre- or post-test radiography: **Not applicable, no interim radiography performed.**		
Completed by: Stephen Forte		Date: 11 JAN 2005

Checklist 4: *Puncture Test*

Step	Test Specimen TP163(A)	
1. Chill the test specimen to a temperature at or below -40°C. **The outer drum thermocouple reading was not measurable prior to this test but was above -40°C based on its temperature prior to the 9 m drop test. Due to the thin material thickness of the steel it was not possible to keep the outer drum at or below -40°C. The drum, lid clamp and drum bolt components are manufactured from stainless steel (plus a brass component in the lid clamp). These materials are not susceptible to brittle fracture at cold temperatures, therefore the drum temperature above -40°C will not adversely affect the test results.**		
2. Measure and record the ambient temperature.	11°C (52°F)	
3. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	Figure 8.7.1.1	
4. Record thermocouple readings:	Drum: **Unable to Measure, thermocouple broke in 9 m drop test.**	Shield Container: **-83.3°C**
5. Start video recorder.		
6. Release the test specimen.		
7. Record any damage to the test specimen. **Upon impact the clamp ring came off the drum. The bolts holding the drum lid to the drum base remained intact and the lid remained in contact with the drum base after the drop. The shield container temperature after the drop was –82.2°C.**		

8. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.		
Test witnessed by: Signature	Print Name	Date
Engineering: Stephen Forasté	STEPHEN FORASTÉ	12 JAN 2005
Regulatory Affairs: Lori Podolak	LORI PODOLAK	22 Oct 04
Quality Assurance: J Beauchamp	Jerry Beauchamp	12 Jan 2005

Data Sheet 4: *Puncture Test*

Test Unit Model and Serial Number: **855 serial number 8**		Test Specimen No.: **TP163(A)**
Test Date: **22 Oct 04**	Test Time: **~12:30 p.m**	Test Location: **Valley Tree, Groveland, MA**

Describe set up:

Package orientation 45.5° angle. Impact on lid side opposite the clamp ring closure.

On-site assessment:

The clamp ring was removed from the drum on impact. The bolts holding the drum lid to the drum base remained intact and the lid remained in contact with the drum base after the drop. The shield container temperature after the drop was –82.2°C.

Engineering: S. Forte Regulatory: [signature] QA: K. Barwell

Describe any post-test disassembly and inspection:

The top of the drum was indented 1 ¾ inches deep by 11 ½ inches wide. The bottom of the drum was indented less, only 7 inches wide. The drum was intact without any air gap. (See TP163 Pre and Post Test Specimen and Source Measurement).

Describe any change in source position:

All of the sources remained in their original positions. The measured source movement was 0.001 inches to 0.011 inches (See TP163 Pre and Post Test Specimen and Source Measurement).

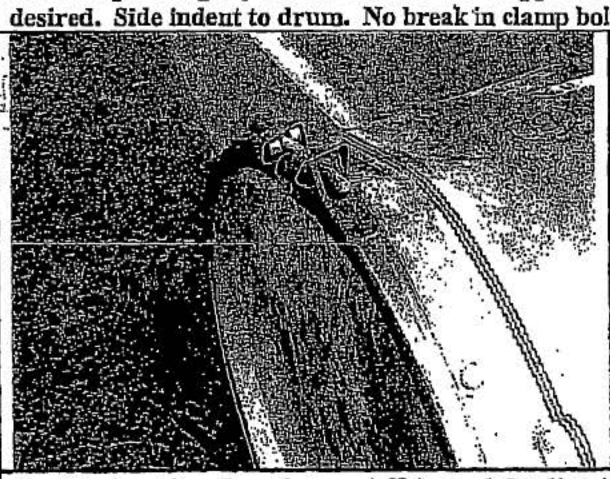
Describe results of any pre- or post-test radiography:

No radiography was performed.

Completed by: Stephen Forte	Date: 12 JAN 2005

Checklist 5: *Puncture Test*

Step	Test Specimen TP163(B)	
1. Chill the test specimen to a temperature at or below -40°C. **The outer drum thermocouple reading was not measurable prior to this test but was above -40°C based on its temperature prior to the 9 m drop test. Due to the thin material thickness of the steel it was not possible to keep the outer drum at or below -40°C. The drum, lid clamp and drum bolt components are manufactured from stainless steel (plus a brass component in the lid clamp). These materials are not susceptible to brittle fracture at cold temperatures, therefore the drum temperature above -40°C will not adversely affect the test results.**		
2. Measure and record the ambient temperature.	11°C (52°F)	
3. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	Figure 8.7.1.1	
4. Record thermocouple readings:	Drum: -15°C	Shield Container: -89°C
5. Start video recorder.		
6. Release the test specimen.		
7. Record any damage to the test specimen. **First drop hit slightly below the bolt. Re-dropped a second time, same orientation. Second drop hit as desired. Side indent to drum. No break in clamp bolt or side bolts.**		



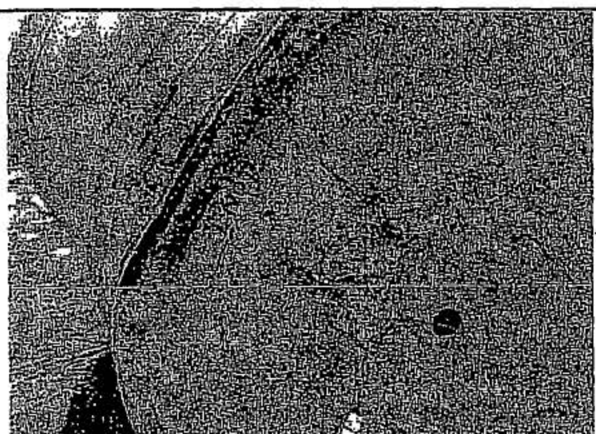
8. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.		
Test witnessed by: Signature	Print Name	Date
Engineering:	STEPHEN FAUSTE	11 JAN 2005
Regulatory Affairs:	LORI PODOLAK	22 Oct 04
Quality Assurance:	Jerry Beauchamp	11 Jan 05

Data Sheet 5: *Puncture Test*

Test Unit Model and Serial Number: **855 serial number 9**		Test Specimen No.: **TP163(B)**
Test Date: **22 Oct 04**	Test Time: **~11:30 a.m.**	Test Location: **Valley Tree, Groveland, MA**
Describe set up: **Package orientation 16° angle. Impact on lid side on the clamp ring bolt.**		
On-site assessment: **The clamp ring bolt and the bolts holding the drum lid to the drum base remained intact.** Engineering: S. Foti Regulatory: [signature] QA: [signature]		
Describe any post-test disassembly and inspection: **The top of the drum was indented ¾ inch deep by 9 inches wide. The bottom of the drum was indented similarly. The drum was intact without any air gap. (See TP163 Pre and Post Test Specimen and Source Measurement).**		
Describe any change in source position: **All of the sources remained in their original positions. The measured source movement was 0.001 inches to 0.013 inches (See TP163 Pre and Post Test Specimen and Source Measurement).**		
Describe results of any pre- or post-test radiography: **No radiography was performed.**		
Completed by: Stephen Foti		Date: 12 JAN 2005

Checklist 6: *Puncture Test*

Step	Test Specimen TP163(C)	
1. Chill the test specimen to a temperature at or below -40°C. **The outer drum thermocouple reading was above -40°C. Due to the thin material thickness of the steel it was not possible to keep the outer drum at or below -40°C. The drum, lid clamp and drum bolt components are manufactured from stainless steel (plus a brass component in the lid clamp). These materials are not susceptible to brittle fracture at cold temperatures, therefore the drum temperature above -40°C will not adversely affect the test results.**		
2. Measure and record the ambient temperature.	11°C (52°F)	
3. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	Figure 8.7.1.1	
4. Record thermocouple readings:	Drum: -22°C	Shield Container: -89°C
5. Start video recorder.		
6. Release the test specimen.		
7. Record any damage to the test specimen. **Hit as desired. Side indent to drum and rim. No break in clamp bolt or side bolts. Final temperatures: 855: -85°C; Drum: -3.2°C**		




8. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.

Test witnessed by: Signature	Print Name	Date
Engineering: S. Forte	STEPHEN FORASTE	11 JAN 2005
Regulatory Affairs: L. Podolak	LORI PODOLAK	22 Oct 04
Quality Assurance: J. Beauchamp	Jerry Beauchamp	11 Jan 05

Data Sheet 6: *Puncture Test*

Test Unit Model and Serial Number: **1911 serial number 013**		Test Specimen No.: **TP163(C)**
Test Date: **22 Oct 04**	Test Time: **~12:00 p.m.**	Test Location: **Valley Tree, Groveland, MA**

Describe set up:

Same orientation as 30 ft drop.

On-site assessment:

The clamp ring bolt and the bolts holding the drum lid to the drum base remained intact.

Engineering: S. Foto Regulatory: [signature] QA: [signature]

Describe any post-test disassembly and inspection:

The top of the drum was indented ½ inch deep by 10 ½ inches wide. The bottom of the drum was indented less, only 9 inches wide. The shield container cover was unbolted, removed and the insert plug was removed. The undamaged sources (inactive) were photographed in the undamaged shield cavity.

Describe any change in source position:

None. The sources were still contained within the shield cavity.

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

No radiography was performed.

Completed by: Stephen Foto	Date: 12 JAN 2005

Test Plan 163 Pre and Post Test Specimen and Source Measurements

Sources positioned in Model 855 Source Changer with connector grooves turned inward.
Measurements in inches, from the top of the lock funnel on the outside,
to the top of the source connector.

Model 855 Serial Number 8; TP163(A)

Source & Pre Test Height Measurements					
Lock #	First	Second	Average	Post Test Height	Difference
1	0.801	0.798	0.800	0.789	-0.011
2	0.746	0.746	0.746	0.745	-0.001
3	0.736	0.739	0.738	0.733	-0.005
4	0.664	0.666	0.665	0.669	0.004
5	0.785	0.791	0.788	0.777	-0.011
6	0.743	0.738	0.741	0.731	-0.009
7	0.732	0.727	0.730	0.729	-0.001
8	0.745	0.747	0.746	0.741	-0.005

Model 855 Serial Number 9; TP163(B)

Source & Pre Test Height Measurements				Post Test Height Measurements			
Lock #	First	Second	Average	First	Second	Average	Difference
1	0.742	0.740	0.741	0.741	0.741	0.741	0.000
2	0.708	0.711	0.710	0.701	0.711	0.706	-0.004
3	0.777	0.777	0.777	0.779	0.774	0.777	-0.001
4	0.823	0.835	0.829	0.807	0.820	0.814	-0.016
5	0.764	0.770	0.767	0.760	0.759	0.760	-0.007
6	0.741	0.747	0.744	0.745	0.740	0.743	-0.002
7	0.718	0.725	0.722	0.724	0.727	0.726	0.004
8	0.791	0.794	0.793	0.676	0.683	0.680	-0.113

Model 1911 Serial Number 13; TP163(C), sources placed loosely in shield container cavity.

Source #	Pre Test	Post Test
1	Located in shield container cavity	Located in shield container cavity
2	Located in shield container cavity	Located in shield container cavity

976 Type B Package Overpack Drum deformations:

	Pre-Test Top original diameter	Post-Test Top indentation depth	Post-Test Top indentation width	Post-Test Bottom indentation width
TP163(A)	19.25	1.75	11.50	7.00
TP163(B)	19.25	0.75	9.00	9.00
TP163(C)	19.25	0.50	10.50	9.00

Section 10. APPENDIX C – MANUFACTURING RECORDS

Section 11. APPENDIX D – PROFILE SHEETS

Section 12. APPENDIX E – ORIGINAL TEST PLAN

TEST PLAN 163

MODEL 976
TRANSPORT DRUM

AEA Technology QSA Inc.
Burlington, MA 01803

Contents

Section 10 List:

Drawing Number	Rev.	Description
R976A	1	976 Type B Package with Model 855 Shield Container
R976F	1	976 Type B Package with Model 1911 Shield Container
R97608	B	20 GAL. Barrel, Model 976
R97615	B	Top Cork Insert, Model 855
R97616	B	Bottom Cork Insert, Model 855
R97623A	1	Bottom Cork Insert, Model 1911
R97637	A	Cork Spacer 0.5" Thick
20046_LID	1	Modified Lid for 1911
RCLM009	B	Clamp Band
R85590	C	Model 855 Shield Container
20046M	A	Model 1911 Shield Container
20046-10	1	DU Insert Plug, Model 1911
20046-11	1	DU Insert Bottom, Model 1911
JB018/001	A	Pot Insert Assembly (Lead Insert for Model 1911)
R42409	C	Source Assembly (placed in Model 855)
87555	D	Source Assembly (placed in Model 1911)

Figures:

Figure	Description
Fig. 8.6.2.1	Specimen TP163(A) Orientation for the 9 m Drop Test.
Fig. 8.6.3.1	Specimens TP163(B) and TP163(C) Orientation for the 9 m Drop Test
Fig. 8.7.1.1	Specimens TP163(A), TP163(B),TP163(C) Orientation for the 1 m Puncture Test

Tables:

Table	Description
Table: 6.1	Model 976 Series Variations

Section 1 Introduction

This document describes the mechanical test plan for the Model 976 Transport Package with the Model 855 and Model 1911 Shield Containers to meet NRC requirements for Type B (U)-96 packages as described in the Code of Federal Regulations, 10 CFR Part 71. 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).

The Model 976 Transport Drum is designed to transport various families of projectors, changers and transport casks. These include the Model 855 Source Changer, Models 3018 and 3056 Source Changers, Models 3015 and 3078 Shield Containers and the Model 1911 shield container.

The Model 976 Transport Package has been tested previously in Test Plan 90. During the test several 976 Transport Packages were dropped containing Model 855s, and a Model 3056.

This test plan incorporates a modification to the drum lid attachment method (e.g., added bolt attachments). Though the Models 3015, 3018, 3056 and 3078 will not be retested in the modified package, their use in the modified package will be assessed in Test Plan Report 163.

This Test Plan 163 will expand on the Test Plan 90 testing. The Model 855 will be re-dropped at a 45° angle which was the most damaging under Test Plan 90. In addition the Model 855 and the Model 1911, which was not tested previously, will be dropped at a 17.5° angle based on information contained in NUREG/CR-6818.

This document describes the test package specification, testing equipment, testing scenario, justifies the package orientations for the different test specimens, and provides test checklists to record essential steps in the testing sequence.

Section 2 Transport Package Description

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

The 976 Transport Drum consists of an open head stainless steel drum with a high density cork liner. The lid is secured with a stainless steel band clamp as well as 4 bolts through the side of the drum into threaded blocks welded to the lid. The arrangement of the cork liner will vary with respect to the type of package being transported within the drum. Specifics on the base container follow:

DRUM
- Manufactured of 16 gauge 304 stainless steel.
- All seams seal welded against ingress of fluids.
- Sides re-enforced with two (2) ¾ to 1-inch outward side ribs.
- In accordance with (IAW) R97608 Rev B (see Section 10 for referenced drawing).
- 20 gallon capacity.
- Lid modified with 4 bolt blocks and drum modified with 4 bolt holes to secure the lid (in addition to the clamp band.)

CLOSURE BAND
- All stainless steel construction.
- Stainless steel closure bolt.
- Brass swivel nut.
- IAW drawing RCLM009 Rev B(see Section 10 for referenced drawing).

LINER
- Medium-high density cork (17 lbs/ft^3) manufactured from medium size granules with a resin binder and bonded with urea formaldehyde resin.
- The liners are formed and cut to block and brace the various packages within the drum.
- The standard liner is designed for the Model 855 family. This liner is present in all drums and is manufactured to R97615 Rev B and R97616 Rev B. The remaining families of devices have supplemental liners that provide additional blocking and bracing within the cavity formed by the standard liner.
- The supplemental liners for Model 1911 are manufactured to R97623A Rev 1 and R97637 Rev A.
- (See Section 10 for referenced drawings).

The source changers and shield containers to be tested within the 976 follow:

Model 855 Family Source Changer

- The units manufactured comply with R85590 Rev C (See Section 10 for referenced drawing).
- The maximum capacity of the device is 1000 Ci of Ir192.
- The maximum weight of the unit is 225 lbs.
- The depleted uranium shield is saucer shaped and contains eight (8) titanium source tubes. The tubes are welded at the distal end into a titanium disk imbedded in the shield.
- The shield is encased by a welded, carbon steel cylindrical shell. Smaller cylinders support the shield within the outer weldment. The interstitial space is filled with 18-lbs./ft^3 Polyurethane foam. All depleted uranium/steel interfaces are separated by copper sheeting to prevent formation of the eutectic during extreme thermal conditions.
- The sources are retained within the device by a sliding lock assembly. The lock plate directly actuated by the plunger type lock, captures either the spiral wrap of the teleflex wire or the stop ball, depending on the source design being transported. The plunger lock is constructed of brass, the locking body and slide are carbon steel. The lock assembly is secured to the top plate of the weldment by four (4) steel screws.
- The cover of the container, which is bolted to a ring welded to the top of the cylindrical weldment during transport, consists of a plate with a small cylinder welded to its underside. During transport, this cylinder stops the slides from withdrawing by preventing horizontal movement of the locks. Additionally, the sources are retained by a cap, which threads onto the lock assembly over the proximal end of the source.

Model 1911 Shield Container

- The maximum capacity of the device is 700 Ci of Ir192 or 350 Ci of Ir192 depending upon the inserts used:

  700 Ci: Depleted Uranium inserts, 20046-10 Rev 1and 20046-11 Rev 1 (max weight 12 lbs) used to transport sealed sources. This heavier set of inserts will be used in the drop test.

  350 Ci: Lead inserts, JB018/001 Rev A (max weight 9 lbs) used to transport one sealed source inside a source holder.
- The units manufactured comply with 20046M Rev A (See Section 10 for referenced drawing).
- The maximum weight of the unit is 184 lbs.
- The unit is a lead shielded, steel encased cavity into which sources and/or additional shielding inserts can be placed.

Section 3 Regulatory Compliance

The purpose of this plan, which was developed in accordance with AEA Technology QSA Inc. Engineering Work Instruction Document Number E-1808, is to demonstrate that the Model 976 Transport Drum, meets the Type B transport package test requirements of 10 CFR 71 and the IAEA Safety Series No. TS-R-1.

The tests for Normal Conditions of Transport (10 CFR 71.71), the compression test, penetration test, and 1.2 m (four-foot) free drop test, will not be performed, due to previous testing in TP90 of this overpack design containing the Model 855, the largest, heaviest shield container to be transported in the 976 Type B Package. Compliance for the modified package will be assessed in the Test Plan Report.

Water spray preconditioning of the package is not performed. The Model 976 Transport Drum is constructed of waterproof materials throughout and while it contains cork liners, no damage or degradation is expected in the short term from exposure to water.

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

The crush test (10 CFR 71.73(c)(2)) will not be performed because the radioactive contents are qualified as Special-Form radioactive material.

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

Section 4 Discussion on System Failure Modes of Interest

4.1 General

The location of the source relative to its stored position in the shield is an important safety element. Displacement of the source from its original stored position or damage to the shield could elevate the dose at the surface of the package above regulatory limits.

The tests in this plan focus on damaging those components of the package which could cause displacement of the source, relative to its stored position, within the shield and which affect the integrity of the shield itself.

There are three possible mechanisms to cause these types of failures:

a) The shield container could shift within the overpack drum if the cork inside is crushed and/or burned away allowing the shield container to move within the drum overpack, increasing radiation intensity to one side of the drum.
b) The shield container could leave the overpack drum if the drum clamp band broke and the lid retention bolts broke and the drum lid came off.
c) The shield container could be affected by the thermal test (particularly if the overpack drum breaks open during drop testing).

These three mechanisms described above may occur simultaneously.

4.2 Normal Conditions of Transport

4.2.1 To be assessed in the TP163 Report by comparison of the revised drum lid closure and Model 1911 to previous tests in TP90.

4.3 Hypothetical accident Conditions of Transport.

4.3.1 Failure of the drum to adequately protect the shield container from the shock of the impact thereby causing displacement of the source and/or shield by mechanism 4.1(a), 4.1(b), and/or 4.1(c) resulting in a dose rate increase above the allowable limit.

4.3.2 Failure of the drum to adequately protect the shield container from the shock of the impact combined with failure of the of the unit itself and the failure of the drum to remain intact, causing exposure of the either cork or shield containers within the drum. If this happens during the 9 m drop, then the puncture test will attempt to inflict damage to shield container components to release the source, or damage the encapsulation of the shield. Degradation of the cork and/or melting/oxidation of the shield in the subsequent fire test could then result in

displacement of the source and/or shield as described in 4.1(a), 4.1(b), and/or 4.1(c) leading to a dose rate increase above the allowable limit.

4.3.3 Previous testing in Test Plan 90 revealed that the heaviest package configuration containing the Model 855 shield container dropped from 9 m at angle of 45 degrees could impact with enough force to break the drum clamp band spot welds. The drum clamp band then separated from the drum. The drum lid did not separate from the drum, however, as it was crimped to the drum by deformation and the shield container stayed within the drum. While it could be assessed that this damaged configuration would still pass the thermal test, it was decided to reinforce the lid attachment. This was done by welding four threaded blocks to the underside of the lid which engage four bolts inserted through holes in the side of the drum. The model 855 with this modified lid design will be dropped from 9 m at an angle of 45° (e.g. the same configuration that was drop tested in Test Plan 90). Both the model 855 and model 1911 package configurations will be dropped from 9 m at an additional shallow angle of 17.5°, as this was demonstrated by Lawrence Livermore National Laboratory (NUREG/CR-6818; UCRL-ID-149067) to be the most likely orientation to separate a clamped lid from a drum.

Section 5 Assessment of Package Conformance

5.1 Regulatory Requirements

5.1.1 Normal Conditions of Transport Tests (71.43(f))

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

IAEA Safety Series No. TS-R-1para. 646 stipulates the same criteria except that it states in paragraph 646(b) 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.

5.1.2 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/h at 1m from the external surface with the maximum radioactive contents which the package is designed to carry.

5.2 Test Package Contents

(Reference:

- *10 CFR 71.33(b)*

- *IAEA TS-R-1, Section IV & paragraph 807(a))*

  The Model 976 Transport Drum is designed to carry Special Form Sources. Containment of the radioactive source is tested at manufacture. The source capsule designs have been certified by the Competent Authority in accordance with the performance requirements for Special Form as specified in 10 CFR Part 71 and 49 CFR.
  (Reference: 10 CFR 71.33(a)(4); IAEA TS-R-1, paragraph 213 and 501(f))

  This test plan therefore does <u>not</u> discuss/specify tests of the containment of the radioactive source. The purpose of the tests is to demonstrate that the shielding remains effective within the limits specified by the regulations.
  (Reference: 10 CFR 71.33(b); IAEA TS-R-1, Section IV & paragraph 807(a))

  Simulated sources will be used during testing of the packages. These simulated sources are manufactured in the same method as radioactive sources, with the exception that they do not contain radioactive material and may have a hole drilled through them to visually identify them as simulated sources.

  Each Model 855 will contain 8 sources modified from R42409 Rev C.

  The Model 1911 will contain two sources modified from 87555 Rev D inside DU inserts 20046-10 Rev 1 and 20046-11 Rev 1. These 87555 sources will not be contained in their source holders as they would be for normal shipments to allow greater potential for damage during the tests. Since these source holders also hold the source away from the wall of the DU shield inserts, or centered within the lead shield inserts, not having the sources contained within source holders will provide slightly higher radiation profile results than will be observed in regular shipping use.

  The radiation levels prior to and after testing will be monitored by replacing the simulated sources with active sources.

Section 6 Construction and Condition of Test Specimens

(Reference:

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

The test specimens will be Model 976 Transport Drum units constructed in accordance with AEA Technology QSA Inc. drawings as enumerated in the Table 6.1. The units will contain the model 855 or the model 1911 as described in Table 6.1.

For the Hypothetical Accident tests, the test temperature of the package must be at or below -40°C at the time of each test, a minimum temperature required by IAEA Safety Series TS-R-1 and 10 CFR 71. The low temperature represents the worst-case condition for the package because of the potential for brittle fracture of any carbon steel components of the shield containers.

Every attempt will be made to keep the entire package below -40°C, however, the thin stainless steel of the drum will quickly absorb ambient heat when removed from our ice box for the drop. Since the drum is made entirely of stainless steel, -40°C temperature would not affect the results of the test. As the liner is constructed of cork, a natural insulator, the shield containers should stay below -40°C during all tests.

Three (3) test specimens are to be tested. None will be subject to normal condition tests, the 976 was tested to normal conditions in TP90(A)with the heavier Model 855 inside. The Three (3) will be subject to the Hypothetical accident tests. The specimens will be above the maximum observed field weight for the shield container within, achieved by placing lead sheets uniformly within the shield container and/or around the body of the shield container. Adding lead will only increase the weight, not the shielding performance of the device. All profiles will be performed without the additional lead.

All shield container units tested will be pulled from the field population. As these units have seen years of service in varying conditions, they represent a worst case scenario with respect to the drums ability to prevent damage. The Model 1911 has been reworked to drawing 20046M Rev A to encase the old lead shield container within a stainless steel jacket. This was done to allow handling of the shield container without directly contacting lead. The Model 1911 used for this test will contain the heavier depleted uranium inserts for the most rigorous test.

Sample Number	Drawings Referenced	Test Condition	Comments
TP163 (A)	R976A Rev A R85590 Rev C	Hypothetical	Model 976 A transport package With a Model 855 shield container
TP163 (B)	R976A Rev A R85590 Rev C	Hypothetical	Model 976 A transport package With a Model 855 shield container
TP163 (C)	R976F Rev A 20046M Rev A	Hypothetical	Model 976 F transport package With a Model 1911 shield container

Table 6.1: Model 976 Test Variations

Note: See Section 10 for all referenced drawing.

Section 7 Material and Equipment List

The test checklists in Section 9 list the equipment to the specification required by 10 CFR 71 and all other necessary equipment and measuring instruments needed to perform the tests.

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

Section 8 Test Procedure

8.1 General

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

Three (3) specimens are to be tested to determine the transport integrity of the package. The test sequence is presented below with testing focusing on three areas.

- Disruption of the containment of the drum such that the device is caused to exit after the 9 m drop.
- The ability of the drum and liners to absorb the impact energy, and substantially protect the shield container in the 9 m drop test.
- To inflict damage to shield container components within the drum.

Should the overpack fail resulting in exposure of the shield container inside, further testing will concentrate on damaging or removing the cover bolts, disrupting the container integrity or attempting to add to previous damage, whichever is considered more appropriate. Furthermore, if the drum has failed and damage has occurred to the inner container such that the cork surrounding the shield or the shield itself is exposed as described in Section 8.8, the package will be evaluated to see if thermal test will be necessary.

The 976 Transport Drum packages are not hand held items and there is no requirement to "condition" a package by subjecting it to normal condition of transport prior to the hypothetical accident conditions of transport testing. For this reason, the specimen will be subjected to the hypothetical accident conditions of transport in the orientation shown in Section 8.6

The tests have the following sequence:

1. Test specimen preparation and inspection.

Hypothetical Accident Conditions Tests. (Specimens TP163 (A)

2. 9 m (30-foot) free drop tests *(10 CFR 71.73(b); IAEA TS-R-1, paragraph 727).*

3. Puncture tests (10 CFR 71.73(c)(3); *IAEA TS-R-1, paragraph 727).*

4. Intermediate test inspection.

5. Thermal tests (if applicable) (10 CFR 71.73; *IAEA TS-R-1, paragraph 728).*

6. Final test inspection.

8.2 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 and 10 CFR 71.

- **Quality Assurance** oversees test execution and test report generation to assure compliance with the AEA Technology QSA Inc. Quality Assurance Program.

- **Engineering, Regulatory Affairs** and **Quality Assurance** are jointly responsible for assessing test and specimen conditions relative to 10 CFR 71.

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

8.3 Specimen Temperature Measurement

The Hypothetical Condition drop tests will be carried out at or below -40°C. Temperature measurements will be made by positioning thermocouples on the shield container as well as on the drum.

8.4 Test Specimen Preparation and Inspection

Use *Checklists 0: Specimen Preparation and Inspection.*

To prepare the test units:

1. Manufacture: Three (3) Model 976 Transport Drum units per drawings in Table 6.1. (See Section 10 for all referenced drawings)

2. Secure two (2) Model 855 and one (1) Model 1911 shield containers. Measure and record the weight of each shield container.

3. Clearly and indelibly, mark the shield containers, simulated sources, liners and drums with unique identification per Table 6.1.

4. Inspect the shield containers, simulated sources, liners and drums to all drawings in Section 10 to ensure that all fabrication and inspection records are documented in accordance with the AEA Technology QSA Inc. Quality Assurance Program in effect at the time of manufacture and comply with test plan requirements.

5. Place the units in the transport drums in accordance with Table 6.1.

6. Perform and record the initial radiation profiles (without the additional lead to be added for weight) in accordance with AEA Technology QSA Inc. Quality Assurance Program.

7. Measure and record the location of the simulated sources in each specimen using appropriate methods.

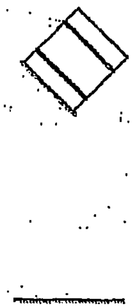
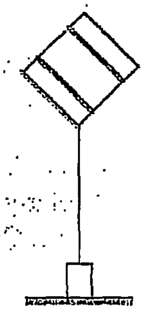
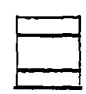
8. Add lead sheets to increase the transport package weights up to or above the maximum gross weight. Record and photograph all weight modifications.

9. **Quality Control, Engineering, Regulatory Affairs** and **Quality Assurance** will jointly verify that each test specimens comply with the AEA Technology QSA Inc. Quality Assurance Program.

10. Prepare the units for transport in accordance with their respective operating instructions.

11. Measure and record the weight of each complete package.

8.5 Summary of Test Schedule

Accident Conditions Test	Parameter	Specimen	Diagram
9 m Drop 45° Angle (See Sec. 8.6.2)	71.73(c)(1)	TP163(A)	
9 m Drop 17.5° Angle (See Sec. 8.6.3)	71.73(c)(1)	TP163(B) TP163(C)	
Puncture (See Sec. 8.7.1)	71.73(c)(3)	TP163(A) TP163(B) TP163(C)	Orientations for each unit are to be determined following completion of the 9 m drop test 
Thermal Will be assessed if needed.	71.73(c)(4)	TP163(A) TP163(B) TP163(C)	Requirement for thermal test to be determined following completion of drop and puncture tests 

8.6 9 m Free Drop Test

(Reference:

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

The first Hypothetical Accident Test is the 9 m (30-foot) free drop test.

Use *Checklist 1, 2 or 3: 9 m Drop Test* to ensure that the test sequence is followed. Date and initial all action items, and record required data on the checklist.

NOTE: *The checklist identifies those steps which must be witnessed by Engineering, Regulatory Affairs and Quality Assurance.*

Figures 8.6.2.1 and 8.6.3.1 illustrate the orientations for the test units.

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

8.6.1 9 m Free Drop Test Set-up

To set up a package for the 9 m (30-foot) drop test:

1. Measure the specimen's internal and surface temperature to ensure that the package is at or below -40°C.
2. Place each specimen on the drop surface and position it according to the specimen-specific orientation described below.
3. Arrange the lifting mechanism/system such that the package is as shown in Figure 8.6.2.1 and 8.6.3.1.
4. Raise each specimen so that the impact target is 9 m (30 feet) above the drop surface.
5. Photograph the set-up.
6. Drop the package.
7. Record the damage to the specimen and take a photographic record.
8. Measure and record the temperature of the package.

8.6.2 Specimen TP163(A) Orientation for the 9 m Drop Test

Figure 8.10.2.1 shows the package orientation for Specimen TP163(A). The drop will be on the top edge, on the lid clamp band bolt, near a lid bolt at about 45° angle to horizontal. The intention is try to shear the lid off by subjecting the drum to the full force of a 9 m impact with the center of gravity above the impact point. If the clamp band were to break and the lid bolts were to break, then the lid could come off. With the lid off, the cork and/or shield container inside would be exposed to direct targeting from the following puncture testing.

Figure 8.6.2.1: Specimen TP163(A) Orientation for the 9 m Drop Test

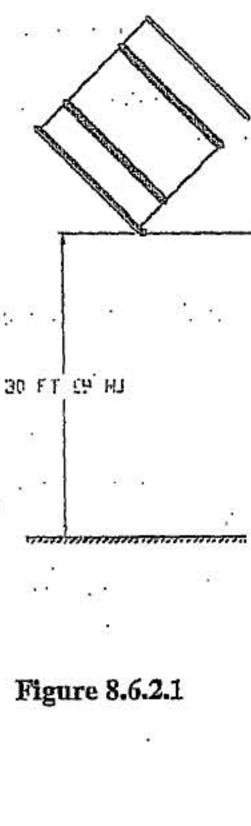


Figure 8.6.2.1

8.6.3 Specimen TP163(B) and TP163(C) Orientation for the 9 m Drop Test

Figure 8.10.2.1 shows the package orientation for Specimens TP163(B) and TP163(C). Specimen TP163(B) will be dropped on the top edge, on the lid clamp band opposite from the bolt, in between the lid bolts at about 17.5° angle to horizontal. The intention is to determine whether the deformation of the drum will cause the locking ring to come off when the opposite end of the drum impacts the drop pad. The 17.5° angle has been shown in tests by Lawrence Livermore National Laboratory (NUREG/CR-6818; UCRL-ID-149067) to be the best orientation to separate the clamp band from the drum. This is most likely due to the variations in plastic and elastic deformation between the drum and clamp band. If the clamp band were to come off and the lid bolts were to break, then the lid could come off. With the lid off, the cork and/or shield container inside would be exposed to direct targeting from the following puncture testing.

If the clamp band stays on the drum, Specimen TP163(C) will be dropped on the top edge, on the lid clamp band opposite from the bolt, near a lid bolt at about 17.5° angle to horizontal. The change in impact point from in between the lid bolts, to near a lid bolt will determine which orientation allows for more deformation of the lid and drum.

Figure 8.6.3.1: Specimens TP163(B) and TP163(C) Orientation for the 9 m Drop Test

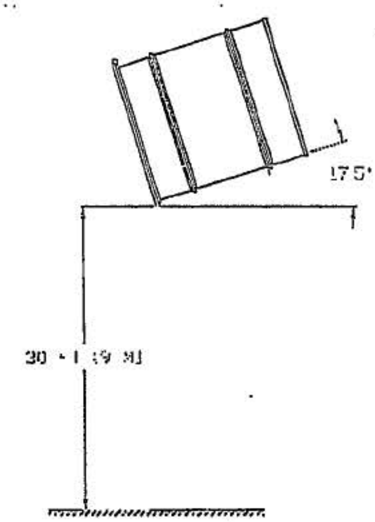


Figure 8.6.3.1

8.6.4 9 m Free Drop Test Assessment

(Reference:

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

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.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.
- Assess the damage to each of the specimens and take one of the following actions based on that assessment.

I. If the package remains intact, i.e. the lid remains in place evaluate the condition of the specimen to determine what orientation of the package will achieve maximum damage for specimen orientation for the puncture test.

II. If the package is not intact, i.e. the lid has opened or broken away, remove the shield container from inside and examine the shield container for damage. The puncture test should be arranged to add or exacerbate this damage. If there is no obvious damage then target its shield cover bolts.

8.7 Puncture Test

(Reference:

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

The 9 m free drop test is followed by the puncture test per 10 CFR 71.73(c)(3), in which a package is dropped from a height of 1m (40") onto the puncture billet.

The billet is to be bolted to the drop surface used in the drop tests.

Use *Checklist 4, 5 or 6: Puncture Test* to ensure that the test sequence is followed. Date and initial all action items and record required data on the checklist.

NOTE: *The checklist identifies those steps which must be witnessed by Engineering, Regulatory Affairs and Quality Assurance.*

8.7.1 Puncture Test Set-up

The orientation for each specimen will be determined from assessment of the condition of the specimen following the 9 m drop testing

---

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.*

This test requires that the test specimen be at or below -40°C at the time of the test. The checklist calls for measuring and recording the specimen temperature before and after the test.

The test uses the 12" or 16" (as appropriate with respect to orientation) high puncture billet. The billet meets the minimum height (8") required in 10 CFR 71.73(c)(3). The billet will be selected with respect to orientation of the package so that no projections or overhanging members could act as impact absorbers, thus allowing the billet to cause the maximum damage to the specimen.

To set up a package for the puncture test:

1. Measure the specimen's internal and surface temperature to ensure that the package is at or below -40°C.

2. Position it according to the specific orientation determined from assessment after the 9 m drop testing.

3. Raise the package so that there is 1 m (40") between the impact point on the package and the top of the puncture billet.

4. Photograph the set-up.

5. Drop the package.

6. Record the damage to the package and take a photographic record.

7. Measure and record the temperature of the package.

Figure 8.7.1.1: Specimens TP163(A), TP163(B) and TP163(C)
Typical orientation for the 1 m Puncture Test

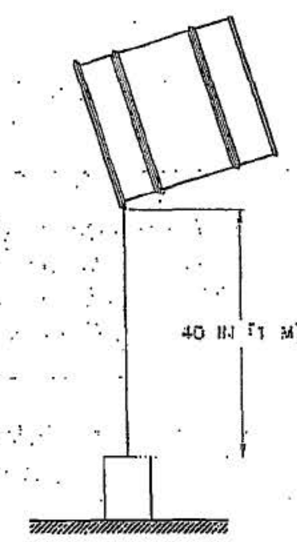


Figure 8.7.1.1

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 test was performed in accordance with 10 CFR 71.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.
- Assess the damage to the specimen to decide whether testing of that specimen is to continue, if the lid has come off the drum <u>and</u> sufficient damage to the inner container has occurred such that the cork surrounding the shield is exposed as defined in Section 8.8, then the need for a thermal test will be assessed.
- If the thermal test needed, evaluate the condition of the specimen to determine the orientation for the thermal test to achieve maximum damage and go to section 8.9.
- If, after assessment, it is determined that the thermal test is not needed, then go to section 8.10.

8.8 Intermediate Test Inspection

After the puncture test, examine all specimens as follows.

1. Measure and record the damage to each of the test specimens.

   Review all results after this and each step and decide whether a thermal test is needed.
   A. If a thermal test is needed, then reassemble the package using the same simulated sources used in the specimen during the first two tests and continue with Section 8.9.
   B. If a thermal test is not needed, continue with the Intermediate Test Inspection.

2. Measure and record the location of the sources using AEA Technology standard practice.

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

4. Reassemble the package using active sources, 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 the test specimen in accordance with AEA Technology QSA appropriate method.

   If a thermal test is not needed, continue with Section 8.10

8.9 Thermal Test

(Reference:

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

The oven is to be pre-heated to a temperature of no less than 810°C prior to the test commencing.

The specimen may comprise just an inner container or a 976 Transport Drum with inner container within.

Thermocouples are to be placed around and inside the specimen such that the temperature; on all external surfaces of the specimen placed in the oven and the center of the shield adjacent to the source, as a minimum is monitored. Other thermocouples may be positioned subject to the damage caused by the impact.

The thermocouples shall be positively fixed to their surfaces and the external ones shall be shielded from radiation from the furnace such that they measure the surface temperature of the specimen.

When the oven has been pre-heated the package is placed inside and positioned centrally within the oven. When the temperature at the surface of the specimen has risen to no less than 810°C the test will start. This temperature, above the required 800°C, includes an allowance for measurement uncertainty.

The package will remain in the oven for a period of 30 minutes after this point.

The test environment is an oven operating up to 900°C. There will be sufficient airflow to allow combustion.

If the specimen is burning when it is removed, the unit shall be allowed to extinguish by itself and then cool naturally. Appropriate measures should be taken to avoid the radiological risks associated with this hazard. The final evaluation of the package is performed when the specimen reaches ambient temperature.

8.9.1 Test Specimen Orientation

The selected orientation should be based on an assessment of the test specimen condition immediately after the puncture test. Record, justify and approve the orientation for this test in accordance with AEA Technology QSA appropriate method.

8.9.2 Thermal Test

To perform the thermal test:

1. Document the thermal test package orientation.
2. Attach thermocouples to the specimen's internal and external measurement locations.
3. Heat the oven to no less than 810°C and start the airflow.
4. When the oven temperature is stable at above 810°C place the specimen in the oven and close the door.
5. When the temperature of all surfaces of the specimen are at or above 810° C, start a 30-minute timer.
6. Throughout the test (5-min. intervals) measure and record the oven temperature, test specimen internal and external temperatures and the air flow rate. Record whether there is any combustion.
7. Remove the test specimen from the oven. WARNING if the package is burning, appropriate safety measures must be in place to avoid the risks associated with burning or melted cork, polyurethane foam, lead and/or depleted uranium. Consult with the oven operator.
8. Allow the package to self-extinguish and cool.
9. Record the damage to the package and make a photographic record and/or X-ray or radiograph.

8.9.3 Thermal Test Assessment

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

1. Review the test execution to ensure that the test was performed in accordance with 10 CFR 71.
2. Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71.

8.10 Final Test Inspection

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

Perform the following inspections after completion of all required testing:
If a thermal test was performed, start with Step 1.
If a thermal test was not performed, start with Step 6.

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

2. Measure and record the location of the sources using AEA Technology standard practice method.

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

4. Reassemble the packages using an active source, making sure that the source wire position, source wire holder 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 AEA Technology QSA Standard practice method.

6. Assess the significance of any change in radiation at the surface or at one meter from each package. Remove the active sources.

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

8. If it is decided to proceed with the inspection, record and photograph the process of removing any component.

9. Measure and record any damage or failure found in the process of dismantling the test specimens.

10. Retain all test components until disposition is authorized by Engineering, Regulatory Affairs and Quality Assurance.

Engineering, Regulatory Affairs, and **Quality Assurance** team members will make a final assessment of each test specimen and jointly determine whether the specimen meets the requirements of 10 CFR 71.73.

Section 9 Checklists

Use the following checklists for executing these tests. There are two checklists for each test: an equipment list and a test procedure checklist.

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

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

Note:

Equipment list 6 and Checklist 7 will only be required if it is determined that damage to a specimen is sufficient to warrant a Thermal Test.

Checklist 0: Specimen *Preparation and Inspection*

Step	TP163(A)	TP163(B)	TP163(C)
1. Record serial number of shield container.			
2. Record serial number of the simulated source(s)			
3. Record shield container weight.			
4. Record overpack weight.			
5. Record added lead weight.			
6. Record total package weight.			
7. Are all fabrication and inspection records documented in accordance with the AEAT Q.A. Program (at the time of manufacture)?			
8. Does the test unit comply with the requirements of Drawing?			
9. Has the radiation profile been recorded in accordance with AEA TECHNOLOGY QSA INC. Standard practice method?			
10. Is the package prepared for transport?			

Witnessed and verified by: Print Name: Date:

Engineering:

Regulatory Affairs:

Q.A.:

Equipment List 1: *9 m (30 foot) Drop Test Equipment List*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		
Signature **Completed by:**	Print Name	Date

Checklist 1: *9 m (30 foot) Drop Test*

Step	Test Specimen TP163(A)	
1. Chill the test specimen to a temperature at or below -40°C.		
2. Measure and record the ambient temperature.		
3. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.6.2.1	
4. Record thermocouple readings:	Drum:	Shield Container:
5. Release the test specimen.		
6. Record any damage to the test specimen.		
7. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test-to achieve maximum damage.		

Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 1: *9 m (30 ft) Drop Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP163(A)**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Checklist 2: *9 m (30 foot) Drop Test*

Step	**Test Specimen TP163(B)**	
2. Chill the test specimen to a temperature at or below -40°C.		
3. Measure and record the ambient temperature.		
4. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.6.3.1	
8. Record thermocouple readings:	Drum:	Shield Container:
9. Release the test specimen.		
10. Record any damage to the test specimen.		
11. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test to achieve maximum damage.		
Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 2: *9 m (30 ft) Drop Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP163(B)**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Checklist 3: *9 m (30 foot) Drop Test*

Step	Test Specimen TP163(C)	
3. Chill the test specimen to a temperature at or below -40°C.		
4. Measure and record the ambient temperature.		
5. Lift and orient the test specimen as shown in the referenced figure. Inspect the orientation set-up and verify the drop height.	Figure 8.6.3.1	
12. Record thermocouple readings:	Drum:	Shield Container:
13. Release the test specimen.		
14. Record any damage to the test specimen.		
15. Engineering, Regulatory Affairs and Quality Assurance to make a preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary in package orientation for the puncture test to achieve maximum damage.		
Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 3: *9 m (30 ft) Drop Test*

Test Unit Model and Serial Number:		Test Specimen No.: TP163(C)
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ______________ Regulatory: ______________ QA: ______________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 2: *Puncture Test Equipment*

Description	Model Number	Serial Number
1.		
2.		
3.		
4.		
5.		
Signature	Print Name	Date
Completed by:		

Checklist 4: *Puncture Test*

Step	Test Specimen TP163(A)	
1. Chill the test specimen to a temperature at or below -40°C.		
2. Measure and record the ambient temperature.		
3. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	Figure 8.7.1.1	
4. Record thermocouple readings:	Drum:	Shield Container:
5. Start video recorder.		
6. Release the test specimen.		
7. Record any damage to the test specimen.		
8. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.		
Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 4: *Puncture Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP163(A)**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ______________ Regulatory: ______________ QA: ______________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Checklist 5: *Puncture Test*

Step	Test Specimen TP163(B)	
2. Chill the test specimen to a temperature at or below -40°C.		
3. Measure and record the ambient temperature.		
4. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	Figure 8.7.1.1	
5. Record thermocouple readings:	Drum:	Shield Container:
6. Start video recorder.		
7. Release the test specimen.		
8. Record any damage to the test specimen.		
9. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.		
Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 5: *Puncture Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP163(B)**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ____________ Regulatory: ____________ QA: ____________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Checklist 6:*Puncture Test*

Step	Test Specimen TP163(C)	
3. Chill the test specimen to a temperature at or below -40°C.		
4. Measure and record the ambient temperature.		
5. Lift and orient the test specimen as shown in the referenced figure or as determined following the previous test. Inspect the orientation set-up and verify the drop height.	Figure 8.7.1.1	
6. Record thermocouple readings:	Drum:	Shield Container:
7. Start video recorder.		
8. Release the test specimen.		
9. Record any damage to the test specimen.		
10. Engineering, Regulatory Affairs and Quality Assurance make preliminary assessment relative to 10 CFR 71. Record the assessment on a separate sheet and attach. Determine what changes, if any are necessary to the Test Plan.		
Test witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 6: *Puncture Test*

Test Unit Model and Serial Number:		Test Specimen No.: TP163(C)
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ______________ Regulatory: ______________ QA: ______________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

Equipment List 3: *Thermal Test Equipment*

(Attach inspection report or calibration certificate for all equipment)

Description	Model Number	Serial Number
Ambient Thermometer.		
Thermocouple surface probe.		
Thermocouple surface probe.		
Thermocouple surface probe.		
Thermocouple recording device.		
Oven		
Oven thermostat.		
Record any additional tools used to facilitate the test and attach the appropriate inspection report or calibration certificate.		
	Signature	Date
Completed by:		
Verified by:		

Checklist 7: *Thermal Test*

Test Location:

Step	Specimen TP163( )
1. Pre-heat the oven to a minimum of 810°C.	
2. Attach the thermocouple(s) to the specimen. Note locations on Data Sheet.	
3. Place the package in the oven and close the door. Record time.	
4. When all surfaces of the specimen exceed 810°C, Start the 30-min test time. Record time.	
5. Continually measure the oven temperature and the specimen's temperatures.	
6. Monitor the specimen's temperatures throughout the 30-minute period to ensure that they are above 810°C.	
7. At the end of the 30-minute period, remove specimen from oven. Record Time.	
8. Describe combustion when door is opened to remove specimen.	
NOTE: If specimen continues to burn, let it self-extinguish and cool naturally.	
9. Continue to monitor the specimen's temperature during cool down. Allow cooling to ambient.	
10. Measure and record the ambient temperature.	
11. Photograph the test specimen and any subsequent damage.	
12. Record the damage to test specimen on a separate sheet and attach.	
13. Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71. Record the assessment on Data Sheet 4	

Test Witnessed by: Signature	Print Name	Date
Engineering:		
Regulatory Affairs:		
Quality Assurance:		

Data Sheet 7: *Thermal Test*

Test Unit Model and Serial Number:		Test Specimen No.: **TP163( )**
Test Date:	Test Time:	Test Location:
Describe set up:		
On-site assessment: Engineering: ______________ Regulatory: ______________ QA: ______________		
Describe any post-test disassembly and inspection:		
Describe any change in source position:		
Describe results of any pre- or post-test radiography:		
Completed by:		Date:

NOTES ON	TEST

Prepared by:	Date:	Sheet

Department	Signature	Print Name	Date
Engineering			
Regulatory			
Quality Assurance			

Section 10 Drawing Reference

Section 13. APPENDIX F – NYCOMED AMERSHAM PLC TEST NUMBER 1835

Test Number 1835 (Submitted to the DOT with Type B(U)-85 Approval Application, Package Design Number 3605B, in the UK by Nycomed Amersham plc. USA Competent Authority Certificate USA/592/B(U)-85)

Commercial - in - confidence

Test number 1835 page 1 of 28 Issue 3, Report Disc reference pack40/tct1835.hpw

AMERSHAM INTERNATIONAL plc

PACKAGING DESIGN GROUP

IAEA Type B package test sequence

Container design number 3605B

Contents

Part A: Specification of test assemblies

A1 Design description: Container design number 3605B

A2 Design drawings: To drawing list DL25068 issue 1

A3 Quality Assurance:

Item	Drawing	Batch / serial number Assembly A	Batch / serial number Assembly B
Drum body & lid	A21716 issue M	10/90	10/90
Clamp	A24793 issue A	Prototype	Prototype
Cork insert, P027	3A21703 issue D	04/93	04/93
Cork spacer, P028	3A21714 issue C	04/93	04/93
Lead pot, P500	3A23165 issue C) 2A22484 issue D)	P500/0952	P500/950
Pot lid, P523	2A21523 issue B	-	-
Insert, P524	BRC21524 issue C	I15/1003	I15/--
Tube cap nuts	ARC21525 issue A		

Clamp band closure torque 7 lbf.ft (9.1 kgf.m)

Measurements were made of a wide variety of features to enable before and after comparisons to be made. Manual records are dated 2 June 1994 in project lab record book.

A4 Variations from design specification:

The test unit was confirmed by inspection to be to specification

A5 Serial number: Test assembly A used outer drum serial number 3605/14
Test assembly B used outer drum serial number 3605/15

A6 Package contents:

Both assemblies contained Orion Components 'Tinytalk-Temp' miniature temperature loggers in addition to a large number of temperature sensitive strips covering the range 50°C - 193°C.

A7 Package weight: 54 kg

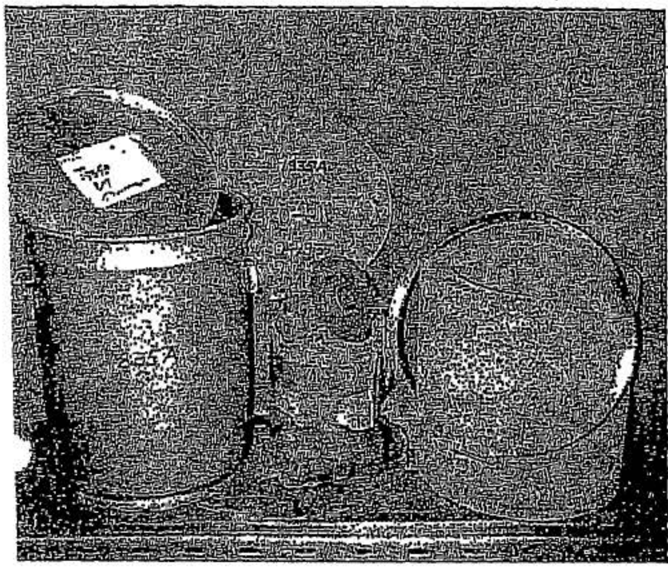


Figure 1
Assembly A components

Figure 2
Pot A orientation in drum

Figure 3
Assembly B components

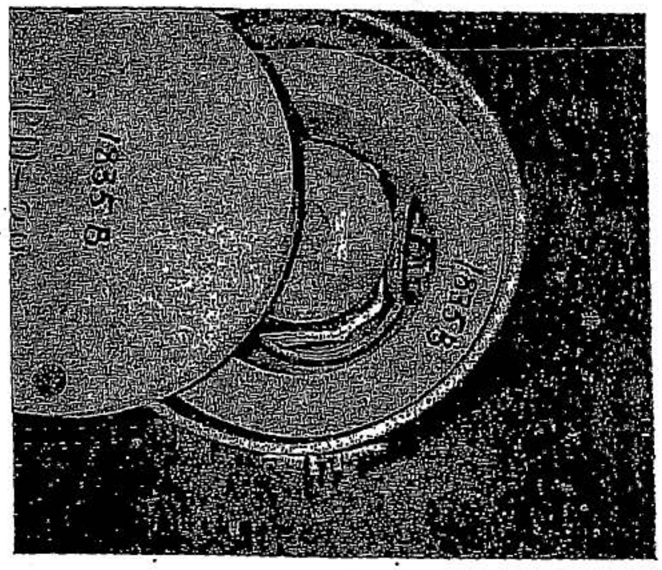


Figure 4
Pot B orientation in drum

Part B: Tests and test procedures

B1 Regulatory description

i) IAEA Safety Series 6 paragraph 622 - 1.2m free drop test

ii) IAEA Safety Series 6 paragraph 627a - Drop I - 9m free drop

iii) IAEA Safety Series 6 paragraph 627b - Drop II - 1m punch test

iv) IAEA Safety Series 6 paragraph 628 - Thermal test (Furnace)

B2 Standard procedures

i) Packaging Group Procedure PGP15 issue 4. A quick release shackle will be used in place of the parachute release shown in PGP15. The operator will stand on a strong platform to measure the 1.2m drop height and to release the package.

ii) Packaging Group Procedure PGP15 issue 4, amended as above and with a drop height of 9m. A 'steady' cord may be attached to the hoist or the package as an aid to eliminating swing at height.

iii) No standard procedure has been written for the Drop II (punch) test. The following procedure will be followed:

Safety As location of impact is as important as orientation in the punch test, it is not practical for the shackle release operator to evacuate the test compound. To ensure his safety and to provide a well controlled access to the release mechanism to ensure impact as planned, he should stand on a suitable strong platform (an 0924 drum is ideal).

Follow PGP15 (as B2(i)), excepting paragraphs 4.3 - 4.6

While ensuring that there is no chance of an unintentional release, hoist the package sufficiently to set punch and package in the intended location and orientation of impact.

Attach a piece of weighted string, 1m long, to the position on the package it is intended to impact the punch.

Hoist the package until the plumb bob weight hangs on the punch at the intended impact position. Do not remove the plumb line.

Ensuring the set alignment remains true by means of the plumb line, gently twist the release lever of the shackle.

iv) IPM108 issue 1

B3 Maintenance

No maintenance will be carried out on the packages between tests.

B4 Drop test facility

Drawing 3A24849 shows a schematic layout of the Amersham Laboratory site drop test target. PGP15 shows a schematic view of the superstructure. The punch is a six inch diameter bar, fifteen inches high as described in IAEA SS6 paragraph 627(b), welded vertically on a base plate 445 x 445 x 12mm.

B5 Recording and instrumentation

The tests will be recorded on video tape and by Polariod photographs. The tape will be available for viewing and used for analysing the impact orientations, although only the photographs will be appended to this report. Photographs will be identified on site by date plus a reference number. Each test package contains a Tinytalk temperature logger, set to record the last two days temperatures, fresh data overwriting previous data. No mechanical instrumentation is installed.

B6 Impact attitudes

Assembly A

i) 1.2m free drop test	1835/1	Centre of gravity above the lid corner at the closure bolt
ii) Drop I (9m free drop)	1835/2	Onto the base at about 5° from flat
iii) Drop II (Punch test)	1835/3	Inverted with impact by the edge of the punch onto the folded drum side

Assembly B

i) 1.2m free drop test	1835/4	Centre of gravity above the lid corner at the closure bolt
ii) Drop I (9m free drop)	1835/5	Centre of gravity above the lid corner at the closure bolt
iii) Drop II (Punch test)	1835/6	Inverted with impact by the edge of the punch onto the folded drum side

B7 Damage assessment criteria

After each test the container will be examined to review the general level of mechanical damage, particular attention being given to continued security of the drum lid and closure clamp. No attempt will be made to remove the lid between tests.

B8 Pass / fail criteria

i) Following the 1.2m free drop test:

The minimum source to surface distance, established by examination of surface distortion, shall be reduced by not more than 10%.

ii) and iii) Following the 9m free drop test and the punch test:

The drum lid shall be retained on the drum body for at least one half of its circumference

The outer surface of the drum shall be intact to such an extent that the package components are securely retained in the design relationship

The damaged assembly shall be secure enough that it may be transported to the thermal test facility under routine conditions without subsequently failing the above criteria.

iv) Following the thermal test:

The assembly shall be essentially intact with the lead pot located approximately central in the package

The lead pot shall be intact and have risen to a temperature of no greater than 193°C (the maximum temperature strip fitted)

Part C - Mechanical test schedule

Date: 10 June 1994

Condition of test equipment: Satisfactory

Condition of height plumb lines: Satisfactory

Indicated condition of video battery: Charged

Ambient weather conditions: Light breeze, dry, generally sunny

Persons present:
A R Webster, Department of Transport
S T Winfield
A Lewis
R Campbell-Grieve

Test reference 1835 / 1 (1.2m free drop test, assembly A)

Check	Operation	Notes
✓	Stand package on the drop test target and hoist from a base flange lifting point to achieve a drop onto the clamp bolt	10/6
✓	Attach slings to the quick release shackle and raise the package for photo record of orientation	1
	Mark test reference 1835/1 on video	
✓	Evacuate the compound of all but the drop operator and secure the gate	
✓	Set the video running	
✓	Raise the package until the 1.2m drop height is confirmed	
✓	Very gently twist the release lever to release the package	
✓	Stop video record. Photo record position of the package as it came to rest	10/6 2
	Set the package to a convenient viewing position and photo record damage	10/6 3
	Figures 5 - 7 refer	

Damage report

No significant damage. Slight distortion of drum rim and clamp band.

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned
Accept. Continue to next test, revised
Fail

Figure 5
1835/1 - Drop test orientation

Figure 6
1835/1 - Immediately post test

Figure 7
1835/1 - Damage

Test reference 1835 / 2 (9m free drop test, assembly A)

Check	Operation	Notes
✓	Stand package on the drop test target and arrange the slings through the drum handles to achieve a base drop at about 5° from flat	
✓	Attach slings to the quick release shackle and raise the package for photo record	10/6 (4)
✓	Mark test reference 1835/2 on video	
✓	Attach the 9m plumb line to the lowest part of the package, and ensure that it will uncurl without tangling. Place the bob weight close to the impact point and lay the withdrawing string and shackle operating string out to the compound gate	
✓	Set video running, evacuate the compound and secure the gate	
✓	Raise the package until the bob weight is just clear of the target. Pull the plumb line clear of the package and the target	
✓	Very gently increase tension in the release string to release the package. Ensure that the package is stationary immediately prior to release	
✓	Stop video record. Photo record position of the package as it came to rest	10/6 (5)
✓	Set the package to a convenient viewing position and photo record damage	10/6 (6) 10/6 (7)
✓	Figures 8 & 11 refer	

Damage report

Impact took place as planned. Three of the four base segments showed evidence of shearing of the drum base sheet around the reinforcement bars. Rust marks showed contact between the base sheet and the target face, a distortion of 19mm

Analysis of damage against criteria of B8

Accept. Continue to next test as planned
✓ Accept. Continue to next test, revised
Fail

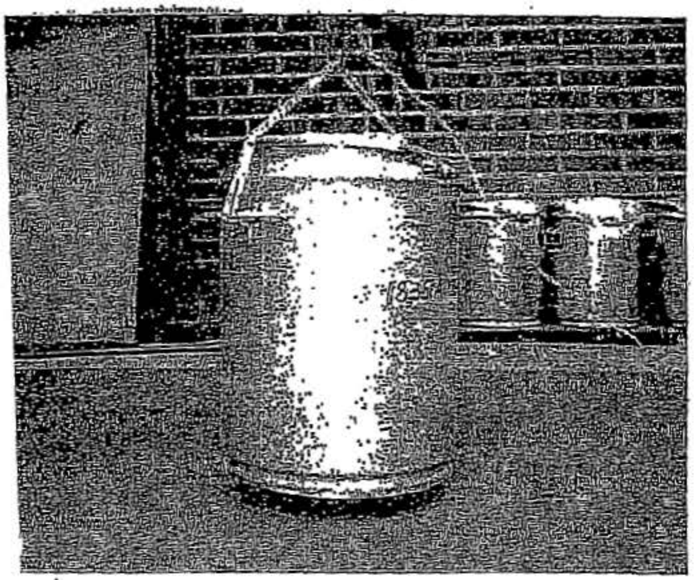


Figure 8
1835/3 - Drop test orientation

Figure 9
1835/3 - Immediately post test

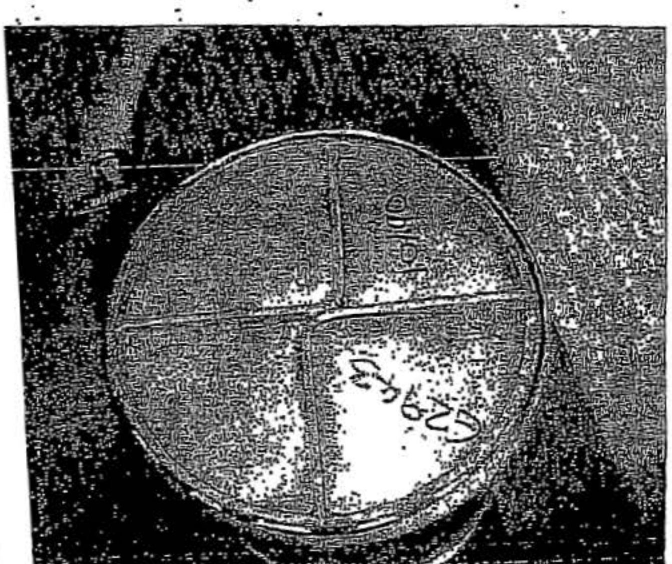


Figure 10
1835/3 - Damage

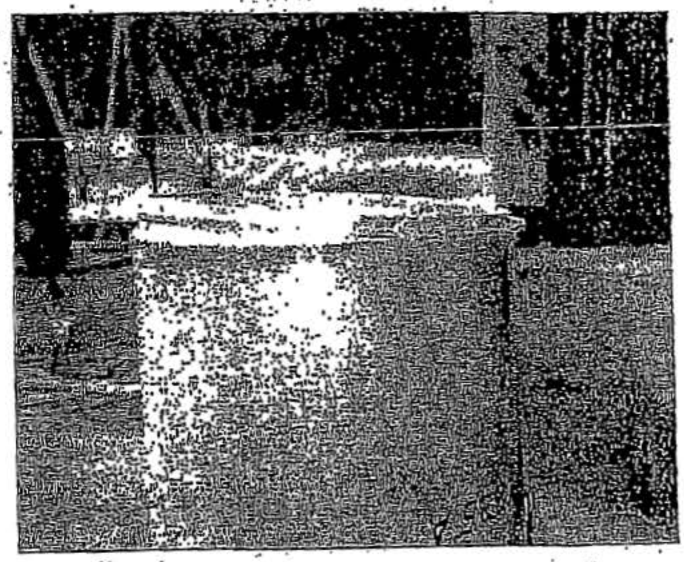


Figure 11
1835/3 - Damage

Test reference 1835 / 3 (1m free drop onto punch, assembly A)

Check	Operation	Notes
✓	Fit slings to the drum handles to achieve a flat centre base drop onto the punch	10/6 8
✓	Mark test reference 1835/3 on video. Leave video running	
✓	Raise the package until a clearance of 1m between drum base and punch top is confirmed	
✓	Very gently rotate the release lever to achieve release.	
✓	Set the package to a convenient viewing position and photo record damage	10/6 9

Figures 12 - 13 refer

Damage report

No noticeable additional damage

Analysis of damage against criteria of B8

✓ Accept: Continue to next test as planned

Fail

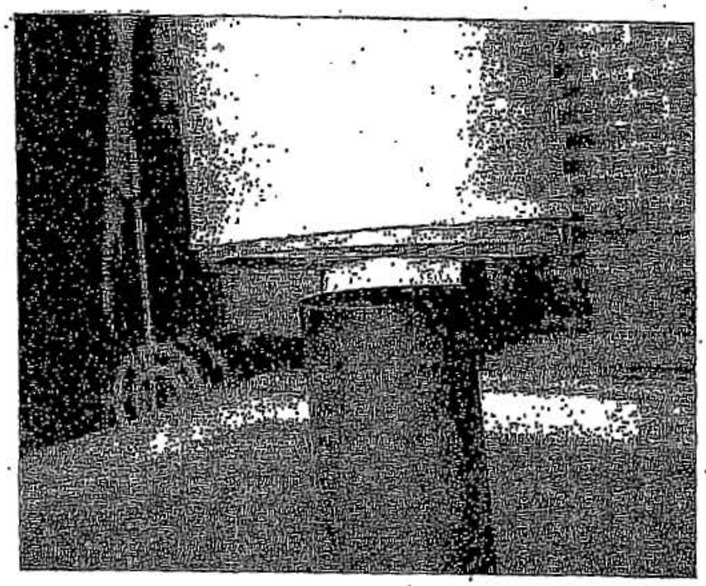


Figure 12
1835/3 - Drop test location and orientation

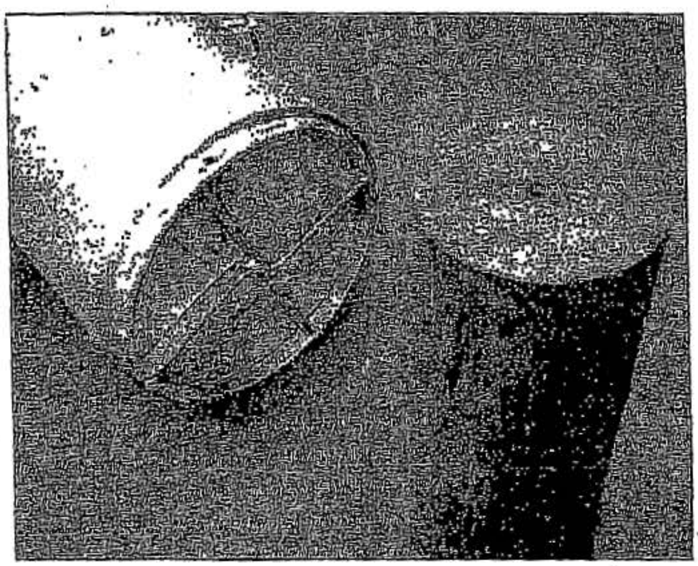


Figure 13
1835/3 - Damage

Test reference 1835 / 4 (1.2m free drop test, assembly B)

Check	Operation	Notes
✓	Stand package on the drop test target and hoist from a base flange lifting point to achieve a drop onto the clamp bolt	
✓	Attach slings to the quick release shackle and raise the package for photo record of orientation	10/6 (10)
✓	Mark test reference 1835/4 on video	
✓	Evacuate the compound of all but the drop operator and secure the gate	
✓	Set the video running	
✓	Raise the package until the 1.2m drop height is confirmed.	
✓	Very gently twist the release lever to release the package	10/6 (11)
✓	Stop video record. Photo record position of the package as it came to rest	
✓	Set the package to a convenient viewing position and photo record damage	(12) 9/6
	Figures 14 - 16 refer	

Damage report

No significant damage. Slight distortion of drum rim and clamp band.

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned
Accept. Continue to next test, revised
Fail

Figure 14
1835/4 - Drop test orientation

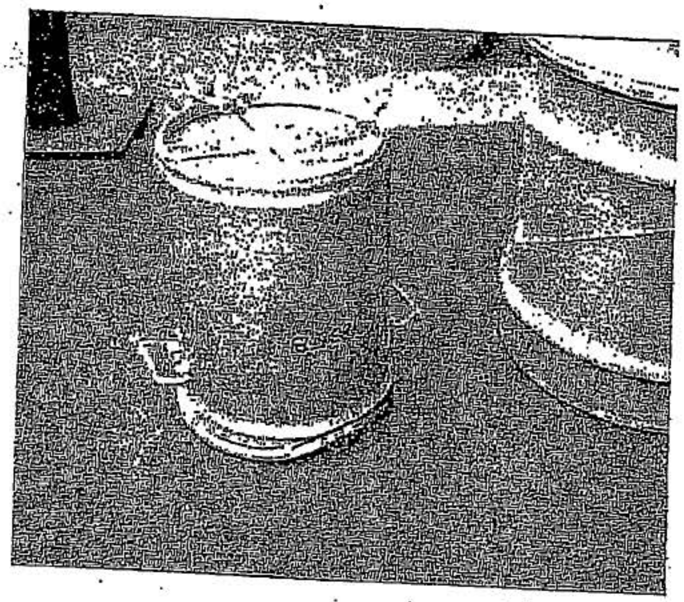


Figure 15
1835/4 - Immediately post test

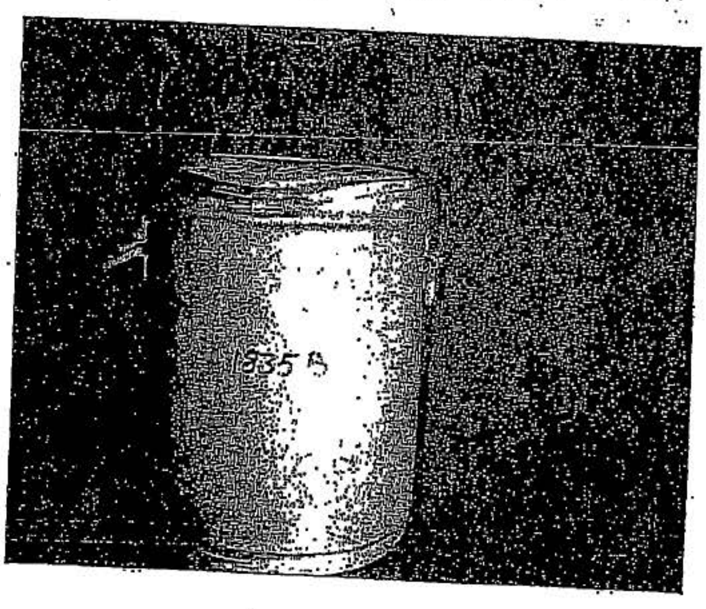


Figure 16
1835/4 - Damage

Test reference 1835 / 5 (9m free drop test, assembly B)

Check	Operation	Notes
✓	Stand package on the drop test target and hoist from a base flange lifting point to achieve a drop onto the clamp bolt	
✓	Attach slings to the quick release shackle and raise the package for photo record	13 10/6
✓	Mark test reference 1835/5 on video	
✓	Attach the 9m plumb line to the lowest part of the package, and ensure that it will uncurl without tangling. Place the bob weight close to the impact point and lay the withdrawing string and shackle operating string out to the compound gate	
✓	Set video running, evacuate the compound and secure the gate	
✓	Raise the package until the bob weight is just clear of the target. Pull the plumb line clear of the package and the target	
✓	Very gently increase tension in the release string, to release the package. Ensure that the package is stationary immediately prior to release	
✓	Stop video record. Photo record position of the package as it came to rest	14 10/6
✓	Set the package to a convenient viewing position and photo record damage	15 10/6

Figures 17 - 19 refer

Damage report

Extensive distortion of the drum and clamp at the point of impact, but the clamp and lid remained fully retained on the drum body.

Analysis of damage against criteria of B8

Accept. Continue to next test as planned
✓ Accept. Continue to next test, revised
Fail

Figure 17
1835/5 - Drop test orientation

Figure 18
1835/5 - Immediately post test

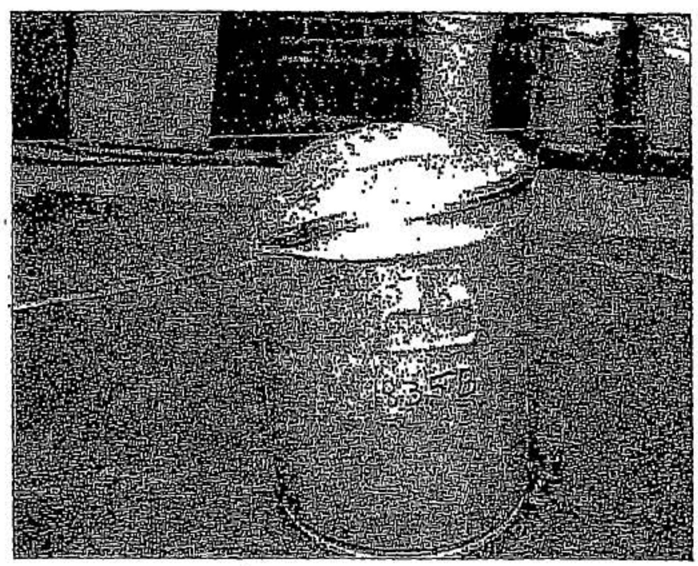


Figure 19
1835/5 - Damage

Test reference 1835 / 6 (1m free drop onto punch, assembly B)

Check	Operation	Notes
✓	Invert the package and arrange the slings to achieve a drop onto the edge of the punch by clamp closure bolt. Photo record	10/6 (16)
✓	Attach a 1m plumb line to the required point of impact on the drum	
✓	Mark test reference 1835/6 on video. Leave video running	
✓	Raise the package until the bob weight is just clear of the punch	
✓	While keeping the bob weight at the desired point of impact on the punch, very gently rotate the release lever to achieve release	
✓	Set the package to a convenient viewing position and photo record damage	10/6 (17)

Figures 20 - 21 refer

Damage report

Clear evidence of impact as planned. No additional damage observed.

Analysis of damage against criteria of B8

✓ Accept. Continue to next test as planned
Fail

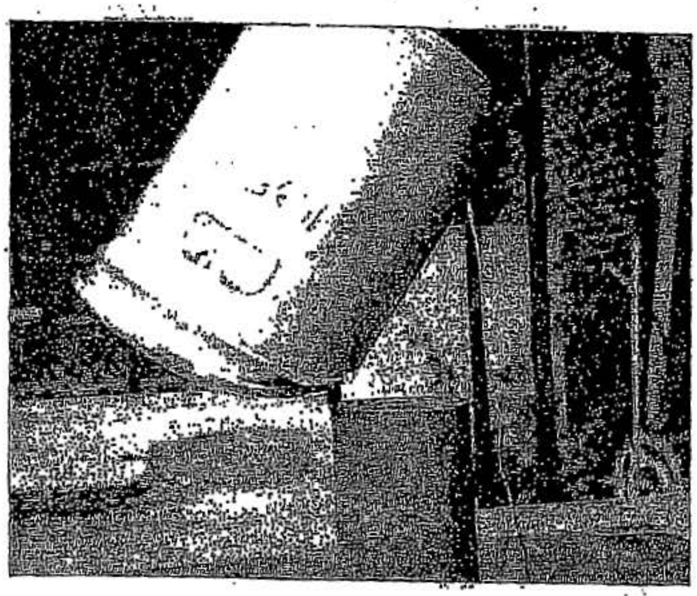


Figure 20
1835/6 - Drop test location and orientation

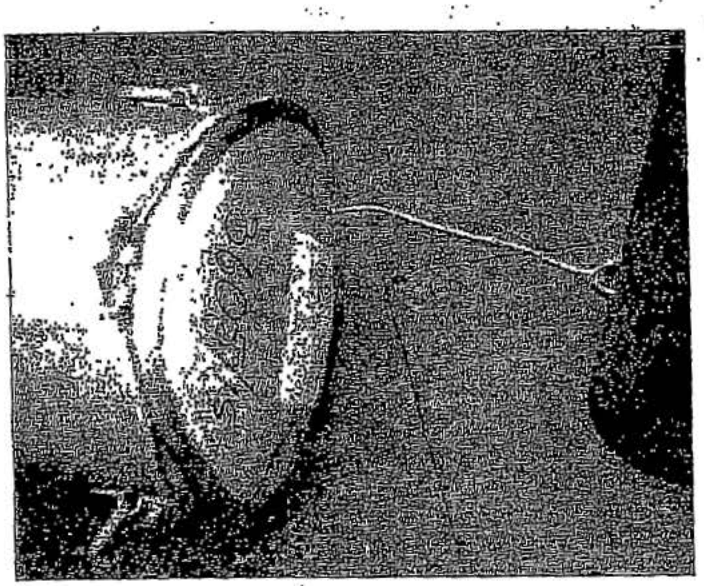


Figure 21
1835/6 - Damage

Part D - Thermal test schedule

Date: 15 June 1994

Test site: Warrington Fire Research Centre

Persons present: A R Webster, Department of Transport
D Williams, Warrington Fire Research Centre
S T Winfield

Test reference 1835 / 7 (Thermal test, assembly A)

Check	Operation	Notes
✓	Position support blocks and ambient thermocouples in the furnace	
✓	Organise lifting equipment to allow access for the package through the furnace roof	
✓	Light the furnace burners and allow the furnace to achieve a steady temperature of 820°C	
✓	Open the furnace roof and insert the package. Replace the roof section with the minimum of delay, and start the test timer when the ambient temperature shows a minimum of 800°C	
✓	Observe progress of the test with intermittent video records of the drum state and the ambient thermocouples output. Maintain an ambient of 800 - 820°C	
✓	After a test duration of 30 minutes, remove the package from the furnace and place on the laboratory floor to cool	15/6 2 16/1 1
✓	After not less than 18 hours, open the package and check the indication on the temperature sensor strips. Photo record the components and the strips	
	Figures 22 + 23 refer	
	Confirm some of the temperature strips' records by heating until the next higher indicator position changes.	

Test commentary

The furnace temperature dropped back to 650°C, returning to 800°C after one minute. Copious flaming observed throughout test, reducing as the test progressed. Minor flaming still in evidence from the base as the drum was lowered to the lab floor.

Figure 22
1835/7 - Assembly A removal from furnace

Figure 23
1835/7 - Assembly A exterior post-thermal test

Test reference 1835 / 8 (Thermal test, assembly B)

Check	Operation	Notes
✓	Allow the furnace to achieve a steady temperature of 820°C	
✓	Open the furnace roof and insert the package. Replace the roof section with the minimum of delay, and start the test timer when the ambient temperature shows a minimum of 800°C	
✓	Observe progress of the test with intermittent video records of the drum state and the ambient thermocouples output. Maintain an ambient of 800 - 820°C	
✓	After a test duration of 30 minutes, remove the package from the furnace and place on the laboratory floor to cool	15/6 4 16/6 2
✓	After not less than 18 hours, open the package and check the indication on the temperature sensor strips. Photo record the components and the strips	
	Figures 24 - 25 refer	
	Confirm some of the temperature strips' records by heating until the next higher indicator position changes.	

Test commentary

The furnace temperature dropped back to 685°C, returning to 800°C after less than one minute. Copious flaming observed throughout test, reducing as the test progressed. Minor flaming still in evidence as the drum was lowered to the lab floor.

Figure 24
1835/8 - Assembly B removal from furnace

Figure 25
1835/8 - Assembly B exterior post thermal test

Approvals

Test Quality Plan comprises Parts A and B and the 'Operation' column of Parts C and D

Quality Plan prepared by S R Winfield, Packaging Design Group

Quality Plan agreed by

Part E - Dismantling and discussion

Both assembly A and assembly B were dismantled on 16 June at Amersham Labs.

E1 Assembly A (Figures 26 - 31 refer)

The clamp bolt sheared despite its being oiled before unscrewing. The cork spacer showed charring to 22mm depth (using a flat ended probe 10x1mm). The upper edge of the cork insert had 26mm of thickness remaining intact, indicating a char depth of 17mm. The bottom of the cork cavity was cracked around the circumference and across diagonals in line with the drum reinforcement bars; there were clear marks from impact by the pot cradle straps. The sides of the cork cavity were sooty but less so than the base. The lead pot was essentially undamaged with resin condensate and soot extending down to the cradle body band. Temperature record strips on top of the lead insert showed a maximum temperature of between 80°C and 82°C (the intervening three indicators were unclear as to whether they had changed fully). Two sets of indicators within the pot body on the insert showed a maximum temperature of between 65°C and 82°C. The Tiny-talk recorder had failed.

E2 Assembly B (Figures 32 - 37 refer)

The clamp bolt unscrewed without breaking. The lid cork showed a char depth of 25mm (using a flat ended probe 10x1mm). The upper edge of the cork insert showed 26mm intact indicating a char depth of 17mm. The cork cavity was sootier than assembly A. The pot was generally undamaged, although one insert tube nut was bent but unbroken. The was a higher degree of condensate and soot on the pot than assembly A. The temperature strip on the top of the insert indicated a maximum temperature of between 77°C and 82°C. Strips on the insert within the pot cavity showed maxima of between 71°C and 82°C (upper portion of pot cavity) and between 77°C and 82°C (lower portion of pot cavity). All the strips were in good condition and easily read. The Tiny-talk recorder had failed.

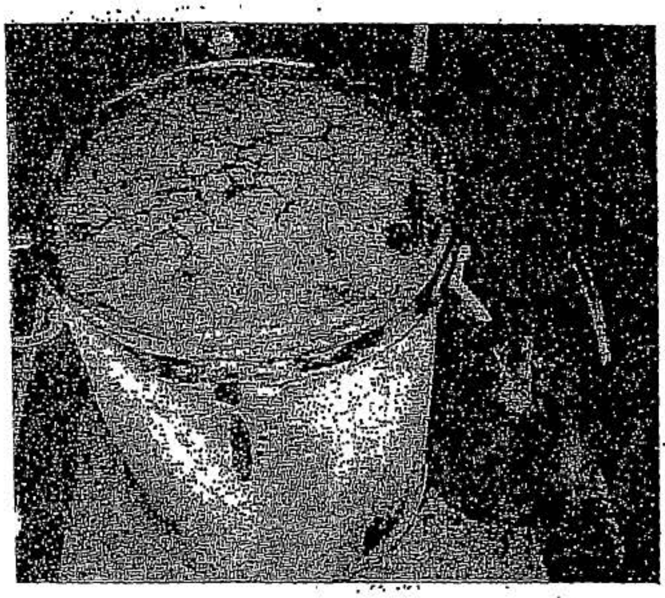


Figure 26
1835/7 - Under drum lid

Figure 27
1835/7 - Char damage to spacer

Figure 28
1835/7 - Damage to lead pot

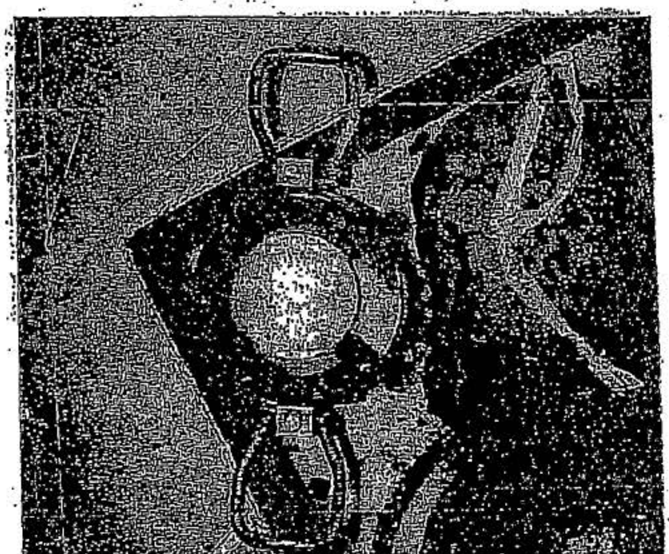


Figure 29
1835/7 - Lead pot, cover removed

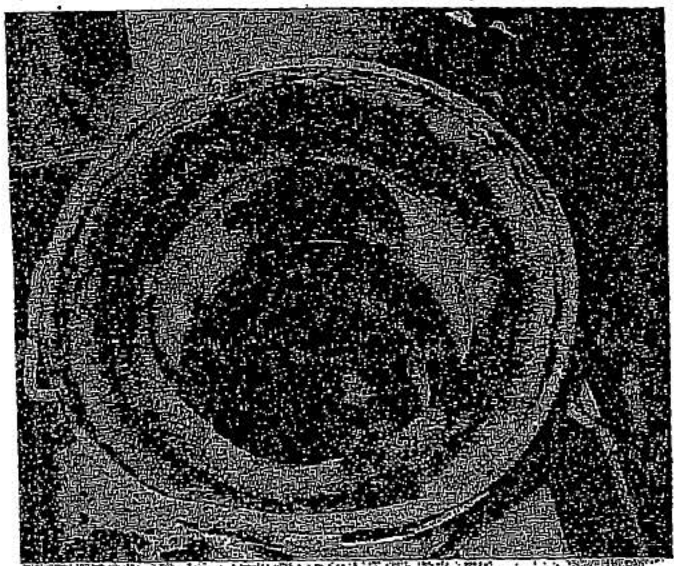


Figure 30
1835/7 - Cork cavity

Illustration
deliberately
omitted

Figure 31
1835/7 - Cork section

Figure 32
1835/8 - Under drum lid

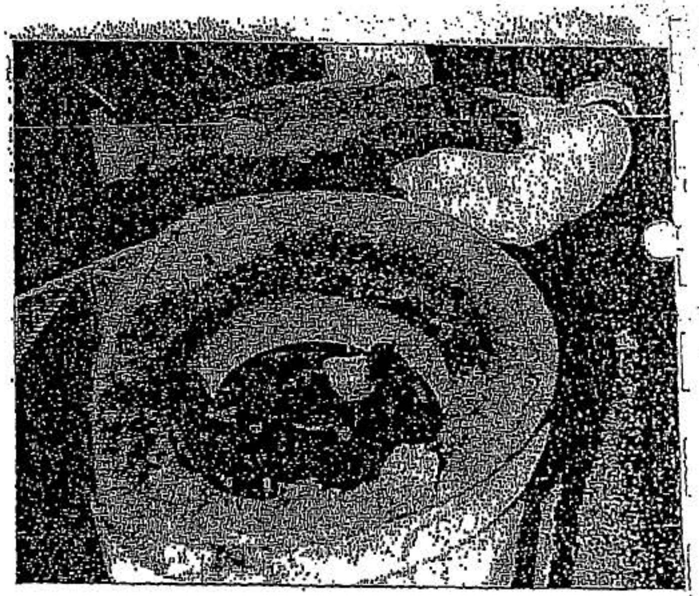


Figure 33
1835/8 - Char damage to spacer

Figure 34
1835/8 - Damage to lead pot

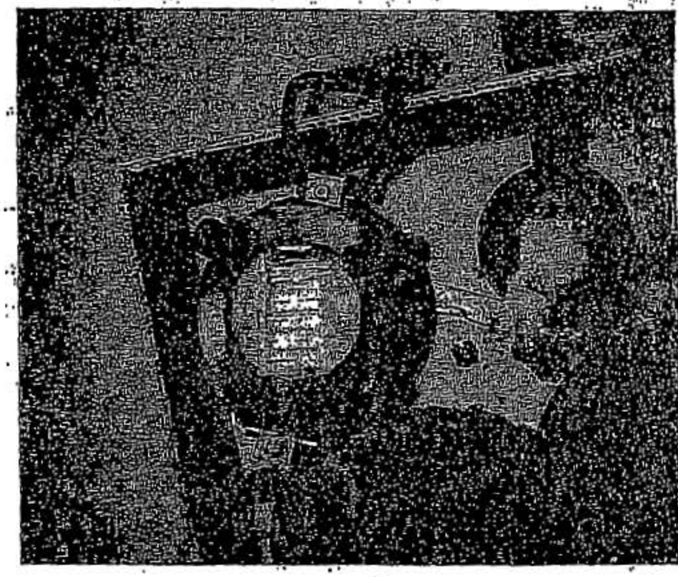


Figure 35
1835/8 - Lead pot, cover removed

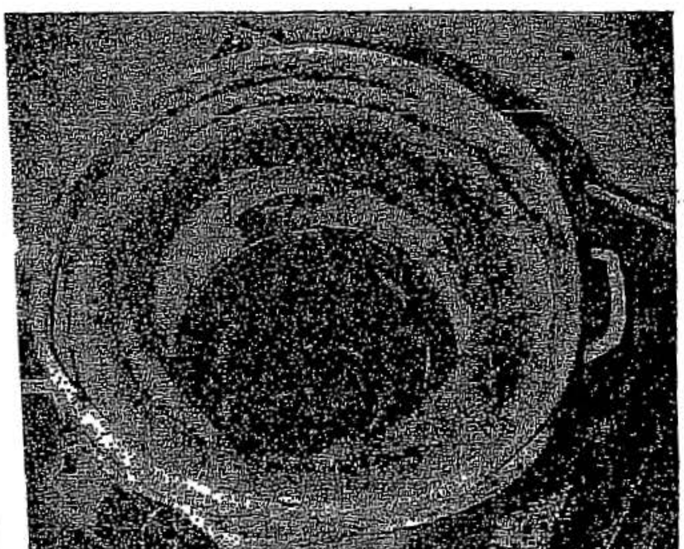


Figure 36
1835/8 - Cork cavity

Illustration
deliberately
omitted

Figure 37
1835/8 - Cork section

E3. Discussion

Both assemblies passed the specified test sequence with a clear margin of safety. Assembly B showed marginally more vulnerability to the thermal test in regard to smoke damage, although the temperature strips showed similar results. Both lead pots were substantially undamaged and would have continued to provide adequate radiation shielding for any source in the tubes. A maximum temperature of less than 82°C is considerably less than the solidus point of the 4% antimonial lead of the pot construction (252°C). The drum assemblies remained intact and could be handled with safety.

Part F - Conclusions

Package design number 3605B has been shown to comply with the requirements of IAEA Safety Series 6 in regard to drop test sequences, in two opposing orientations, comprising a 1.2m free drop test (paragraph 622), a Drop I (9m free drop) test (paragraph 627 (a)) and a Drop II (1m punch) test (paragraph 627 (b)). These mechanical tests were followed by thermal tests (paragraph 628) in which the packages remained essentially undamaged.

Test carried out by S T Winfield

S Winfield 11 July 1994

Witnessed by

A Lewis 13/7/94.

Section 14. APPENDIX G – TYPE A CHECK LIST

AEA TECHNOLOGY QSA

Rev. 1 December, 2004
AEA 976 Series Type A Packages

TYPE A Package Evaluation Checklist

Use this checklist as a guide for evaluating a device or package to the following Type A regulations:

(1) USDOT, 49 CFR Part 171, et al., dated Thursday, September 28, 1995.
(2) USNRC, 10 CFR Part 71, dated Thursday, September 28, 1995.
(3) IAEA, Regulations for the Safe Transport of Radioactive Material No. TS-R-1, 1996 Edition (Revised).

Product Model/Description: Model 976 Series Packages

Package Specifications/Limitations: 976 Series Packages, consists of a source shield inside of cork inserts, inside of a stainless steel drum. The drum is closed with a lid held on by 4 lid bolts and a clamp band tightened with a stainless steel M8 x 1.25 – 130 mm Long bolt and a tamper evident seal wire. One of 6 different source shield models will be shipped in each package. They are:

- **Model 855 (maximum weight 225 lbs).**
- **Model 3015 (maximum weight 104 lbs).**
- **Model 3018 (maximum weight 104 lbs).**
- **Model 3056 (maximum weight 104 lbs).**
- **Model 3078 (maximum weight 126 lbs).**
- **Model 1911 (maximum weight 163 lbs).**

Special Form Source Assemblies Authorized for Transport

Type A Approved Activity (Max.)[1]	Isotope	Source Assembly Model Number
27 Ci	Ir-192	Various, special form. Minimum ANSI pressure classification of 3.
81 Ci	Se-75	Sources in the Model 855, 3018 and 3056 must be attached to flexible source wire assemblies compatible with the shield assemblies.

References: Test Plan 90 Report and Test Plan 163 Report ; Type B SAR Revision 1 Model 976 Series package; DWG's R976A, R976B, R976C, R976D, R976E, R976F, R97608, RCLM009, R97615, R97616, R97623, R97623A, R97637, R85590, R3015, R3018, R3056, R3078, and R1911.

Max Weight of Package 300 lbs

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

L. R. Alle — Regulatory Signature | 11 Jan 05 — Date | Stephen [illegible] — Engineering Signature | 11 JAN 2005 — Date

1. General Requirements.

1-1. Handling:

The package must be easily handled and properly secured in or on a conveyance during transport.
* USDOT, 49 CFR 173.410 (a)
* IAEA TS-R-1, para. 606

> Comply. Drum is cylindrical and can be secured and handled using standard transportation

1-2. Lifting Attachment:

Each lifting attachment that is a structural part of the package must be designed with a minimum safety factor of three (3) against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting attachment under excessive load would not impair the ability of the package to meet other requirements. Any other structural part of the package which could be used to lift the package must be capable of being rendered inoperable for lifting during transport or must be designed with strength equivalent to that required for lifting attachments.
* USDOT, 49 CFR 173.410 (b)
* USNRC, 10 CFR 71.45 (a)
* IAEA TS-R-1, para. 607, 608

Comply. The Model 976 Series packages are designed to be lifted by the base using a hand truck or other suitable mechanical means. For this analysis, the base is the bottom surface of the drum inside the rolled edge, assumed to be a flat, circular plate 18 1/8 inches (459 mm) in diameter and 0.06 inches (1.5 mm) thick, fixed about its outer edge. We take the supporting cylinder (the walls and bottom welded rim of the drum) to be essentially rigid for the magnitude of stresses encountered here. Any lifting would span all edges of the drum and thus allow the bottom to be supported and suspended by the edges. As such, the maximum stress on the base is:

$$\sigma_{max} = k\,wr^2/t^2$$

Where:

k	=	A tabulated factor for this case of flat plate, 0.75. [1]
w	=	The weight of the transport package 136 kg (300 lb) taken as a distributed load over the base 8.02 kPa (1.16 psi).
r	=	The radius of the base plate 244 mm (9.6 inches)
t	=	The thickness of the base plate 1.5 mm (0.06 inches)

[1] - Marks' Handbook, 9th Edition, pp5-52 – 5-53

Therefore, the stress generated in the base is 19,840 psi. With a Safety Factor of 3 applied, the maximum stress in the drum base is 59,500 psi. This is below the tensile strength of the stainless steel base, which is 70,000 psi. Therefore, the lifting device is capable of supporting more than three times the weight of the transport package as required by 10 CFR 71.45(a).

1-3. Tie-down:

See the listed regulatory requirement for full details.
* USNRC, 10 CFR 71.45 (b) (1) (2) (3)

Not applicable. This package has no tie-down system

1-4. External Surface:

The external surface, as far as practicable, shall be free from protruding features and easily decontaminated.
* USDOT, 49 CFR 173.410 (c)
* IAEA TS-R-1, para. 609

Comply. External surfaces of this package have no protruding features. Should the drum become contaminated its smooth stainless steel surfaces can be easily decontaminated.

1-5. Outer Layer:

The outer layer, as far as practicable, shall be free pockets or crevices where water might collect.
* USDOT, 49 CFR 173,410 (d)
* IAEA TS-R-1, para. 610

Comply. The surfaces of this package are flat or cylindrical and contain no pockets or crevices where water might collect, except for a slight depression in the lid, which has no holes.

1-6. Added Features:

Each feature that is added to the package will not reduce the safety of the package.
* USDOT, 49 CFR 173.410 (e)
* IAEA TS-R-1, para. 611

Not applicable. There are no added features which would reduce the safety of the package.

1-7. Vibration:

The package will be capable of withstanding the effects of any acceleration, vibration or vibration resonance that may arise under normal conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole and without loosening or unintentionally releasing the nuts, bolts, or other securing devices even after repeated use.
* USDOT, 49 CFR 173.410 (f)
* IAEA TS-R-1, para. 612

Comply. The 855 shield containers have been used for years as a Type B Package without any detrimental effect being observed due to vibration changes incurred during shipment. The addition of the cork inserts and the stainless steel barrel overpack will dampen vibration. The Model 3015, 3018, 3056 ,3078 and 1911 have been shipped for years as Type B Package components inside an overpack similar to the 976, but smaller in height and diameter, without any detrimental effect being observed due to vibration changes incurred during shipment. The thicker cork inserts in the 976 design will dampen vibration better than the previous overpack.

1-8. Seals:

Incorporates a feature, such as a seal, that is not readily breakable and that, while intact, would be evidence that the package has not been opened by unauthorized persons.
* USDOT, 49 CFR 173.412 (a)
* USNRC, 10 CFR 71.71 (b)
• IAEA TS-R-1, para. 635

Comply. The barrel clamp band is sealed with wire at the time of shipment. Breakage of this wire would be evidence that the package may have been opened by unauthorized persons and would imply the need to initiate special handling precautions to ensure the integrity of the package contents.

1-9 External Radiation Levels:

Each package must be designed so that, under conditions normally incident to transportation, the radiation level does not exceed 200 mR/hr at any point on the external surface of the package and the transport index does not exceed 10, unless shipped exclusive use.
* USNRC, 10 CFR 71.47 (a)
* USDOT, 49 CFR 173.441 (a)
* IAEA TS-R-1, para. 531, 532

Comply. Each package is surveyed before shipment.

2. Additional Requirements.

2-1. Overall Size:

Smallest overall dimension must be 4 inches (10 cm) or greater.
* USDOT, 49 CFR 173.412 (b)
* USNRC, 10 CFR 71.43 (a)
* IAEA TS-R-1, para. 634

Comply. The package inner dimensions are Ø19"ID by 21" deep.

2-2. Tie-down:

Tie-down attachment that is a structural part of the package, under both normal and accident conditions, shall not impair the ability of the package to meet other requirements of the governing regulations.
* USDOT, 49 CFR 173.412 (i)
* IAEA TS-R-1, para. 636

Not applicable. There are no tie-down attachments that are a structural part of this package.

2-3. Containment:

Containment and shielding is maintained during transportation and storage in a temperature range of -40°C (-40°F) to 70°C (158°F). The design of the package will take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport. For radioactive material having other dangerous properties, the package design shall take into account those properties.
* USDOT, 49 CFR 173.412 (c)
* IAEA TS-R-1, para. 637, 615, 616

Comply. The primary containment are the welded stainless steel sources. All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 3. They have complied with external temperatures of -40°C (-40°F) to 80°C (176°F). The capsules are shielded within one of the previously mentioned shields, inside the cork inserts inside the stainless steel barrel. This temperature range will have no adverse affect on the integrity of the source or the shielding and package materials, with the exception of the carbon steel jacket on the Model 855 Source Changer. While carbon steel is susceptible to brittle fracture at -40°C, the Model 855 has served for years as a Type B Package on its own without fracture. The 976 Package, containing the Model 855 chilled to -40°C was subjected to several drop tests. The Model 855 suffered no damage. See Test Plan 90 Report and Test Plan 163 Report.

Containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package.
* USDOT, 49 CFR 173.412 (d)
* USNRC, 10 CFR 71.43 (c)
* IAEA TS-R-1, para. 639

Comply. The primary containment are the welded stainless steel sources. No pressures will be generated within the sources or the package that could adversely affect the containment system. See Type B SAR Model 976 Series package for further assessment.

If the containment system forms a separate unit of the package, it shall be capable of being securely closed by a positive fastening device which is independent of any other part of the packaging.
* USDOT, 49 CFR 173.412 (d)
* IAEA TS-R-1, para. 641

Comply. The primary containment is the welded stainless steel sources.

Components of the containment system shall take into account, where applicable, the radiolytic decomposition of liquids and other vulnerable materials and the generation of gas by chemical reaction and radiolysis.
* USDOT, 49 CFR 173.412 (e)
* IAEA TS-R-1, para. 642

Not applicable. No reactions known and no liquids.

The containment system shall retain its radioactive contents under a reduction of ambient pressure to 60 kPa (8.6 psi) (25 kPa for USDOT).
* USDOT, 49 CFR 173.412 (f)
- IAEA TS-R-1, para. 643

Comply. The primary containment are the welded stainless steel sources. All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 3. They have complied with external pressure of 25 MN/m^2 abs. (290 lbs/in^2 abs). The rest of the package is unaffected by pressure.

Packages containing liquids will be capable of withstanding, without leakage, an internal pressure that produces a differential of not less than 95 kPa (13.8 lb/in^2).
* USDOT, 49 CFR 173.410 (i)(3)

Not applicable. No liquids.

Packages containing liquids will either provide sufficient absorbent material to absorb twice the volume of the liquid contents or be provided with a containment system composed of primary inner and secondary outer containment components designed to ensure retention of the liquid contents within the secondary containment even if the primary containment leaks.
* IAEA TS-R-1, para. 648(b)

Not applicable. No liquids.

Packages containing liquids will provide for ullage (the amount of liquid within a container that is lost, as by leakage, during shipment or storage) to accommodate variations in the temperature of the contents, dynamic effects and filling dynamics.
* IAEA TS-R-1, para. 647

Not applicable. No liquids.

Packages containing gases (excluding tritium or noble gases) shall prevent loss or dispersal of the radioactive contents when subjected to the tests specified in para 725.
* IAEA TS-R-1, para. 649

Not applicable. No gases.

Any radiation shield that encloses a component of the packaging specified as part of the containment system shall prevent the unintentional release of that component from the shield. Where the radiation shield and such component within it form a separate unit, the radiation shield shall be capable of being securely closed by a positive fastening device which is independent of any other packaging structure.
* USDOT, 49 CFR 173.412 (h)
- IAEA TS-R-1, para. 645

Comply. The primary containment is the welded stainless steel sources, which are separate from the shields.

- The Model 855 Source changer has 8 independent "J" tubes that contain and protect one source each and extend into the depleted uranium radiation shield. The top of each J tube has a stop mechanism, which captures the stop ball or the teleflex cable on the source wire. These stop mechanisms have key activated locks. If these locks should fail, the Model 855 cover plate has a cylinder on the underside of it, that prevents movement of the stop mechanisms when the cover plate is bolted on for transport.
- The Model 3015 Shield has a cavity to contain the sources. This cavity is closed by a shielding plug, which is covered with a cap that bolts to the shield jacket.
- The Model 3018 has 4 independent "J" tubes that contain and protect one source each and extend into the radiation shield. The top of each J tube is closed with a threaded cap.
- The Model 3056 has 10 independent "J" tubes that contain and protect one source each and extend into the radiation shield. The top of each J tube is closed with a threaded cap. These caps are protected by the top cover, which is bolted to the shield jacket.
- The Model 3078 Shield has a cavity to contain the sources. This cavity is closed by a shielding plug, which is covered with a cap that bolts to the shield jacket.
- The Model 1911 Shield has a cavity to contain the sources. This cavity is closed by a shielding plug, which is covered with a cap that bolts into threaded inserts in the shield.

2-4. Chemical Reaction:

Materials and construction assures no significant chemical, galvanic, or other reaction among contents and components of package, including possible reaction resulting from in leakage of water. Also consider behavior of materials under irradiation.

* USDOT, 49 CFR 173.410 (g)
* USNRC, 10 CFR 71.43 (d)
* IAEA TS-R-1, para. 613

Comply. Package components are stainless steel, depleted uranium, which is separated from all carbon steel by copper spacers and poured foam, tungsten, lead, cork and carbon steel. Based on the low level of radiation emitted from the shield, no adverse effects to the cork inserts or the stainless steel barrel will occur. These materials will have no significant chemical, galvanic or other reactions among the contents and components of the package.

2-5. Valves:

All valves, other than pressure relief valves, shall be provided with an enclosure to retain any leakage from the valve. If valve failure allows release of radioactive contents, then valve shall have protection from unauthorized operation.

* USDOT, 49 CFR 173.412 (g), 173.410 (h)
* USNRC, 10 CFR 71.43 (e)
* IAEA TS-R-1, para. 614, 644

Not applicable. This package has no valves.

2-6. Integrity:

Package must be designed, constructed, and prepared to ensure; no loss or dispersal of the radioactive contents, no more than a 20% increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging, when evaluated against the performance and test requirements.
* USDOT, 49 CFR 173.412 (j) (1) (2)
* USNRC, 10 CFR 71.43 (f)
* IAEA TS-R-1, para. 646

Comply. See Test Plan 90 Report and Test Plan 163 Report.

2-7. No Venting:

A package may not incorporate a feature intended to allow continuous venting during transport.
* USNRC, 10 CFR 71.43 (h)

Not applicable. This package does not incorporate any feature intended to allow continuous venting during transport.

2-8. Air Transport

Package must be designed, constructed, and prepared for transport so that in still air at 38°C (100°F) and in the shade, no accessible surface of a package would have a temperature exceeding 50°C (122°F) in a nonexclusive use shipment, or 85°C (185°F) in an exclusive use shipment.
* USDOT, 49 CFR 173.410 (i) (1)
* USNRC, 10 CFR 71.43 (g), 71.71 (c)(1)
* IAEA TS-R-1, para. 617

Comply. The Specific heat output of Ir-192 is 8.6 mW/Ci. The maximum Type A Ir-192 activity for this container is 62 Ci. (The output activity is corrected by a factor of 2.3 to account for source attenuation and self-absorption). The Specific heat output of Se-75 is 5.1 mW/Ci. The maximum Type A Se-75 activity for this container is 81 Ci. The controlling nuclide heat output is for Ir-192 and equals:

$$8.6\ \mathrm{mW/Ci} \times 62\ \mathrm{Ci} = 533.2\ \mathrm{mW}$$

The radiant energy of the shield without addition of the source at 50°C (122°F) is calculated as follows:

$$q = \sigma A\, \varepsilon (T_1^4 - T_2^4) \qquad \text{Ref. (pg.408)}$$

where: σ = Stefan-Boltzman constant = 5.669×10^{-8} w/m^{2}K^4 Ref. (pg.14)

A = surface area of the drum = $\pi dh + \pi d^2/2 = 1.00\mathrm{m}^2$ (d-dia of the drum=0.49m; h-height =0.53m)

ε = emmisivity of the drum material (stainless steel) = 0.3 Ref. (pg.648)

T_1 = 50°C or 323K

T_2 = 38°C or 311K

Calculating q from the above equation produces the need for a source term of at least 26 W to produce a surface temperature on the surface of the drum of 50°C. The Ir-192 transported in shield in this package is much less than the minimum energy necessary to increase the temperature of the lead to 50°C and therefore the surface temperature of the package will remain less than 50°C.

The integrity of containment will not be impaired if the package is exposed to ambient temperatures ranging from -40°C (-40°F) to 55°C (131°F).
* USDOT, 49 CFR 173.410 (i)(2)
* USNRC, 10 CFR 71.71 (c)(2)
* IAEA TS-R-1, para. 618

Comply. Comply. The primary containment is the welded stainless steel sources. . All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 2. The capsules are shielded within the shield containers, inside the cork inserts inside the stainless steel drum. This temperature range will have no adverse affect on the integrity of the source or the shielding.

Packages containing liquids will be capable of withstanding, without leakage, an internal pressure that produces a differential of not less than 95 kPa (13.8 lb/in^2) (5 kPa for IAEA).
* USDOT, 49 CFR 173.410 (i)(3)
* IAEA TS-R-1, para. 619

Not applicable. No liquids.

2.9 Increased External Pressure

Evaluate the effects of an external pressure of an external pressure of 140 kPa (20 psia) on a package at an initial internal pressure at the minimum normal operating pressure and at a temperature between -20°F and 100°F most unfavorable to the package.
* USNRC, 10 CFR 71.71 (c)(4)

Comply. . All sources in this package must meet a minimum BS/ISO/ANSI N 43.6-1977 Pressure Classification of 3. They have complied with external pressure of 2MN/m^2 abs. (290 lbs/in^2 abs). The rest of the package is unaffected by pressure.

3. Test Requirements.

3-1. Water Spray Test:

Subject test specimen to a water spray that simulates exposure to rainfall of approximately 5 cm per hour for at least an hour. The free drop, stacking, and penetration test below are to be preceded in each case by the water spray test. Do not allow test specimen to dry before each test.
* USDOT, 49 CFR 173.465 (b)
* USNRC, 10 CFR 71.71 (c) (6)
* IAEA TS-R-1, para. 721

Comply. The stainless steel drum is not affected by water and shields the internal components from water. The internal components are not affected by water within the time period of this test. Although the carbon steel jacket on the Model 855 source changer could oxidize over a long period of time, years of experience with this source changer as a standalone transport package have shown no decreased structural integrity. See Test Plan 90 Report and Test Plan 163 Report.

3-2. Free Drop Test:

Subject the test specimen to drop onto a hard, flat, horizontal surface so as to suffer maximum damage in respect of the safety features to be tested. The height of the drop measured from the lowest point of the specimen to the upper surface of the target shall not be less than 1.2m (4 ft) for packages less than 5000 kg (11,000 lbs). See additional regulations for fissile and wood materials. Corner drops of 1 ft onto each corner of the package for cardboard packages.

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

Comply. See Test Plan 90 Report and Test Plan 163 Report.

3-3. Stacking/Compression Test:

Subject the test specimen to a compressive load equal to 5 times the mass of the actual package for a period of 24 hours.

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

Comply. See Test Plan 90 Report and Test Plan 163 Report.

3-4. Penetration Test:

Place the test specimen on a rigid, flat, horizontal surface which will not move significantly while the test is being carried out. Drop a bar, 6 kg (13.25 lb), 3.2 cm (1.26) diameter with hemispherical end, with its longitudinal axis vertical, onto the center of the weakest part of the specimen, so that, if it penetrates sufficiently far, it will hit the containment system. The height of drop measured from the bars lower end to the intended point of impact on the upper surface of the test specimen shall be 1 m (39.37 in).

* USDOT, 49 CFR 173.465 (e)
* USNRC, 10 CFR 71.71 (c) (10)
* IAEA TS-R-1, para. 724

Comply. See Test Plan 90 Report and Test Plan 163 Report.

3-5. Tests for Packages Containing Liquids and Gases:

Subject the test specimen to drop onto a hard, flat, horizontal surface so as to suffer maximum damage in respect of the safety features to be tested. The height of the drop measured from the lowest point of the specimen to the upper surface of the target shall not be less than 9 m (30 ft).
* USDOT, 49 CFR 173.466 (a)(1)
* IAEA TS-R-1, para. 725(a)

Not applicable. No liquids or gases.

Place the test specimen on a rigid, flat, horizontal surface which will not move significantly while the test is being carried out. Drop a bar, 6 kg (13.25 lb), 3.2 cm (1.26) diameter with hemispherical end, with its longitudinal axis vertical, onto the center of the weakest part of the specimen, so that, if it penetrates sufficiently far, it will hit the containment system. The height of drop measured from the bars lower end to the intended point of impact on the upper surface of the test specimen shall be 1.7 m (66.93 in).
* USDOT, 49 CFR 173.466 (a)(2)
* IAEA TS-R-1, para. 725(b)

Not applicable. No liquids or gases.

Section 2.12.4 Appendix: USDOT Special Form Certificate USA/0392/S-96 Rev 12.

U.S. Department
of Transportation

Pipeline and
Hazardous Materials
Safety Administration

East Building, PHH-23
1200 New Jersey Ave, SE
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS

CERTIFICATE USA/0392/S-96, REVISION 12

This certifies that the source described has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - QSA Global, Inc. Model 875 Capsule.

2. Source Description - Cylindrical single encapsulation made of Type 304 or 304L stainless steel and tungsten inert gas or laser welded. Approximate exterior dimensions are 5.2 mm (0.205 in.) in diameter and 7.84 mm (0.309 in.) in length. Inside dimensions vary, but minimum wall thickness is 0.482 mm (0.019 in.). Construction shall be in accordance with attached QSA Global, Inc. Drawing No. R875 INNER, Rev. C.

3. Radioactive Contents - No more than either 8.9 TBq (240.0 Ci) of Cobalt-60 or 14.8 TBq (400.0 Ci) of Iridium-192 in the form of metallic wafers or pellets.

4. Management System Activities - Records of Management System activities required by Paragraph 306 of the IAEA regulations shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on October 31, 2022. Previous editions which have not reached their expiration date may continue to be used.

[1] "Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

CERTIFICATE USA/0392/S-96, REVISION 12

This certificate is issued in accordance with paragraph(s) 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the October 13, 2017 petition by QSA Global, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified By:

for William Schoonover
Associate Administrator for Hazardous Materials Safety

November 03, 2017
(DATE)

Revision 12 - Issued to extend the expiration date.

[redacted]

NOTES:

1. MATERIAL: 304L STAINLESS STEEL.
2. INTERNAL VOID VOLUME TO BE 0.010 mL OR GREATER.
3. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GUARDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL WITHIN THE CAPSULE MAY BE USED.
4. MINIMUM WALL THICKNESS TO BE 0.019.

APPROVALS	DATE
R. [signature]	25 JUL 07
L. [signature]	25 JUL 07

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE 875 SERIES INNER CAPSULE

SIZE	DWG. NO.	REV
A	R875 INNER	C
	SCALE: NONE SHEET 1 OF 1	

ERF # 1739

Section 2.12.5 Appendix: USDOT Special Form Certificate USA/0335/S-96 Rev 12.

U.S. Department
of Transportation

**Pipeline and
Hazardous Materials
Safety Administration**

East Building, PHH-23
1200 New Jersey Ave, SE
Washington, D.C. 20590

**IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS**

CERTIFICATE USA/0335/S-96, REVISION 12

This certifies that the sources described have been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - QSA Global, Inc. Model 875 Series.

2. Source Description - Cylindrical single or double encapsulations with the outer capsule made of Type 304L stainless steel and tungsten inert gas or laser welded. Approximate outer dimensions are 6.35 mm (0.25 in.) in diameter and either 19.05 mm (0.75 in.) or 24.2 mm (0.954 in.) in length. Inner capsules, when present, are made of stainless steel or titanium. Construction of the outer capsule shall be in accordance with attached QSA Global, Inc. Drawing No. R875 OUTER, Rev. C. Construction of any inner capsule shall be in accordance with attached QSA Global, Inc. Drawing No. R875 INNER, Rev. C, or QSA Global, Inc. Drawing No. R87527-40, Rev. A.

3. Radioactive Contents - No more than either 14.8 TBq (400 Ci) of Iridium-192 as a solid metal; 8.14 TBq (220 Ci) of Cobalt-60 as a solid metal; 5.56 TBq (150 Ci) of Selenium-75 as an encapsulated solid metal; 1.11 TBq (30 Ci) of Cesium-137 as encapsulated $CsCl_2$; 1.85 TBq (50 Ci) of Thulium-170 as Tm_2O_3; or 7.4 TBq (200 Ci) of Ytterbium-169 as Yb_2O_3.

[1] "Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

CERTIFICATE USA/0335/S-96, REVISION 12

4. Management System Activities - Records of Management System activities required by Paragraph 306 of the IAEA regulations shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on June 30, 2018. Previous editions which have not reached their expiration date may continue to be used.

This certificate is issued in accordance with paragraph(s) 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the September 6, 2017 petition by QSA Global, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified By:

for William Schoonover
Associate Administrator for Hazardous Materials Safety

September 28, 2017
(DATE)

Revision 12 - Issued to extend the expiration date.

[redacted]

NOTES:

1. INTERNAL VOID TO BE 0.010 mL OR GREATER.
2. MATERIAL: 304L STAINLESS STEEL.

APPROVALS	DATE
[illegible]	7-24-07
[illegible]	24 Aug 07

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

QSA GLOBAL
40 NORTH AVE. BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE 875 SERIES SSDR OUTER CAPSULE

SIZE	DWG. NO.	REV
A	R875 OUTER	C
	SCALE: NONE · SHEET 1 OF 1	

ERF # 1739

[redacted]

NOTES:

1. MATERIAL: 304L STAINLESS STEEL.
2. INTERNAL VOID VOLUME TO BE 0.010 mL OR GREATER.
3. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GUARDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL WITHIN THE CAPSULE MAY BE USED.
4. MINIMUM WALL THICKNESS TO BE 0.019.

APPROVALS	DATE
[illegible signature]	25 Jul 07
[illegible signature]	25 Jul 07

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE 875 SERIES INNER CAPSULE

SIZE	DWG. NO.	REV
A	R875 INNER	C

SCALE: NONE SHEET 1 OF 1

ERF # 1739

[redacted]

1. MATERIAL: 316L STAINLESS STEEL OR EQUIVALENT, OPTIONAL MATERIAL: COMMERCIALLY PURE TITANIUM, GRADE 4.

2. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GAURDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL WITHIN THE CAPSULE MAY BE USED.

3. MINIMUM WALL THICKNESS TO BE 0.009.

APPROVALS	DATE
[signature]	7-24-07
L. [signature]	24Aug07

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE X540N CAPSULE ASSEMBLY

SIZE	DWG. NO.		REV
A	R87527-40		A
	SCALE: NONE	SHEET 1 OF 1	

ERF # 1739

Section 2.12.6 Appendix: USDOT Special Form Certificate USA/0502/S-96 Rev 11.

U.S. Department
of Transportation

Pipeline and
Hazardous Materials
Safety Administration

East Building, PHH-23
1200 New Jersey Ave, SE
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS

CERTIFICATE USA/0502/S-96, REVISION 11

This certifies that the sources described have been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - QSA Global, Inc. Model Nos. X54 (Manufactured before January 1, 1998), X540 (Manufactured on or after February 17, 1981), and X540/1 (Manufactured on or after September 27, 2000).

2. Source Description - Tungsten inert gas or laser seal welded cylindrical single or double encapsulations. The outer encapsulation is made of titanium or stainless steel and the inner encapsulation, if used, is made of titanium, stainless steel, or aluminum. Approximate exterior dimensions are 5.15 mm (0.2 in.) maximum diameter and 15.15 mm (0.6 in.) in length (Model X54); and 5.16 mm (0.2 in.) in diameter and 7.65 mm (0.3 in.) in length (Models X540 and X540/1). Construction shall be in accordance with attached Amersham Drawing No. A10639, Issue C (Model X54) or QSA Global Inc. Drawing No. R87527, Rev. H (Models X540 and X540/1).

3. Radioactive Contents - No more than 17.0 TBq (459.5 Ci) of Cobalt-60 (Model X54); or no more than either 20.0 TBq (540.5 Ci) of Cobalt-60, 17.0 TBq (459.5 Ci) of Iridium-192, or 5.56 TBq (150.3 Ci) of Selenium-75 (Models X540 and X540/1). The Co-60, Ir-192, and Se-75 are in the form of a metal.

[1] "Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

CERTIFICATE USA/0502/S-96, REVISION 11

4. Management System Activities - Records of Management System activities required by Paragraph 306 of the IAEA regulations shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on June 30, 2018. USA/0502/S-96 Revision 10 may be used until February 28, 2018. All other revisions are not authorized for use.

This certificate is issued in accordance with paragraph(s) 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the December 4, 2017 petition by QSA Global, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified By:

for William Schoonover
Associate Administrator for Hazardous
Materials Safety

January 11, 2018
(DATE)

Revision 11 - Issued to update QSA Global Inc. Drawing No. R87527.

DRG NO. A10639

Item	Description	Material	Drawing No.	No.off
1	BODY	STAIN.STL.	A10636 ITEM.1	1
2	PLUG	STAIN.STL.	A10638	1
◇C 3	ACTIVE MATERIAL			—

[redacted]

TOLERANCES	MATERIAL	GENERAL NOTES
———	———	THIRD ANGLE PROJECTION
UNLESS OTHERWISE STATED		MODIFICATIONS INDICATED BY ISSUE IN ◇
SURFACE TEXTURE	FINISH	THIS DRAWING CONFORMS TO BS308.
———	———	ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.
UNLESS OTHERWISE STATED	REMOVE ALL BURRS	DO NOT SCALE

APPROVAL
THIS DRAWING IS NOT TO BE USED FOR ANY PURPOSE UNLESS SIGNED AS APPROVED

SCALE	ISSUE	MOD No.	DATE	DRAWN	CHECKED	APPROVED	QA APPROVED
10:1	C	MS1211	4.1.95	M.A.	[signature]	[signature]	[signature]

Amersham
The Health Science Group

TITLE ASSEMBLY OF CAPSULE X54

USED ON ——— | SHT. SIZE A3 | DRG NO. A10639 | SHT 1 OF SHTS 1

[redacted]

NOTES:

1. INTERNAL VOID TO BE 0.010 mL OR GREATER.
2. MATERIAL: SEE TABLE
3. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GUARDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL OR INNER SOURCE CAPSULE WITHIN THE CAPSULE MAY BE USED.
4. MINIMUM WALL THICKNESS TO BE 0.22.
5. DIMENSIONS ARE IN MILLIMETERS

NOTES:
1. MATERIAL: SEE TABLE

APPROVALS	DATE
[illegible signature]	04DEC17
[illegible signature]	4Dec17

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE X540 CAPSULE SERIES

SIZE A | DWG. NO. R87527 | REV H

SCALE: NONE | SHEET 1 OF 1

ERF # 3726

Section 2.12.7 Appendix: USDOT Special Form Certificate USA/0179/S-96 Rev 12.

U.S. Department
of Transportation

Pipeline and
Hazardous Materials
Safety Administration

East Building, PHH-23
1200 New Jersey Ave, SE
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS

CERTIFICATE USA/0179/S-96, REVISION 12

This certifies that the source described has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - QSA Global, Inc. Series 900 Iridium Capsule.

2. Source Description - Cylindrical single encapsulation made of Type 304L stainless steel and tungsten inert gas or laser welded. Approximate exterior dimensions are 5.2 mm (0.205 in.) in diameter and 15.5 mm (0.611 in.) in length. Inside dimensions vary, but minimum wall thickness is 0.71 mm (0.028 in.). Construction shall be in accordance with attached QSA Global, Inc. Drawing No. 900 CAP, Rev. B.

3. Radioactive Contents - No more than 8.88 TBq (240.0 Ci) of Iridium-192 in solid, metallic form.

4. Management System Activities - Records of Management System activities required by Paragraph 306 of the IAEA regulations shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on October 31, 2022. Previous editions which have not reached their expiration date may continue to be used.

---

[1] "Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

CERTIFICATE USA/0179/S-96, REVISION 12

This certificate is issued in accordance with paragraph(s) 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the October 6, 2017 petition by QSA Global, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified By:

for William Schoonover
Associate Administrator for Hazardous Materials Safety

November 03, 2017
(DATE)

Revision 12 - Issued to extend the expiration date.

[redacted]

NOTES:

1. INTERNAL VOID VOLUME TO BE 0.010 mL OR GREATER
2. MATERIAL: 304L STAINLESS STEEL
3. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GUARDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL WITHIN THE CAPSULE MAY BE USED
4. MINIMUM WALL THICKNESS TO BE 0.028

APPROVALS	DATE
[illegible signature]	7-24-07
[illegible signature]	24 Jul 07

QSA GLOBAL

40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

TITLE 900 SERIES CAPSULE

SIZE A | DWG. NO. **900 CAP** | REV **B**

SCALE: NONE | SHEET 1 OF 1

ERF # 1739

Section 2.12.8 Appendix: USDOT Special Form Certificate USA/0497/S-96 Rev 6

U.S. Department
of Transportation

Pipeline and
Hazardous Materials
Safety Administration

East Building, PHH-23
1200 New Jersey Ave, SE
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS

CERTIFICATE USA/0497/S-96, REVISION 6

This certifies that the source described has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - QSA Global, Inc. Model X.444.

2. Source Description - Cylindrical single or double encapsulation made of Type 316 or 316L stainless steel and tungsten inert gas or laser seal welded. Approximate maximum exterior dimensions are 5.6 mm (0.22 in.) in diameter and 15.0 mm (0.59 in.) in length. Minimum wall thickness is 0.63 mm (0.025 in.). Any inner encapsulation shall be made of stainless steel, aluminum, or titanium. Construction shall be in accordance with attached QSA Global, Inc. Drawing No. R87522, Rev. B.

3. Radioactive Contents - No more than 10.92 TBq (295.0 Ci) of Iridium-192 or Cobalt-60 in solid metal form.

4. Management System Activities - Records of Management System activities required by Paragraph 306 of the IAEA regulations shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on January 31, 2023. Previous editions which have not reached their expiration date may continue to be used.

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[1] "Regulations for the Safe Transport of Radioactive Material, 2012 Edition, No. SSR-6" published by the International Atomic Energy Agency (IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

CERTIFICATE USA/0497/S-96, REVISION 6

This certificate is issued in accordance with paragraph(s) 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the January 2, 2018 petition by QSA Global, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified By:

for William Schoonover
Associate Administrator for Hazardous Materials Safety

January 19, 2018
(DATE)

Revision 6 - Issued to extend the expiration date.

[redacted]

NOTES:

1. INTERNAL VOID TO BE 0.010 mL OR GREATER.
2. MATERIAL: 316L STAINLESS STEEL OR EQUIVALENT.
3. INNER CAVITY DIMENSIONS MAY VARY. METALLIC SPACERS, SPRINGS AND GUARDS WHICH SECURE AND/OR LOCATE THE RADIOACTIVE MATERIAL WITHIN THE CAPSULE MAY BE USED.
4. MINIMUM WALL THICKNESS TO BE 0.025.

APPROVALS	DATE
[signature]	7-24-09
[signature]	27Jul09

UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES
TOLERANCES:
FRACTIONS ± 1/8
X.X ± 0.12
X.XX ± 0.06
X.XXX ± 0.020

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

TITLE X444 CAPSULE ASSEMBLY

SIZE A | DWG. NO. R87522 | REV B

SCALE: NONE | SHEET 1 OF 1

ERF # 1739

Section 2.12.9 Appendix: USDOT Special Form Certificate USA/0805/S-96 Rev 0.

U.S. Department
of Transportation
Pipeline and
Hazardous Materials
Safety Administration

East Building, PHH-23
1200 New Jersey Avenue Southeast
Washington, D.C. 20590

IAEA CERTIFICATE OF COMPETENT AUTHORITY
SPECIAL FORM RADIOACTIVE MATERIALS
CERTIFICATE USA/0805/S-96, REVISION 0

This certifies that the source described has been demonstrated to meet the regulatory requirements for special form radioactive material as prescribed in the regulations of the International Atomic Energy Agency[1] and the United States of America[2] for the transport of radioactive material.

1. Source Identification - QSA Global, Inc. Model X9103.

2. Source Description - Cylindrical single encapsulation made of 300 series stainless steel and tungsten inert gas or laser seal welded. The radioactive material may be inside an inner assembly made of vanadium, titanium, titanium alloy, or zirconium alloy. The capsule may also contain stainless steel, titanium, titanium alloy, or vanadium spacers or springs to secure the radioactive material or inner assembly within the capsule. Approximate outer dimensions are 6.86 mm (0.27 in.) in diameter and 26.92 mm (1.06 in.) in length. Construction shall be in accordance with attached QSA Global, Inc. Drawing No. R90017-1, Rev. A.

3. Radioactive Contents - No more than 7.4 TBq (200 Ci) of Selenium-75. The Se-75 is in the form of a physically inert and stable metal-selenide compound.

4. Quality Assurance - Records of Quality Assurance activities required by Paragraph 310 of the IAEA regulations[1] shall be maintained and made available to the authorized officials for at least three years after the last shipment authorized by this certificate. Consignors in the United States exporting shipments under this certificate shall satisfy the applicable requirements of Subpart H of 10 CFR 71.

5. Expiration Date - This certificate expires on November 30, 2019.

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[1] "Regulations for the Safe Transport of Radioactive Material, 1996 Edition (Revised), No. TS-R-1 (ST-1, Revised)," published by the International Atomic Energy Agency(IAEA), Vienna, Austria.

[2] Title 49, Code of Federal Regulations, Parts 100-199, United States of America.

CERTIFICATE USA/0805/S-96, REVISION 0

This certificate is issued in accordance with paragraph 804 of the IAEA Regulations and Section 173.476 of Title 49 of the Code of Federal Regulations, in response to the October 24, 2014 petition by QSA Global, Inc., Burlington, MA, and in consideration of other information on file in this Office.

Certified By:

for Dr. Magdy El-Sibaie
Associate Administrator for Hazardous Materials Safety

Dec 09 2014
(DATE)

Revision 0 - Original issue.

[redacted]

1. STAINLESS STEEL, TITANIUM, TITANIUM ALLOY, OR VANADIUM SPACERS OR SPRINGS TO SECURE AND/OR LOCATE THE ACTIVE INNER SOURCE CAPSULE OR TARGET (MADE USING VANADIUM, TITANIUM, TITANIUM ALLOY, OR ZIRCONIUM ALLOY COMPONENTS) WITHIN THE SOURCE LINK MAY BE USED.

ITEM	QTY	TITLE	MATERIAL
4	1	X9103 Se LINK BODY	STAINLESS STEEL
3	1	X9103 Se LINK SHANK	STAINLESS STEEL
2	1	ACTIVE CAPSULE / TARGET	--
1	1	INNER CAPSULE ASSEMBLY (OPTIONAL)	--

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

QSA GLOBAL
40 NORTH AVE, BURLINGTON, MA 01803

DESCRIPTIVE DRAWING

ERF #	APPROVALS	DATE
3160	[signature] MAP	20 OCT 14
	[signature]	24 oct 14

TITLE	X9103
SIZE	A
DWG. NO.	**R90017-1**
SCALE	NONE
SHEET	1 OF 1
REV	A

Section 2.12.10 Appendix: Test Plan 214 Rev 0 dated July 2017

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

TEST PLAN 214

MODEL 976 CONTAINER

TYPE (B) TRANSPORT PACKAGE DROP TEST

Originator	e-Signed by Steve Grenier on 2017-07-13 20:10:32 GMT

APPROVALS	
Engineering	e-Signed by Paul Benson on 2017-07-14 12:39:02 GMT
Regulatory	e-Signed by Lori Podolak on 2017-07-14 14:42:19 GMT
Quality Assurance	e-Signed by John Hieber on 2017-07-17 13:07:16 GMT

Contents

Section 1 Introduction

This plan tests the Model 976 transport package without the lid closure clamp, CLM009, to the requirements of 10 CFR Part 71, revised as of January 26, 2004 and the IAEA Regulations for the Safe Transport of Radioactive Material, No. TS-R-1 (2005 Edition). Lid closure for the package will depend solely on the four radial lid closure bolts during the tests.

If the Model 976 package can pass the transport tests of 10 CFR Part 71 without the clamp, then the clamp can be designated as optional and will not be required for the Type-B transport package.

The plan describes the test package, testing equipment, testing scenario, justifies the package orientation, 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 to this 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.

Section 2 Transport Package Description

The Model 976 consists of three transport package versions, the Model 976A, 976C and 976F. These are described on the currently approved descriptive drawing R97600 Revision B.

More information about the Model 976 package can be found in the original transport Test Plan 90 and Amersham Test Number 1835. **Figure 2.1** is a cross-sectional view of the 976A transport container. The Model 976A version is selected for testing because it is the heaviest package configuration and is made with the least amount of cork impact absorbing material.

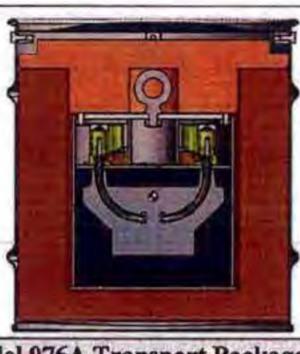


Figure 2.1. Model 976A Transport Package – Section View

Section 3 Regulatory Compliance

The test specimen shall first be subjected to the required normal conditions of transport tests of 10 CFR Part 71.71followed by the hypothetical accident condition test sequence of 10 CFR Part 71.73. The complete testing order is given in section 8.1 of this plan.

3.1 Normal Transport Condition Tests

The **water spray** preconditioning of 10 CFR 71.71 (c)(6) will not be performed as the package is constructed of waterproof materials throughout. Water spray would not degrade the structural integrity of the Model 976 transport package.

The Model 976 package shall be subjected to the **1.2-meter free drop test** per 10 CFR 71.71 (c)(7).

The **compression test** of 10 CFR 71.71 (c)(9) will not be performed since the clamp band does not contribute significantly to the structural integrity of the package during the compression test. Results of the test as performed under Test Plan 90 demonstrated the drum body and lid along with the four radial lid closure bolts maintained the package integrity under this test condition. Testing is not expected to change for a Model 976 package without the lid closure band.

The **penetration test** of 10 CFR 71.71 (c)(10) will not be performed since the penetration test results given in the plan 90 is not expected to change for a Model 976 package without the lid closure band.

Without the clamp band, the drum outer surface and any one of the four lid closure bolts would be the only other external items available to be damaged by a dropped penetration bar. The following assessment indicates these items will remain intact with minimal damage and any damage that does occur will not reduce the overall safety of the transport package.

The maximum impact force generated by the 13-pound penetration bar dropped from 40-inches is equal to about 600 pounds (rounded up) if we conservatively assume the bar stops at about 0.01 seconds on impact. The maximum impact force calculation: $(((W / G) \times (2 \times G \times H)^{1/2}) / T)$, where W is 13-pounds, G is 32.2 feet/sec^2, H is 3.33 feet, and T is 0.01 seconds.

A quick and conservative calculation of the maximum piercing force required to breach the outer surface of the 0.054-inch thick stainless steel drum with a 1.25-inch diameter bar is about 12,000 pounds. The piercing force is calculated using (Pi x D x t x S), where Pi is 3.14, D is 1.25-inches, t is 0.054-inches, and S is 57,000 lb/in^2 (See reference #1). Compared to the minimum 57,000 pierce strength of the drum material, the pierce stress is about 1/5 of the allowable piercing strength. Therefore, the penetration bar will not pierce through the drum outer surface when dropped from 40-inches on any external surface of the drum.

The penetration bar dropped onto one of the lid closure bolt heads will be assessed in two different orientations, the first orientation is a hit applied axially onto the flat surface of the bolt head and the second is a hit applied radially onto the side of the bolt head.

A 600-pound axial load applied to the flat surface of the bolt head is not expected to compress or deform the 3/8 bolt head enough to cause the bolt to fail. The impact generates a maximum compressive stress of 777 lb/in^2 based on the load acting on the stress area of the bolt. The compressive stress is equal to (W / Ah), where Ah is the area under the bolt head, 0.772 in^2.

Compared to the minimum 30,000 lb/in^2 yield strength of the drum and bolt material, the 777 lb/in^2 impact stress is insignificant and not expected have any effect.

The drum geometry does not allow the entire 600-pound load to be applied radially to the side of the bolt head. The contact point on the bar is about 37 degrees from the axis of the bar. This means only about 80% or 480-pounds of the load is applied radially. The radial impact generates a maximum direct shear of 20,645 lb/in^2 based on the load acting on the end of the 0.3-inch long head. The shear force is equal to (W / Ab x L), where Ab is the stress area of the 3/8-16 bolt thread, 0.0775 in^2, and L is the unsupported length of the bolt head, 0.3-inch. Compared to the minimum 61,500 lb/in^2 (0.82 x 75,000: See reference #2) shear strength for the bolt material, the maximum direct shear stress is only 1/3 of the allowable strength.

Therefore, a 13-pound penetration bar dropped from 40-inches onto any external feature of the Model 976 package will not reduce the integrity or overall effectiveness of the package.

References:

1. Mark's Standard Handbook for Mechanical Engineers, Tenth Edition, Page 13-14,13-15 & Table 13.2.2.

2. Machine Design, Theory and Practice, Macmillan Publishing, Copyright 1975, page 89.

3.2 Hypothetical Accident Condition Tests

The **crush test** in 10 CFR 71.73 (c)(2) will not be performed because the package contents are qualified as Special-Form radioactive material and therefore this test is not required.

The Model 976 package shall be subjected to the **9-meter free drop test** as described in 10 CFR 71.73 (c)(1), and then the **puncture test** in accordance with 10 CFR 71.73 (c)(3).

The **thermal test** in 10 CFR 71.73 (c)(4) will be assessed and will not be performed. The assessment shall be based on the cumulative damage to the test specimen immediately after the puncture test.

The **immersion test** in 10 CFR 71.73 (c)(6) will not be performed. Only the source capsule (containment vessel) is sealed and able to pressurize in 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 will be adjusted higher because the actual test specimens are expected to weigh less than the maximum allowable package weight.

Individual adjusted drop heights will be determined after each test specimen is weighed and just before the drop tests. The adjusted heights will provide each test specimen with the same impact energy as a package weighing the maximum transport package weight. The maximum weight for any Model 976 transport package is 300 pounds.

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 to produce equivalent impact (potential) energy of a heavier test specimen dropped at a lower height.

The ratio of the maximum package weight over the actual specimen weight times the required drop height equals the adjusted drop height. As an example:

Maximum package weight = $\mathbf{W_1}$ = 300 lbs

Actual test specimen weight = $\mathbf{W_2}$ = 250 lbs

Required drop height = $\mathbf{H_1}$ = 30-feet

Adjusted drop height = $\mathbf{H_2} = (W_1/W_2) \times H_1 = (300/250) \times 30 = 36$-feet

The adjusted drop height shall be recorded on the test worksheets.

Section 4 Discussion on System Failure Modes of Interest

The primary failure mode of interest in all tests is to attempt to dislodge the inner shield container, in this case, the Model 855, from the drum assembly enough to cause damage, failure, and/or malfunction to the inner shield and/or source securing features.

All test specimens are to be built with a Model 855 inner shield container which is relatively fire resistant compared to the other Model 976 inner shield containers made with lead. The condition of the drum assembly and the location of the inner shield container relative to the drum assembly shall be evaluated to ensure all three versions of the Model 976 package will continue to meet the NCT and HAC test requirements of 10 CFR Part 71.

The thermal test assessment discussed in this report shall rely heavily upon the state of the drum lid after being subjected to all the drop tests in the sequence.

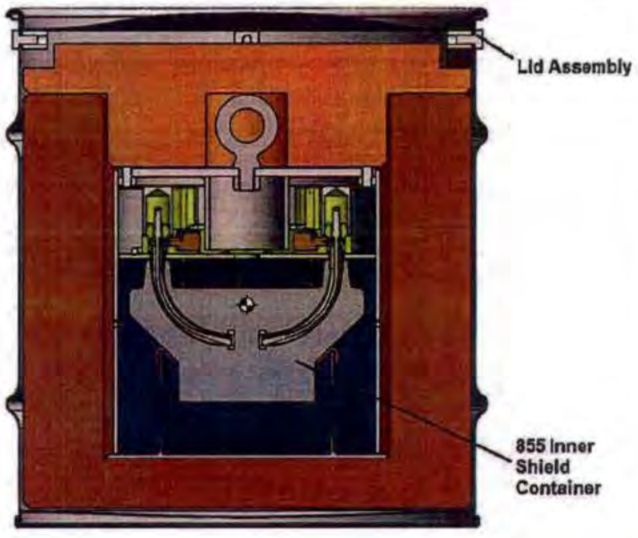


Figure 4.1. Safety components affected by the drop tests

Section 5 Assessment of Package Conformance

5.1 Normal Conditions of Transport (71.43 (f)) Pass Criteria

After being subject to any of the normal conditions of transport tests, the specimen shall be assessed to the following pass criteria.

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 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)) Pass Criteria

After being subjected to the hypothetical accident conditions test sequence, the specimen shall be assessed to the following pass criteria.

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 Model 976 transport package is designed to carry multiple special form radioactive source capsules certified to 10 CFR Part 71 and IAEA TS-R-1. The source capsules have already been tested to the special form test requirements and their welds verified during manufacturing.

This test plan does not address any additional tests associated with radioactive source containment except 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 radiation measurements will then be compared with the pre-test measurements to evaluate the source shielding capability of the package after testing.

Section 6 Construction and Condition of Test Specimens

The test specimens shall be constructed in accordance with QSA Global engineering drawings and Quality Assurance Program. The drawings accurately depict the design intent and the quality assurance program ensures the specimen are built and inspected in a manner consistent with the actual transport package. The general assembly drawing for the test specimen and the test specimen build documents shall be included in the test report.

6.1 Test Specimen Justification

A total of six test specimens (See **Table 6.1.**) will be built to test three different methods for attaching the drum lid to the drum. Four of the six will be built to drawing TP214-NCB which is identical to the currently approved Type-B package but without the CLM009 band. One of the six will be built to drawing TP214-ASB which is identical to TP214-NCB except the CLM009 band is replaced by the standard band supplied by the manufacturer with the 20-gallon drum. Another one of the six will be built to drawing TP214-FSB replaces the fixed nuts welded on the lid with floating nuts retained in square tubes welded to the lid.

Table 6.1. Test Specimen top level assemblies

Dwg. Name	Dwg. Number	Revision	Quantity	TMI#
Model 976A as approved but without CLM009 band	TP214-NCB	A	4	976
Model 976A as approved but with a standard band	TP214-ASB	A	1	983
Model 976A floating fasteners without a band	TP214-FSB	A	1	984

The reason for testing the TP214-NCB specimens is to allow the flexibility of transporting the Model 976 package without the CLM009 band currently required for the approved Type-B package.

TP214-ASB will be tested to allow the Model 976 package to be transported with the clamp band provided with the drum from the manufacturer.

TP214-FSB is to be tested to allow the package to be transported with an improved lid bolting system in place of the current lid bolting system. The improved system allows the lid nut to float within a square tube welded to the lid. The floating nut provides position adjustment to help reduce the potential for the bolt binding in the drum hole during assembly.

The object is to have all test specimen keep the drum lid attached to the drum and the inner shield container inside the drum during the entire test sequence. If successful, then the currently specified clamp band will no longer be required for the transport package and one of the other options could be used instead if they can also keep the lid attached.

There are only a small number of Model 855 inner shield containers available for testing and use. Therefore, just one Model 855 container will be used and reused for each orientation specific test specimen.

After the puncture test, the specimen will be fully examined and photographed to assess the test damage and then the Model 855 inner shield container will be transferred into the drum assembly of another test specimen for testing in a different drop orientation. This process will be repeated until the last test orientation has been tested.

The final radiation profile inspection shall be performed on each orientation specific specimen with the common Model 855 container loaded with active sources unless it is deemed unsafe to do so.

6.2 Test Specimen Structural Materials

The structural components of the lid assembly and drum are type 304 series stainless steel. This material was selected for its corrosion protection properties, but more importantly for its toughness over a wide temperature range when subjected to an energy limited event like any of the three transport drop tests (1.2-meter, 9-meter, & 1-meter puncture). These components are expected to bend but not break upon impact.

6.3 Temperature Conditions

The mechanical properties of the drum and lid assemblies do not change significantly over the temperature range of -40°F to +100°F (-40°C to +38°C). The test results of test plan 90 show the 976 package inner shield containers, including the welded carbon steel Model 855 inner shield container is not adversely affected by the low temperatures down to -40°C. Therefore, the test specimen temperature shall be ambient to the surrounding environment at the time of the test.

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 successfully tested to withstand a pressure range of at least 3.6 PSI absolute to 290 PSI absolute. This was based on Class 3 pressure test requirements of ANSI/HPS 43.6-2007. The tests will therefore be performed at atmospheric pressure.

6.5 Vibration Conditions

Vibration normally occurring in transport has been addressed under the existing 976 SAR Revision 8 Section 2.6.5. The elimination of the lid closure band is not expected to change the vibration performance of the Model 976 transport package since the four lid closure bolts are sufficient to ensure the lit remains secured to the drum body during 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

The test specimen shall follow the planned sequence presented below. Any change to the planned sequence or drop orientations shall require pre-approval by Engineering, Regulatory and Quality Assurance based on a documented justification and description for the new orientation.

8.1 Overall Test Sequence

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

8.2 Test Specimen Preparation and Inspection

1. Manufacture the test specimens using TMI #976, 983, & 984.
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 specimen complies 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 specimen complies with the drawings and the QSA Global Quality Assurance Program.
5. Prepare the test specimens for transport.

8.2.1 1.2m & 9m Free Drop Test Set-up

To set up a package for the specified drop test:

1. Place the specimen on the drop surface and position it to the planned orientation.
2. Measure and record the ambient temperature.
3. Raise the package slightly and photograph the set-up.
4. Start the video recorder.

5. Raise the package so that the impact target is at the weight adjusted specified height above the drop surface. Ensure the center of gravity is over the impact point
6. Drop the package.
7. Stop the video recorder.
8. Record the damage to the package and take a photographic record.

8.2.2 Drop Test Orientations

There are essentially only six possible drop orientations for a drum style transport package. Figures 8.1 through 8.4 show the four orientations evaluated in this test plan.

The other two orientations not tested in this plan are the side impact and the bottom corner impact orientations. These are not expected to damage or remove the lid assembly more than the four orientations to be tested.

The shallow-angle orientation shown in Figure 8.4 is not expected to generate high impact loads but is expected to cause the drum lid to buckle outward on the first impact and then possibly separate the lid from the drum on the second impact.

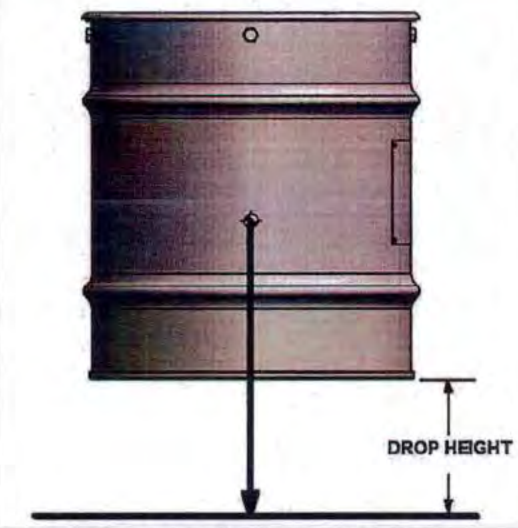


Figure 8.1 Bottom Surface Orientation

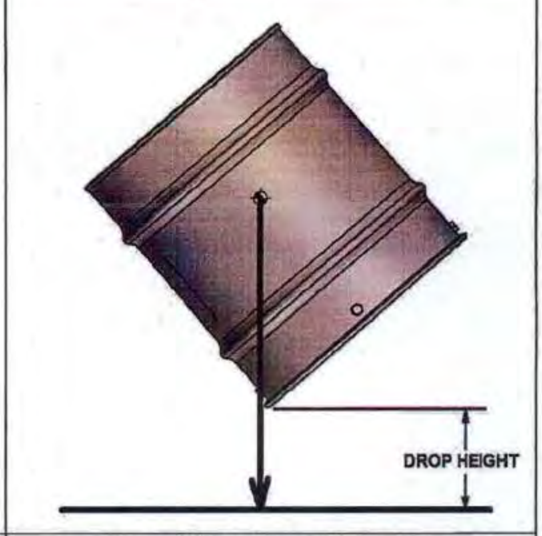


Figure 8.2 Top Corner Orientation

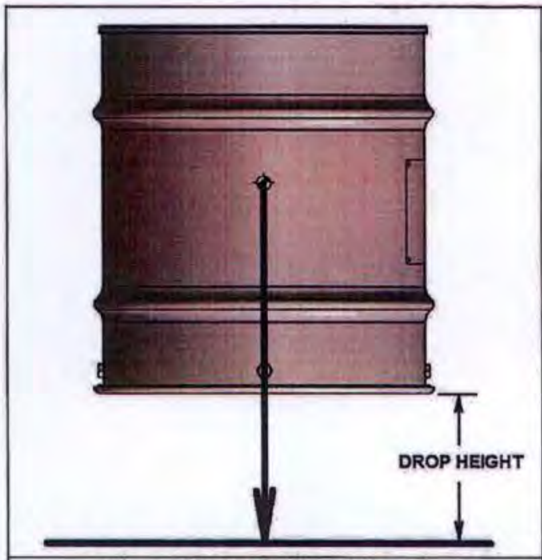


Figure 8.3 Top Surface Orientation

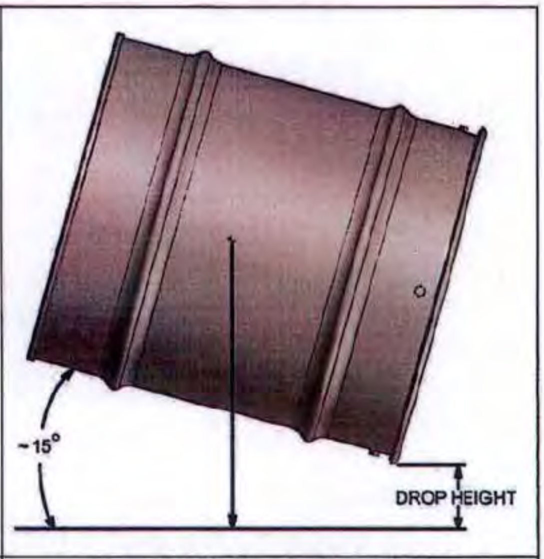


Figure 8.4 Shallow Angle Orientation

8.2.3 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, and this test plan.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71 and IAEA TS-R-1.
- Assess the damage to the specimen to decide whether testing of that specimen is to continue.
- Evaluate the condition of the specimen after the free drop test to determine what changes, if any, are necessary in package orientation to achieve maximum damage in the next drop test.

8.3 Puncture Drop Test

The package is dropped from a height of at least 1m (40-inch) onto the puncture billet. This test uses the 12-inch high puncture billet. The billet meets the minimum height (8-inch) required in 10 CFR 71.73(c) (3). The specimen has no projections or overhanging members longer than 12-inch 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 (Figures 8.1 thru 8.4). 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 as compared to the planned orientation.

8.3.1 Puncture Test Set-up

To set up a package for the puncture test:

1. Position the test specimen in the test orientation.
2. Measure and record the ambient temperature.

3. Raise the package slightly and photograph the set-up.
4. Start the video recorder.
5. Raise the package so that the impact target is the weight adjusted equivalent to 1m (40") between the impact point on the package and the top of the puncture billet.
6. Drop the package.
7. Stop the video recorder.
8. Do not move the test specimen until a photo is taken.
9. Photograph and record any damage to the package.
10. Unless testing the last orientation, transfer the inner shield container into another specimen and secure the drum lid.
11. Measure and record the weight of the test specimen.

8.3.2 *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, and this test plan.
- Make a preliminary evaluation of the specimen relative to the requirements of 10 CFR 71 and IAEA TS-R-1.

8.4 *Post Test Inspection*

Perform the test inspection after the puncture tests.

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

8.5 *Thermal Test Assessment*

Refer to Test Plan Report 90 for details pertaining to the thermal test results of the currently approved Model 976 package design.

The final resting position of each test specimen after the puncture drop shall be used to evaluate and assess the package to the thermal test conditions of 10 CFR Part 71.73 (c)(4).

The assessment will also be based on an examination of the cumulative damage to the test specimen up to that point of the test sequence.

Experience from previous thermal tests performed on the Model 660 & Model 680 transport packages has found the depleted uranium (DU) shield will oxidize and diminish its ability to block radiation only after the foam fill surrounding the shield combusts, chars, and then falls away from the shield.

Charred foam or in this case cork provides enough thermal insulation to prevent the shield from oxidizing if the charred foam or cork remains in place before and during the thermal test. A large tear or hole in the encasement of the Model 855 inner shield container would need to be assessed to determine whether the transport package would pass or fail the thermal test.

And since the Model 976 also includes lead shielded inner containers, any opening in the drum large enough to allow heated air and/or thermal radiant energy to access the lead shield would also need to be assessed against the pass criteria of section 5.2.

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.

8.6 Test Specimen Storage

Place the test specimen in an appropriate storage location. Engineering and Regulatory approvals are required before disposing of 976 drum body and lid assembly test specimens. Model 855 inner shield container, if not evaluated and justified for continued use as a Type B transport container component, should be stored in the appropriate low level activity area because it contains DU.

Section 9 Worksheets

Use the following worksheets for executing the tests of section 8. 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 Documentation

Test Specimen

Model #	Drawing Number	Serial Number	Weight (lbs.)	Attach TMI/RC	Attach IIR	Attach NCR

Tools & Equipment

Tool Description	Enter the Model and Serial Number Mark NA when not used.	Attach Inspection Report or Calibration Certificate
Drop Surface	**T10740, S/N 001**	**Yes**
Puncture Billet	**T10119, SN01**	**Yes**

Signature/Date

Engineering:	Regulatory:	Quality Assurance:

<table>
<tr><th colspan="6">1.2-Meter Drop Test Data Sheet</th></tr>
<tr><td>Step</td><td>Instruction</td><td colspan="4">Test Data</td></tr>
<tr><td>1</td><td>Record test location.</td><td colspan="4">QSA Global, Inc. 40 North Ave, Burlington, MA</td></tr>
<tr><td>2</td><td>Record test date & time.</td><td colspan="2">Date:</td><td colspan="2">Time:</td></tr>
<tr><td>3</td><td>Record test specimen serial number.</td><td colspan="4"></td></tr>
<tr><td>4</td><td>Record Model 855 serial number.</td><td colspan="4"></td></tr>
<tr><td>5</td><td>Measure test specimen weight.</td><td></td><td colspan="2">Scale S/N:</td><td></td></tr>
<tr><td>6</td><td>Measure the ambient temperature (°C):</td><td></td><td colspan="2">Instrument S/N:</td><td></td></tr>
<tr><td>7</td><td>Record actual drop height.</td><td colspan="4"></td></tr>
<tr><td>8</td><td colspan="5">Place the specimen on the drop surface and position it in the planned drop orientation.</td></tr>
<tr><td>9</td><td colspan="5">Raise the specimen slightly and photograph the set-up in at least two perpendicular planes.</td></tr>
<tr><td>10</td><td colspan="5">Begin the video recorder</td></tr>
<tr><td>11</td><td colspan="5">Release the test specimen.</td></tr>
<tr><td>12</td><td colspan="5">Stop the video recorder.</td></tr>
<tr><td>13</td><td colspan="4">Was the point of impact achieved?</td><td>Yes or No</td></tr>
<tr><td>14</td><td colspan="5">Photograph the test specimen immediately after the drop.</td></tr>
<tr><td>15</td><td>Record the damage to the test specimen.</td><td colspan="4"></td></tr>
<tr><td rowspan="3">16</td><td rowspan="3">Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.</td><td colspan="3">Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?</td><td>Yes or No</td></tr>
<tr><td colspan="3">Were there any changes in the planned drop orientation? If yes, then explain.</td><td>Yes or No</td></tr>
<tr><td colspan="3">Can testing continue for this specimen?</td><td>Yes or No</td></tr>
<tr><td colspan="6">Test witnessed by (Signature/Date)</td></tr>
<tr><td colspan="2">Engineering:</td><td colspan="2">Regulatory Affairs:</td><td colspan="2">Quality Assurance:</td></tr>
</table>

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data		
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA		
2	Record test date & time.	Date:	Time:	
3	Record test specimen serial number.			
4	Record Model 855 serial number.			
5	Measure test specimen weight.		Scale S/N:	
6	Measure the ambient temperature (°C):		Instrument S/N:	
7	Record actual drop height.			
8	Place the specimen on the drop surface and position it in the planned drop orientation.			
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes.			
10	Begin the video recorder			
11	Release the test specimen.			
12	Stop the video recorder.			
13	Was the point of impact achieved?			Yes or No
14	Photograph the test specimen immediately after the drop.			
15	Record the damage to the test specimen.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?		Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.		Yes or No
		Can testing continue for this specimen?		Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:

Puncture Drop Test Data Sheet

Step	Instruction	Test Data		
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA		
2	Record test date & time.	Date:	Time:	
3	Record test specimen serial number.			
4	Record Model 855 serial number.			
5	Measure test specimen weight.		Scale S/N:	
6	Measure the ambient temperature (°C):		Instrument S/N:	
7	Record actual drop height.			
8	Place the specimen on the drop surface and position it in the planned drop orientation.			
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes.			
10	Begin the video recorder			
11	Release the test specimen.			
12	Stop the video recorder.			
13	Was the point of impact achieved?			Yes or No
14	Photograph the test specimen immediately after the drop.			
15	Record the damage to the test specimen.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?		Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.		Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:

Post Test Inspection Data Sheet	
Test Specimen Serial No.:	Last Test Performed:
1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.:	
2. Describe the condition and position of the simulated source wire assembly.	
3. 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. 4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806. 5. 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.	
6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No	
7. If radiography is performed, describe any damage or failures found.	
Completed by:	Date:

Section 2.12.11 Appendix: Test Plan Report No. 214 dated March 2018 (minus Appendices C & D).

TEST PLAN 214 REPORT

MODEL 976 TRANSPORT PACKAGE

TRANSPORT TEST RESULTS

Rev 0

Originator	S Grenier 23 MARCH 2018

APPROVALS	
Engineering	23 Mar 18
Regulatory	23 Mar 18
Quality Assurance	23 MAR 18

Contents

Test Plan 214 Report

Section 1 Introduction

This report documents the test results performed on the Model 976 transport package in three special configurations to the tests in Test Plan 214. The results confirm the Model 976 transport package in any one of the three proposed configurations passes all the transport test requirements specified in Test Plan 214, the Code of Federal Regulations, 10 CFR Part 71, revised as of January 26, 2004 and criteria stated in the IAEA Regulations for the Safe Transport of Radioactive Material, No. TS-R-1 2009 Edition.

Three alternate configurations proposed for the Model 976 package tested under test plan 214 are as follows;

- The package in its currently approved configuration but without a closure ring (clamp band). In this configuration, the cover relies solely on the four radial bolts to keep the cover on and contents in the drum.
- The package in its currently approved configuration but without a clamp band and with the four fixed cover nuts on the approved configuration replaced by four floating cover nuts as a proposed alternate configuration. This configuration is proposed to help increase the life of the cover nuts and bolts.
- The package in its currently approved configuration but clamp band CLM009 is replaced by a standard steel clamp band supplied with the drum. This configuration allows the package to use a less expensive and readily available clamp band.

The sequence of the testing began with the 1.2-meter free drop test required under the normal conditions of transport (NCT) as a worst-case preconditioning of the package followed by the 9-meter free drop and then the 1-meter puncture drop, both required under the hypothetical accident condition (HAC) tests of 10 CFR Part 71. The final test in the sequence, the thermal test, is an assessment of the specimen in its position and condition immediately after the puncture drop test.

To satisfy the IAEA Regulations, the 9-meter free drop and 1-meter puncture drop tests are also assessed in reverse order.

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

- The ***water spray*** preconditioning is not required since the exterior of the package is constructed of waterproof materials.
- The ***compression test*** is not performed because the cover retaining system is not adversely affected by the compression test as found in the results of Test Plan 90. Both test plan 90 and the recommended transport configuration for these packages specified in Section 7 require use of a clamp band with similar material strengths/properties. Therefore, results of the compression testing under TP 90 are representative of the package configuration recommended under Section 7.
- The ***penetration test*** is not performed based on the assessment in Test Plan 214 and previous results in Test Plan 90. These demonstrate that the package integrity is not adversely affected by the penetration test.

- The ***crush test*** was not performed because the package is used to transport special form radioactive material only which is excluded from the testing under 10 CFR 71.73(c)(2).
- The ***immersion – fissile material test*** is not required since the Model 976 package does not transport fissile material.
- The ***immersion – all packages test*** is not needed since the materials of construction used in the Model 976 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 test specimens were constructed in accordance with QSA Global engineering drawings and Quality Assurance Program. The drawings and manufacturing documents accurately depict the intended design at the time of testing along with methods for building and verifying the finished product. There were no significant deviations and/or changes to the test specimen configuration before testing. The only modifications were the addition of holes and hoist rings, and the attachment of a strip of duct tape used to secure the height measure to the specimen prior to drop testing. These minor changes were made to aid in test specimen orientation setup. The added holes, hoist rings and piece of duct tape used during testing did not aid in the ability of the specimens to pass any of the tests. See **Appendix C**.

The same Model 855 shielded unit, serial number 10, was transferred into each test specimen drum/cork assembly before the sequence of drops. The four cover bolts were tightened to five foot-pounds as specified on each test specimen drawing. All specimens were weighed just before testing at the drop pad using the hanging weight scale, serial number QSA215.

The test specimens built for this test were made in the Model 976A configuration. **Table 2.1** is a summary of the build documentation. Shipping labels and nameplates were not attached for testing.

Table 2.1: Test Specimen Manufacturing Documentation

Test Specimen	Drawing No.	TMI	Serial No.	Weight
Model 976A	TP214-NCB	976	TP214-NCB-1	274.5
Model 976A	TP214-NCB	976	TP214-NCB-2	274.5
Model 976A	TP214-NCB	976	TP214-NCB-3	274.5
Model 976A	TP214-NCB	976	TP214-NCB-4	274.5
Model 976A	TP214-ASB	983	TP214-ASB-1	279.5
Model 976A	TP214-FSB	984	TP214-FSB-1	276

Figure 2.1 a schematic diagram of the Model 976 transport package. The nomenclature used in **Figure 2.1** is referenced throughout this report.

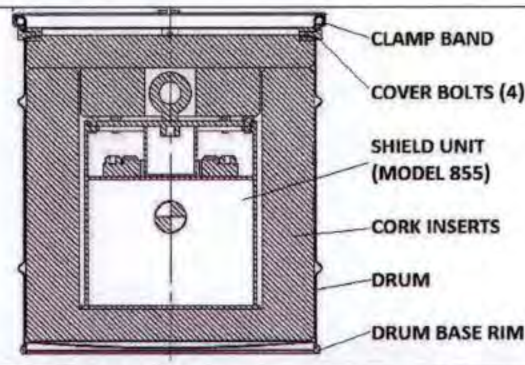


Figure 2.1. Model 976 Transport Package Schematic.

Test specimens TP214-NCB-1 through -4 were built to the currently approved design, but without the clamp band (closure ring), CLM009.

Test Specimen TP214-ASB-1 was the same as the currently approved design but replaced the currently approved clamp band with the standard carbon steel clamp band supplied with the drum. See **Appendix E**. The clamp band, hex bolt, and hex nut tested was painted/plated carbon steel. The bolt was tightened to 10 +/- 2 ft-lb.

Test specimen TP214-FSB-1 replaced the four weld-on nuts fixed to the cover in the currently approved design with four floating stainless steel nuts captured inside hollow stainless steel retainers welded to the cover. The clamp band was not included or tested with this specimen.

The primary containment system consists of each seal welded source capsule assembly held securely in the shield unit. The capsule assembly, tested to a minimum ANSI/ISO Class 3, or 2 MPa pressure test requirements, is manufactured at atmospheric pressure and ambient temperature and therefore does not need to be adjusted for the test assessment. The secondary containment system consists of the shield unit.

The materials of construction used in the Model 976 transport packages have sufficient mechanical and physical properties between -40°C (-40°F) and +38°C (+100°F). The test results from Test Plan 90 and 163 indicate the cork inserts will crack but remain intact when dropped at temperatures at or below -40°C. We can expect the cork inserts to crack and remain in place so long as the cover remains on the drum. Therefore, final test assessments shall consider cracked cork inserts without having to lower the specimen temperature for the testing.

2.1 Test Specimen Modification

There are no deviations or changes to the test specimens except for lifting point holes and duct tape use to attach drop height measures to the specimens prior to testing. All build data is recorded on the temporary manufacturing instructions (TMI) for each test specimen presented in **Appendix C**.

Section 3 Failure Modes and Test Orientations

3.1 Test Failure Modes

The primary failure mode of interest in all tests attempted to completely remove or damage the package cover enough to cause one or more of the following:

- Loss or dispersal of radioactive material or contents.
- A significant increase in external surface radiation levels after NCT testing.
- A substantial reduction in the effectiveness of the packaging after NCT testing.
- Damage to the package which could indicate it would not pass the HAC Thermal Testing if performed.
- External radiation dose rate exceeding 10-mSv/h (1-rem/h) at 1 m (40 in) from the external surface of the package.
- Escape of other radioactive material exceeding a total amount A_2 in 1 week.

The condition of the drum assembly and the location of the inner shield unit relative to the drum assembly are evaluated and assessed to ensure all three versions of the Model 976 package will continue to meet the NCT and HAC test requirements of 10 CFR Part 71. Refer to **Section 6.4** for this assessment.

The thermal test assessment which is included in the hypothetical accident condition test assessment of **Section 6.2** relies heavily upon the condition of the package immediately after being subjected to the puncture test.

Each of the test orientations, shown in **Table 3.1,** target specific areas on the package to either remove the cover, create significant gaps in the cover/lid seal that could adversely impact the package during the HAC Thermal test, or cause enough damage to elevate post-test radiation measurements.

3.2 Test Orientations

Table 3.1 shows the planned orientation for test specimens TP214-NCB-1 through -4. The post-test visual examinations of all four specimens were used as the basis for justifying the test orientations for the last two specimens, TP214-FSB-1 and TP214-ASB-1. Initially the shallow-angle or slap down orientation was expected to be selected, but the insignificant damage to the package after the series of tests shifted the selection to the cover edge orientation.

All orientations attempt to exploit the failure modes discussed in **Section 3.1**. The same orientation was used for the entire series of drops, 1.2-meter, 9-meter, and puncture, for each specimen.

Table 3.1: Planned Drop Test Orientations

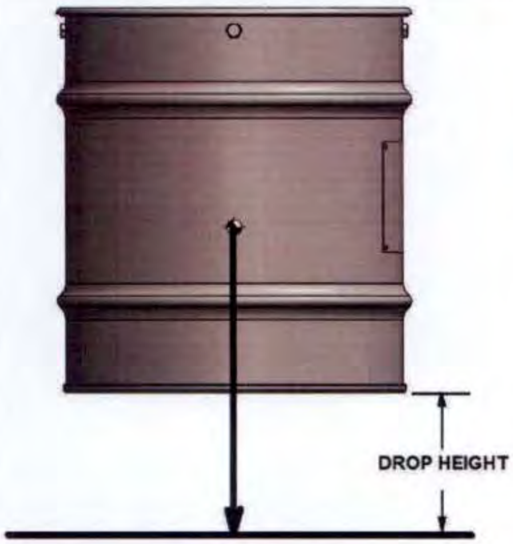


Figure 3.1.A. Bottom Surface Impact.
(Planned for TP214-NCB-1)

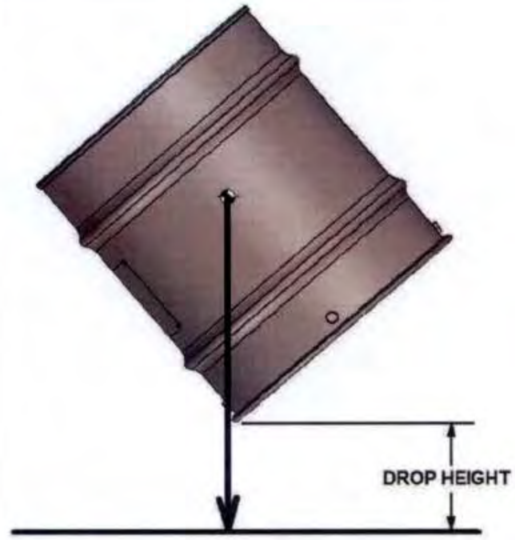


Figure 3.1.B. Cover Edge Impact.
(Planned for TP214-NCB-2)

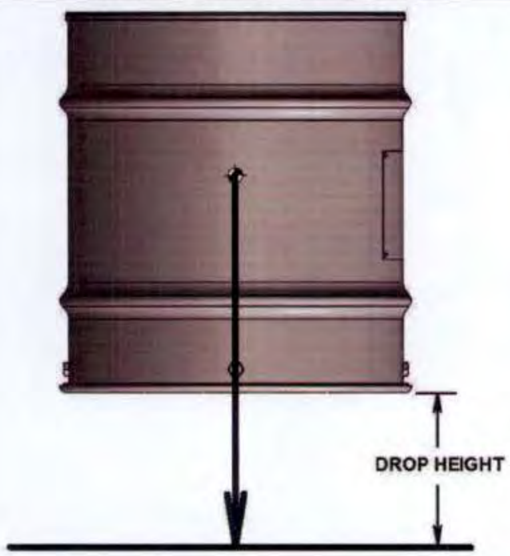


Figure 3.1.C. Cover Surface Impact.
(Planned for TP214-NCB-3)

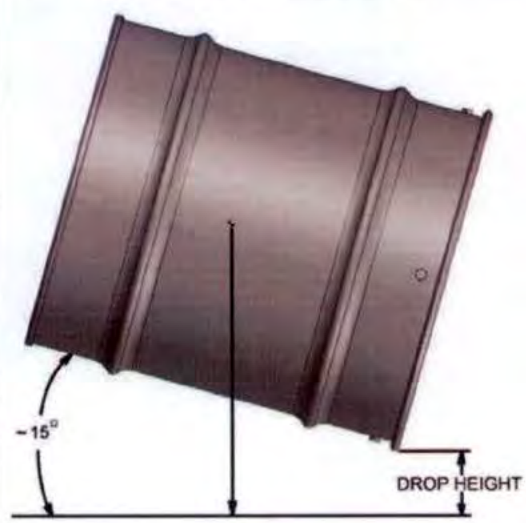


Figure 3.1.D. Slap-Down Impact.
(Planned for TP214-NCB-4)

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 allows for future Model 976 transport packages built heavier than the actual test specimens, but less than the maximum allowable weight specified for the transport package configuration to comply with 10 CFR Part 71.

The lightest weight of any of the test specimens built for Test Plan 214 was 274.5 pounds. The maximum allowable transport weight for any Model 976 package is 300 pounds Therefore, the weight ratio used for the height adjustment of all test specimens was 300 lb / 275 lb = 1.09.

The adjusted minimum drop heights were as follows:

- Adjusted 1.2-meter drop test height = 1.3-meters
- Adjusted 9-meter drop test height = 9.8-meters
- Adjusted 1-meter puncture drop test height = 1.1-meters

The impact energy produced by the adjusted height in all drop tests was equal to or greater than the impact energy produced by the transport package built to its maximum weight and dropped at the required drop height specified in 10 CFR Part 71.

Section 4 Test Results

4.1 Test Specimen TP214-NCB-1 Test Results

Table 4.1A: 1.2-meter Drop Test #1.	
Specimen serial number.	TP214-NCB-1
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to test orientation.	None. See **Figure 3.1.A**.
Actual drop height.	52-inches (1.3-meters)
Temperature during test.	6.4 °C (44 °F)

Figure 4.1A.1: 1.2-meter Drop Test #1 – Orientation View #1.

Figure 4.1A.2: 1.2-meter Drop Test #1 – Orientation View #2.

Figure 4.1A.3: TP214-NCB-1 immediately after 1.2-meter Drop Test.

Damage: None found. Cover on. Bolts intact. No lid/base gaps.

Table 4.1B: 9-meter Drop Test #1.	
Specimen serial number.	TP214-NCB-1
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Test specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.A**.
Actual drop height.	32-feet 9-inches (9.9-meters)
Temperature during test.	6.2 °C (43 °F)

Figure 4.1B.1: 9-meter Drop Test #1 – Orientation View #1.

Figure 4.1B.2: 9-meter Drop Test #1 - Orientation View #2.

Figure 4.1B.3: TP214-NCB-1 immediately after 9-meter Drop Test.

Figure 4.1B.4: TP214-NCB-1 immediately after 9-meter Drop Test.

Damage: Slight compression dent on outer side wall & base of drum. Cover on. Bolts intact. No lid/base gaps.

Table 4.1C: Puncture Test #1.	
Specimen serial number.	TP214-NCB-1
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Test specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.A**.
Actual drop height.	44-inches (1.1-meters)
Temperature during test.	5.9 °C (43 °F)

Figure 4.1C.1: Puncture Test #1 – Orientation View #1.

Figure 4.1C.2: Puncture Test #1 – TP214-NCB-1 Orientation View #2.

Figure 4.1C.3: TP214-NCB-1 immediately after Puncture Test.

Figure 4.1C.4: TP214-NCB-1 immediately after Puncture Test.

Damage: No additional damage found. Cover on. Bolts intact. No lid/base gaps.

4.2 Test Specimen TP214-NCB-2 Test Results

Table 4.2A: 1.2-meter Drop Test #2.	
Specimen serial number.	TP214-NCB-2
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.B.**
Actual drop height.	52-inches (1.3-meters)
Temperature during test.	6 °C (43 °F)

Figure 4.2A.1: 1.2-meter Drop Test #2 – Orientation View #1.

Figure 4.2A.2: 1.2-meter Drop Test #2 – Orientation View #2.

Figure 4.2A.3: TP214-NCB-2 immediately after 1.2-meter Drop Test.

Figure 4.2A.4: TP214-NCB-2 immediately after 1.2-meter Drop Test.

Damage: Slightly crushed cover and drum edge about 0.5-inch. Cover on. Bolts intact. No lid/base gaps.

Table 4.2B: 9-meter Drop Test #2.	
Specimen serial number.	TP214-NCB-2
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.B**.
Actual drop height.	32-feet 9-inches (9.9-meters)
Temperature during test.	5.9 °C (43 °F)
	
Figure 4.2B.1: 9-meter Drop Test #2 – Orientation View #1.	**Figure 4.2B.2: 9-meter Drop Test #2 – Orientation View #2.**
	
Figure 4.2B.3: TP214-NCB-2 immediately after 9-meter Drop Test.	**Figure 4.2B.4: TP214-NCB-2 immediately after 9-meter Drop Test.**
Damage: Significantly crushed cover and drum edge. Cover on. Bolts intact. No lid/base gaps.	

Table 4.2C: Puncture Test #2.	
Specimen serial number.	TP214-NCB-2
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.B.**
Actual drop height.	44-inches (1.1-meters)
Temperature during test.	6.1 °C (43 °F)
	
Figure 4.2C.1: Puncture Test #2 – Orientation View #1.	**Figure 4.2C.2: Puncture Test #2 – Orientation View #2.**
	
Figure 4.2C.3: TP214-NCB-2 immediately after Puncture Test.	**Figure 4.2C.4: TP214-NCB-2 immediately after Puncture Test.**
Damage: No additional damage found. Cover on. Bolts intact. No lid/base gaps.	

4.3 Test Specimen TP214-NCB-3 Test Results

Table 4.3A: 1.2-meter Drop Test #3.	
Specimen serial number.	TP214-NCB-3
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.C**.
Actual drop height.	52-inches (1.3-meters)
Temperature during test.	6.5 °C (44 °F)

Figure 4.3A.1: 1.2-meter Drop #3 – Orientation View #1.

Figure 4.3A.2: 1.2-meter Drop #3 – Orientation View #2.

Figure 4.3A.3: TP214-NCB-3 immediately after 1.2-meter Drop Test.

Damage: None found. Cover on. Bolts intact. No lid/base gaps.

Table 4.3B: 9-meter Drop Test #3.	
Specimen serial number.	TP214-NCB-3
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.C**.
Actual drop height.	32-feet 9-inches (9.9-meters)
Temperature during test.	6.3 °C (43 °F)
	
Figure 4.3B.1: 9-meter Drop #3 – Orientation View #1.	**Figure 4.3B.2: 9-meter Drop #3 – Orientation View #2.**

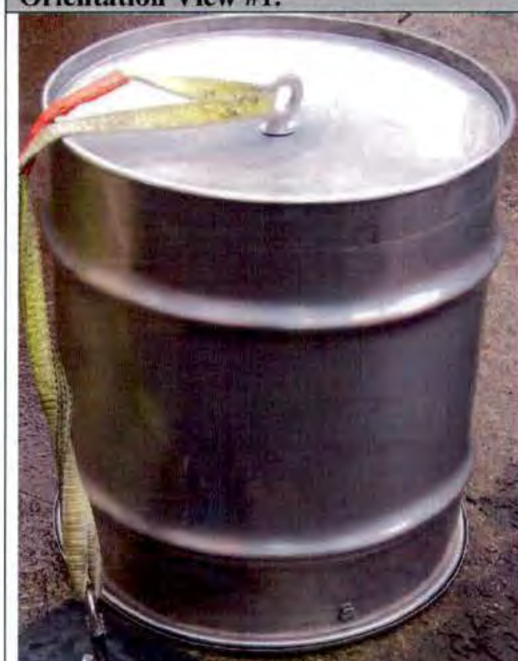
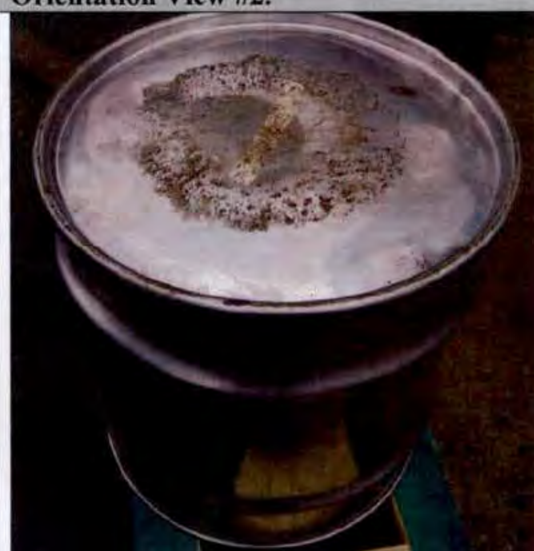



Figure 4.3B.3: TP214-NCB-3 immediately after 9-meter Drop Test.	**Figure 4.3B.4: TP214-NCB-3 immediately after 9-meter Drop Test.**
Damage: Slight outer drum wall compression. Cover on. Bolts intact. No lid/base gaps.	

Table 4.3C: Puncture Test #3.	
Specimen serial number.	TP214-NCB-3
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.C.**
Actual drop height.	44-inches (1.1-meters)
Temperature during test.	6.6 °C (44 °F)
	
Figure 4.3C.1: Puncture Test #3 – Orientation View #1.	**Figure 4.3C.2: Puncture Test #3 – Orientation View #2.**
	
Figure 4.3C.3: TP214-NCB-3 immediately after Puncture Test.	**Figure 4.3C.4: TP214-NCB-3 immediately after Puncture Test.**
Damage: None found. Cover on. Bolts intact. No lid/base gaps.	

4.4 Test Specimen TP214-NCB-4 Test Results

Table 4.4A: 1.2-meter Drop Test #4.	
Specimen serial number.	TP214-NCB-4
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.D**.
Actual drop height.	52-inches (1.3-meters)
Temperature during test.	7.4 °C (45 °F)

Figure 4.4A.1: 1.2-meter Drop #4 – Orientation View #1.

Figure 4.4A.2: 1.2-meter Drop #4 – Orientation View #2.

Figure 4.4A.3: TP214-NCB-4 immediately after 1.2-meter Drop Test.

Damage: Slight flattening of drum outer wall. Cover on. Bolts intact. No lid/base gaps.

Table 4.4B: 9-meter Drop Test #4.	
Specimen serial number.	TP214-NCB-4
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.D.**
Actual drop height.	32-feet 9-inches (9.9-meters)
Temperature during test.	7.7 °C (46 °F)
	
Figure 4.4B.1: 9-meter Drop #4 – Orientation View #1.	**Figure 4.4B.2: 9-meter Drop #4 – Orientation View #2.**
	
Figure 4.4B.3: TP214-NCB-4 immediately after 9-meter Drop Test.	**Figure 4.4B.4: TP214-NCB-4 immediately after 9-meter Drop Test.**
Damage: Significant flattening of drum outer wall. Cover on. Bolts intact. No lid/base gaps.	

Table 4.4C: Puncture Test #4.	
Specimen serial number.	TP214-NCB-4
Specimen configuration.	Same as the currently approved package, but with no clamp band included.
Specimen weight.	274.5 pounds
Changes to orientation.	None. See **Figure 3.1.D**.
Discussion on possible orientation change: Based on damage to TP214-NCB-2, an impact on the cover or bolts is expected to cause only negligible damage.	
Actual drop height.	44-inches (1.1-meters)
Temperature during test.	8.1 °C (47 °F)
	
Figure 4.4C.1: Puncture Test #4 – Orientation View #1.	**Figure 4.4C.2: Puncture Test #4 – Orientation View #2.**
	
Figure 4.4C.3: TP214-NCB-4 immediately after Puncture Test.	**Figure 4.4C.4: TP214-NCB-4 immediately after Puncture Test.**
Damage: Imprint of puncture billet on drum. Cover on. Bolts intact.	

4.5 Test Specimen TP214-FSB-1 Test Results

Table 4.5A: 1.2-meter Drop Test #5.	
Specimen serial number.	TP214-FSB-1
Specimen configuration.	Same as the currently approved package, but with no clamp band included and fixed nuts replaced with floating nuts welded to cover.
Specimen weight.	276 pounds
Orientation selected.	**Figure 3.1.B** based on damage to TP214-NCB-2.
Actual drop height.	52-inches (1.3-meters)
Temperature during test.	9.4 °C (49 °F)

Figure 4.5A.1: 1.2-meter Drop #5. Orientation View #1.

Figure 4.5A.2: 1.2-meter Drop #5 – Orientation View #2.

Figure 4.5A.3: TP214-FSB-1 immediately after 1.2-meter Drop Test.

Damage: Minor crushed cover and drum edge. Cover on. Bolts intact. No lid/base gaps.

Table 4.5B: 9-meter Drop Test #5.	
Specimen serial number.	TP214-FSB-1
Specimen configuration.	Same as the currently approved package, but with no clamp band included and fixed nuts replaced with floating nuts welded to cover.
Specimen weight.	276 pounds
Orientation selected.	**Figure 3.1.B** based on damage to TP214-NCB-2.
Actual drop height.	32-feet 9-inches (9.9-meters)
Temperature during test.	10 °C (50 °F)
	
Figure 4.5B.1: 9-meter Drop #5 – Orientation View #1.	**Figure 4.5B.2: 9-meter Drop #5 – Orientation View #2.**
	
Figure 4.5B.3: TP214-FSB-1 immediately after 9-meter Drop Test.	**Figure 4.5B.4: TP214-FSB-1 immediately after 9-meter Drop Test.**
Damage: Two gaps between cover and drum. Each one about 0.3-inch wide maximum then tapering down to no gap. Total length for each gap is about 6 inches. Cover on. Bolts intact.	

Table 4.5C: Puncture Test #5.	
Specimen serial number.	TP214-FSB-1
Specimen configuration.	Same as the currently approved package, but with no clamp band included and fixed nuts replaced with floating nuts welded to cover.
Specimen weight.	276 pounds
Orientation selected.	**Figure 3.1.B** based on damage to TP214-NCB-2.
Actual drop height.	44-inches (1.1-meters)
Temperature during test.	9.4 °C (49 °F)
	
Figure 4.5C.1: Puncture Test #5 – Orientation View #1.	**Figure 4.5C.2: Puncture Test #5 – Orientation View #2.**
	
Figure 4.5C.3: TP214-FSB-1 immediately after Puncture Test.	**Figure 4.5C.4: TP214-FSB-1 immediately after Puncture Test.**
Damage: No additional damage found. Cover on, with 2 gaps ~180° apart. Bolts intact.	

4.6 Test Specimen TP214-ASB-1 Test Results

Table 4.6A: 1.2-meter Drop Test #6.	
Specimen serial number.	TP214-ASB-1
Specimen configuration.	Same as the currently approved package, but with clamp band CLM009 replaced by a standard carbon steel clamp band.
Specimen weight.	279.5 pounds
Orientation selected.	**Figure 3.1.B** based on damage to TP214-FSB-1.
Actual drop height.	52-inches (1.3-meters)
Temperature during test.	9.7 °C (49 °F)

Figure 4.6A.1: 1.2-meter Drop #6 – Orientation View #1.

Figure 4.6A.2: 1.2-meter Drop #6 – Orientation View #2.

Figure 4.6A.3: TP214-ASB-1 immediately after 1.2-meter Drop Test.

Damage: Minor crushed cover and drum edge. Cover on. Bolts intact. No lid/base gaps.

Table 4.6B: 9-meter Drop Test #6.	
Specimen serial number.	TP214-ASB-1
Specimen configuration.	Same as the currently approved package, but with clamp band CLM009 replaced by a standard carbon steel clamp band.
Specimen weight.	279.5 pounds
Orientation selected.	**Figure 3.1.B** based on damage to TP214-FSB-1.
Actual drop height.	32-feet 9-inches (9.9-meters)
Temperature during test.	9.9 °C (50 °F)

Figure 4.6B.1: 9-meter Drop #6 – Orientation View #1.

Figure 4.6B.2: 9-meter Drop #6 – Orientation View #2.

Figure 4.6B.3: TP214-ASB-1 immediately after 9-meter Drop Test.

Figure 4.6B.4: TP214-ASB-1 immediately after 9-meter Drop Test.

Damage: Significant cover and drum edge crushed. No gaps. Cover on. Bolts intact. No lid/base gaps.

Table 4.6C: Puncture Test #6.	
Specimen serial number.	TP214-ASB-1
Specimen configuration.	Same as the currently approved package, but with clamp band CLM009 replaced by a standard carbon steel clamp band.
Specimen weight.	279.5 pounds
Orientation selected.	**Figure 3.1.B** based on damage to TP214-FSB-1.
Actual drop height.	44-inches (1.1-meters)
Temperature during test.	11.1 °C (52 °F)

Figure 4.6C.1: Puncture Test #6 – Orientation View #1

Figure 4.6C.2: Puncture Test #6 – Orientation View #2

Figure 4.6C.3: TP214-ASB-1 immediately after Puncture Test.

Damage: No additional damage found. No gap. Cover on. Bolts intact. No lid/base gaps.

Section 5 Test Specimen Profile Inspections

Radiation measurements were taken before and after the testing for each specimen adjusted to the maximum Ir-192 capacity for the Model 976A transport package. The maximum radiation values found on the surface and at one meter from the surface of each specimen is given in **Tables 5.1** and **5.2** respectively. The results show all measurements are significantly lower than the normal transport limits of 200 mR/hr at the surface of the package and 10 mR/hr at 1-meter from the surface of the package. In addition, there is essentially no change between the before and after test measurements.

Table 5.1 Radiation measurements at surface.

Test Specimen	Maximum Dose Measured (mR/hr)			
	Before Test	Location	After Test	Location
TP214-NCB-1	32	Bottom	29	Bottom
TP214-NCB-2	30	Bottom	32	Bottom
TP214-NCB-3	28	Bottom	30	Top
TP214-NCB-4	47	Bottom	31	Bottom
TP214-ASB-1	34	Top	34	Bottom
TP214-FSB-1	30	Bottom	32	Top

Table 5.2 Radiation measurements at 1-meter from surface.

Test Specimen	Maximum Dose Measured (mR/hr)			
	Before Test	Location	After Test	Location
TP214-NCB-1	1.3	Top	1.2	Top
TP214-NCB-2	1.1	Bottom	1.5	Bottom
TP214-NCB-3	1.6	Bottom	1.4	Top
TP214-NCB-4	1.2	Top	1.4	Bottom
TP214-ASB-1	1.4	Bottom	1.4	Bottom
TP214-FSB-1	1.1	Bottom	1.5	Bottom

Section 6 Test Assessments

6.1 Normal Conditions of Transport Test Assessment

All 1.2-meter free drop tests were performed in accordance with the test requirements of this test plan, 10 CFR part 71, and IAEA TS-R-1 2009 Edition.

Visual examination and radiation measurements taken after testing confirms all specimen had:

- No loss or dispersal of radioactive material or contents.
- No significant increase in external surface radiation levels.

- No substantial reduction in the effectiveness of the packaging.

The lack of damage and the low levels of radiation on and around the package after testing confirms the package meets the normal conditions of transport requirements of 10 CFR 71 and IAEA TS-R-1 2009 Edition.

6.2 Hypothetical Accident Condition Test Assessment

All 9-meter free drop and puncture tests were performed in accordance with the requirements of this test plan, 10 CFR part 71, and IAEA TS-R-1 2009 Edition.

Visual examination and radiation measurements taken after testing confirms all specimen had:

- 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.

The most significant damage to the package resulted when it was dropped from 9-meters in the cover edge orientation. Three test specimens each configured slightly differently were dropped in this same orientation. These specimens are identified as, TP214-NCB-2, TP214-FSB-1, and TP214-ASB-1. All sustained pronounced deformation at the cover edge, but all covers on all test specimen remained attached to their drums and the source assemblies contained within the Model 855 shielded container were unaffected and fully secured.

An interesting observation was found in testing the three specimens dropped in the cover edge orientation. It appears the alignment of the cover bolts in relation to the impact point directly affects the crumple bend in the cover caused by the primary impact when dropped at 9-meters. The reason for the affect is explained below with a description of each of the three specimens.

- Test specimen TP214-NCB-2 was tested with the cover bolts aligned at 90 degrees from the impact point on the package. In this case, the deformation produced no gaps between the cover and drum opening.

- Test specimen TP214-FSB-1 was tested with the cover bolts aligned at 45 degrees from the impact point on the package. In this case, the deformation produced two small gaps between the cover and drum opening, one on each side of the impact point.

- Test specimen TP214-ASB-1 was also tested with the cover bolts aligned at 45 degrees from the impact point on the package. But in this case, the deformation produced no gaps between the cover and drum opening. In this configuration, the steel clamp band provided enough compressive resistance to limit the lid bending thereby preventing the gap formation.

The thermal test is assessed based on the condition and position of all the test specimens immediately after the puncture test. The thermal test assessment already given in the Test Plan 163 test report will be used to support this assessment.

The condition of the all the test specimens, except for TP214-FSB-1, had damage identical to the specimens tested under Test Plan 163. With TP214-FSB-1, the two small gaps between the cover and drum could increase the heat load into the top layers of the cork inserts during the fire test. This condition is not included with the thermal assessment given in the Test Plan 163 report. Since the two gaps in the cover could affect the lead shielding of the other Model 976C

and 976F packages, and since no additional thermal testing was perform, a clamp band, meeting the minimum coverage area and strength requirements as the one tested on specimen TP214-ASB-1, will be required for Type B shipments for these package designs. However, the clamp band no longer needs to be the special version currently approved for the package (Ref: RCLM009 Rev C). A standard carbon steel clamp band and hardware, possessing the dimensions and material construction important to safety as the one tested in specimen TP214-ASB-1 and shown in **Appendix E**, will be sufficient to prevent the two gaps in the cover and match the thermal assessment as given in Section 5.5 of Test Plan 163 report Revision 1 (**See Appendix F**)

Based on the above assessment, the Model 976A using either the fixed or floating nut cover configurations, in conjunction with the standard steel clamp band/hardware criteria, will meet the hypothetical accident conditions transport requirements of 10 CFR 71 and IAEA TS-R-1 2009 Edition.

6.3 Reverse Sequence of 30-Foot Free Drop & Puncture Assessment

If the test sequence were reversed and performed with the puncture test before the 9-meter free drop, the Model 976 transport package would continue to meet the HAC requirements of 10 CFR Part 71. The test results show no obvious opportunity for the puncture billet to pierce through the package, remove the cover from the drum, increase the size of the two gaps found on one specimen, or affect the source location and security within the package.

Based on this assessment, the Model 976 transport package successfully meets the hypothetical accident conditions transport test requirements of IAEA TS-R-1 2009 Edition.

6.4 Other Model 976 Configuration Assessments

The test assessments below are given for the other two untested Model 976 configurations, Models 976C and 976F. The assessments are based on the test results and a comparison of the differences between key features of the tested model and the untested models.

6.4.1 Model 976C Configuration Assessment

Table 6.4.1. shows the key (features) differences between the tested Model 976A and the untested Model 976C as well as the effect these differences may have on the untested model if it had been tested.

Table 6.4.1. Model 976C Assessment.

Feature	Model 976A (Tested)	Model 976C (Assessed)	Effect on results
Maximum Package Weight	300 lb	190 lb	Less impact damage
Maximum Shield Weight	225 lb	114 lb	Less impact load
Cork Insert Volume	3,486 in^3	4,266 in^3	More impact absorption
Shielding Materials	Depleted Uranium	Lead	No impact if using configuration with clamp band

The Model 976C weighs about 37% less and contains 18% more cork than the Model 976A. **Table 6.4.1.** indicates significantly less damage and better test results compared to the tested Model 976A.

6.4.2 Model 976F Configuration Assessment

Table 6.4.2. shows the key (features) differences between the tested Model 976A and the untested Model 976F as well as the effect these differences may have on the untested model if it had been tested.

Table 6.4.2. Model 976F Assessment.

Feature	Model 976A (Tested)	Model 976F (Assessed)	Effect on results
Maximum Package Weight	300 lb	263 lb	Less impact damage
Maximum Shield Weight	225 lb	184 lb	Less impact load
Cork Insert Volume	3,486 in^3	4,129 in^3	More impact absorption
Shielding Materials	Depleted Uranium	Lead	No impact if using configuration with clamp band

The Model 976F weighs about 12% less and contains 16% more cork than the Model 976A. Table 6.4.2. indicates slightly less damage or equivalent test results compared to the tested Model 976A.

Section 7 Final Test Assessment

The Model 976 transport package configured with a standard clamp band and with either the fixed or floating nuts for cover bolt down meets the requirements of 10 CFR Part 71.

The package configured without a clamp band with just the bolt down cover may not meet the requirements of 10 CFR Part 71. Additional thermal testing would be required to make a full assessment of the no clamp band package configuration. This configuration will not be requested for Type B approval unless a determination is made to perform additional thermal testing to support its compliance.

The results and assessments in this report confirm the Model 976 transport packages, with a standard clamp band/hardware and with either the floating or fixed cover nut arrangement, meet the test requirements of Test Plan 214, 10 CFR Part 71, and IAEA TS-R-1 2009.

Appendix A: Radiation Profile Results

TP214-NCB-1 Radiation Profile Inspection

Initial Build Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

TMI # 976

Sheet 1 of 10

Shield Data

Model: 976A | Serial # TP214-NCB-1 | Radionuclide: Ir-192 | Max. Capacity 1000 Ci
Shield P/N: NA | Shield Heat # NA | Lot # NA

Profile Process Data

Source Model: 424-9	Source Ser. # See attached	Radionuclide: Ir-192	Activity: 887.5 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA

Capacity Correction Factor: 1.12

Location	Measured Dose Rate mR/hr: At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	Adjusted Dose Rate mR/hr: At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	23	1.04	NA	1.2	27	NA	1.3
Right	7	1.10		.2	9		.2
Front	7	1.10		.3	9		.3
Left	7	1.10		.3	9		.3
Rear	7	1.10		.3	9		.3
Bottom	26	1.08		1.0	32		1.1
				Acceptance Criteria:	≤ 200	NA	< 10.0
				Result: (Check one) Accept	✓	Reject	

Inspector: [signature] Date: 12/1/17 NCR #

Comments:
- Source Container model 855, SN10
- Orientation is front SN mostly facing forward
- All Readings include a background of .05 mR/hr

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

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Post Test Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 5 of 10

Shield Data

Model: 976A | Serial # TP214-NCB-1 | Radionuclide: Ir-192 | Max. Capacity 1000 Ci
Shield P/N: NA | Shield Heat # NA | Lot # NA

Profile Process Data

Source Model: 424-9	Source Ser. # See attached	Radionuclide: Ir-192	Activity: 909.7 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA

Capacity Correction Factor: 1.10

Location	Measured Dose Rate mR/hr: At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	Adjusted Dose Rate mR/hr: At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	22	1.04	NA	1.1	25	NA	1.2
Right	8	1.10		.3	10		.3
Front	8	1.10		.2	10		.2
Left	9	1.10		.3	11		.3
Rear	8	1.10		.3	10		.3
Bottom	24	1.08		1.0	29		1.1
				Acceptance Criteria:	≤ 200	N/A	< 10.0
				Result: (Check one) Accept	✓	Reject	

Inspector: [signature] Date: 1/22/18 NCR #

Comments:
- Source Container 855, SN10
- Orientation is front SN mostly facing front forward
- All Readings include background of .05 mR/hr

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 Page 1 of 1 27 January 2010

TP214-NCB-2 Radiation Profile Inspection

Initial Build Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

TMI # 976

Sheet 2 of 10

Shield Data

Model: 976A | Serial # TP214-NCB-2 | Radionuclide: Ir-192 | Max. Capacity 1000 Ci
Shield P/N: NA | Shield Heat # NA | Lot # NA

Profile Process Data

Source Model: 424-9	Source Ser. # See attached	Radionuclide: Ir-192	Activity: 777.8 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA

Capacity Correction Factor: 1.11

Location	Measured Dose Rate mR/hr: At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	Adjusted Dose Rate mR/hr: At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	24	1.04	NA	1.0	28	NA	1.1
Right	7	1.10		.3	9		.3
Front	8	1.10		.3	10		.3
Left	8	1.10		.3	10		.3
Rear	8	1.10		.3	10		.3
Bottom	25	1.08		.8	30		.9
				Acceptance Criteria:	≤ 200	NA	< 10.0
				Result: (Check one) Accept	✓	Reject	

Inspector: [signature] Date: 11/30/17 NCR #

Comments:
- Source Container model 855, SN10
- Orientation is front SN mostly facing forward
- All Readings include background of .05 mR/hr

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 Page 1 of 1 27 January 2010

Post Test Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 2 of 10

Shield Data

Model: 976A | Serial # TP214-NCB-2 | Radionuclide: Ir-192 | Max. Capacity 1000 Ci
Shield P/N: NA | Shield Heat # NA | Lot # NA

Profile Process Data

Source Model: 424-9	Source Ser. # See attached	Radionuclide: Ir-192	Activity: 872.8 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA

Capacity Correction Factor: 1.12

Location	Measured Dose Rate mR/hr: At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	Adjusted Dose Rate mR/hr: At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	25	1.04	NA	1.3	29	NA	1.5
Right	6	1.10		.2	7		.2
Front	8	1.10		.3	10		.3
Left	8	1.10		.2	10		.2
Rear	7	1.10		.3	7		.3
Bottom	26	1.08		.7	32		.8
				Acceptance Criteria:	≤ 200	N/A	< 10.0
				Result: (Check one) Accept	✓	Reject	

Inspector: [signature] Date: 1/24/18 NCR #

Comments:
- Source Container 855, SN10
- Orientation is front SN mostly facing front forward
- All Readings include background of .05 mR/hr

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

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TP214-NCB-3 Radiation Profile Inspection

Initial Build Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 3 of 10

Shield Data			
Model: 976A	Serial #TP214-NCB-3	Radionuclide: IR-192	Max. Capacity 1000 Ci
Shield P/N: N/A	Shield Heat #: N/A	Lot #: N/A	

Profile Process Data			
Source Model: 424-9	Source Ser. #: SEE ATTACHED	Radionuclide: IR-192	Activity: 889.5 Ci
Survey Inst. 1: E600	Serial #: 2578	Date Cal.: 11/2/17	Date Due: 3/2/18
Survey Inst. 2: NA	Serial #: NA	Date Cal.: NA	Date Due: NA
Inst. Probe: 1 SHP270	Serial #: 724626	Inst. Probe: 2 NA	Serial #: NA
Capacity Correction Factor: 1.12			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	24	1.04	NA	.9	28	NA	1.1
Right	7	1.10		.3	9		.3
Front	7	1.10		.2	9		.2
Left	7	1.10		.3	9		.3
Rear	7	1.10		.4	9		.5
Bottom	23	1.08		1.4	28		1.6
				Acceptance Criteria:	≤ 200	NA	
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 12/5/17 NCR #:

Comments:
* Source container model 855 S/N #10
* Orientation is front facing marking, forward
* All readings include a background of .05 mR/HR

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 Page 1 of 1 27 January 2010

Post Test Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 6 of 10

Shield Data			
Model: 976A	Serial #TP214-NCB-3	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat #: NA	Lot #: NA	

Profile Process Data			
Source Model: 424-9	Source Ser. #: S30 attached	Radionuclide: Ir-192	Activity: 909.7 Ci
Survey Inst. 1: E600	Serial #: 2578	Date Cal.: 11/2/17	Date Due: 3/2/18
Survey Inst. 2: NA	Serial #: NA	Date Cal.: NA	Date Due: NA
Inst. Probe: 1 SHP270	Serial #: 724626	Inst. Probe: 2 NA	Serial #: NA
Capacity Correction Factor: 1.10			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	26	1.04	NA	1.3	30	NA	1.4
Right	8	1.10		.3	10		.3
Front	8	1.10		.3	10		.3
Left	8	1.10		.3	10		.3
Rear	8	1.10		.3	10		.3
Bottom	22	1.08		1.0	26		1.1
				Acceptance Criteria:	≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 1/22/18 NCR #:

Comments:
* Source Container 855, SN10
* Orientation is front SN marking facing front forward
* All readings include background of .05 mR/hr

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 Page 1 of 1 27 January 2010

TP214-NCB-4 Radiation Profile Inspection

Initial Build Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

TMI # 976

Sheet 4 of 10

Shield Data			
Model: 976A	Serial #TP214-NCB-4	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat #: NA	Lot #: NA	

Profile Process Data			
Source Model: 424-9	Source Ser. #: See attached	Radionuclide: Ir-192	Activity: 897.8 Ci
Survey Inst. 1: E600	Serial #: 2578	Date Cal.: 11/2/17	Date Due: 3/2/18
Survey Inst. 2: NA	Serial #: NA	Date Cal.: NA	Date Due: NA
Inst. Probe: 1 SHP270	Serial #: 724626	Inst. Probe: 2 NA	Serial #: NA
Capacity Correction Factor: 1.11			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	25	1.04	NA	1.1	29	NA	1.2
Right	7	1.10		.3	9		.3
Front	8	1.10		.3	10		.3
Left	7	1.10		.3	9		.3
Rear	7	1.10		.3	9		.3
Bottom	39	1.08		1.0	47		1.1
				Acceptance Criteria:	≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 11/30/17 NCR #:

Comments:
* Source Container model 855, SN10
* Orientation is front SN marking facing forward
* All readings include background of .05 mR/h

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 Page 1 of 1 27 January 2010

Post Test Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 4 of 10

Shield Data			
Model: 976A	Serial #TP214-NCB-4	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat #: NA	Lot #: NA	

Profile Process Data			
Source Model: 424-9	Source Ser. #: S30 attached	Radionuclide: Ir-192	Activity: 901.2 Ci
Survey Inst. 1: E600	Serial #: 2578	Date Cal.: 11/2/17	Date Due: 3/2/18
Survey Inst. 2: NA	Serial #: NA	Date Cal.: NA	Date Due: NA
Inst. Probe: 1 SHP270	Serial #: 724626	Inst. Probe: 2 NA	Serial #: NA
Capacity Correction Factor: 1.11			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	26	1.04	NA	1.3	30	NA	1.4
Right	7	1.10		.4	9		.4
Front	6	1.10		.3	7		.3
Left	9	1.10		.3	11		.3
Rear	7	1.10		.3	9		.3
Bottom	26	1.08		1.0	31		1.1
				Acceptance Criteria:	≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 1/23/17 NCR #:

Comments:
* Source Container 855, SN10
* Orientation is front SN marking facing front forward
* All readings include background of .05 mR/h

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 Page 1 of 1 27 January 2010

TP214-ASB-1 Radiation Profile Inspection

Initial Build Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

TMI# 983 — Sheet 1 of 87 7 of 1.

Shield Data			
Model: 976A	Serial # TP214-ASB-1	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat # NA	Lot # NA	

Profile Process Data			
Source Model: 424-9	Source Ser. # attached	Radionuclide: Ir-192	Activity: 906.3 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA
Capacity Correction Factor: 1.10			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	30	1.04	NA	1.3	34	NA	1.4
Right	7	1.10	↓	.2	8	↓	.2
Front	9	1.10	↓	.2	11	↓	.2
Left	7	1.10	↓	.2	9	↓	.2
Rear	7	1.10	↓	.2	9	↓	.2
Bottom	24	1.08	↓	.8	29	↓	.9
			Acceptance Criteria:		≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 11/27/17 NCR #

Comments: • Source Container model 855, SN 10
• Orientation is front w/ marking facing forward
• All readings include a background of .05 mR/h

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 — Page 1 of 1 — 27 January 2010

Post Test Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 3 of 10

Shield Data			
Model: 976A	Serial # TP214-ASB-1	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat # NA	Lot # NA	

Profile Process Data			
Source Model: 424-9	Source Ser. # attached	Radionuclide: Ir-192	Activity: 901.2 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA
Capacity Correction Factor: 1.11			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	27	1.04	NA	1.3	31	NA	1.4
Right	7	1.10	↓	.3	9	↓	.3
Front	7	1.10	↓	.3	9	↓	.3
Left	7	1.10	↓	.3	9	↓	.3
Rear	8	1.10	↓	.3	10	↓	.3
Bottom	28	1.08	↓	.8	34	↓	.9
			Acceptance Criteria:		≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 1/23/17 NCR #

Comments: • Source Container 855, SN 10
• Orientation is front w/ marking facing forward
• All readings include background of .05 mR/h

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

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TP214-FSB-1 Radiation Profile Inspection

Initial Build Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

TMI# 984 — Sheet 1 of 7

Shield Data			
Model: 976A	Serial # TP214-FSB-1	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat # NA	Lot # NA	

Profile Process Data			
Source Model: 424-9	Source Ser. # attached	Radionuclide: Ir-192	Activity: 906.3 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 1 NA	Serial # NA
Capacity Correction Factor: 1.10			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	26	1.04	NA	1.0	30	NA	1.1
Right	8	1.10	↓	.3	10	↓	.3
Front	8	1.10	↓	.3	10	↓	.3
Left	7	1.10	↓	.2	9	↓	.2
Rear	7	1.10	↓	.3	9	↓	.3
Bottom	23	1.08	↓	.9	27	↓	1.0
			Acceptance Criteria:		≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 11/27/17 NCR #

Comments: • Source Container model 855, SN 10
• Orientation is front w/ marking facing forward
• All readings include a background of .05 mR/h

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

F-Q-1806-2, rev. 4 — Page 1 of 1 — 27 January 2010

Post Test Profile Results

QSA GLOBAL

SHIELDING PROFILE AND INSPECTION FORM (SPIF) F-Q-1806-2

Sheet 1 of 10

Shield Data			
Model: 976A	Serial # TP214-FSB-1	Radionuclide: Ir-192	Max. Capacity 1000 Ci
Shield P/N: NA	Shield Heat # NA	Lot # NA	

Profile Process Data			
Source Model: 424-9	Source Ser. # attached	Radionuclide: Ir-192	Activity: 892.8 Ci
Survey Inst. 1 E600	Serial # 2578	Date Cal. 11/2/17	Date Due: 3/2/18
Survey Inst. 2 NA	Serial # NA	Date Cal. NA	Date Due: NA
Inst. Probe: 1 SHP290	Serial # 724626	Inst. Probe: 2 NA	Serial # NA
Capacity Correction Factor: 1.12			

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr		
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 2]	At One Meter	At Surface	At 30 Cm [Note 2]	At One Meter [Note 1]
Top	27	1.04	NA	1.3	32	NA	1.5
Right	10	1.10	↓	.3	12	↓	.3
Front	8	1.10	↓	.3	10	↓	.3
Left	6	1.10	↓	.3	7	↓	.3
Rear	7	1.10	↓	.3	9	↓	.3
Bottom	26	1.08	↓	1.0	32	↓	1.1
			Acceptance Criteria:		≤ 200	NA	< 10.0
			Result: (Check one)	Accept	✓	Reject	

Inspector: [signature] Date: 1/24/18 NCR #

Comments: • Source Container 855, SN 10
• Orientation is front w/ marking facing forward
• All readings include background of .05 mR/h

Notes:
1. Refer to F-Q-1806-1, Shield Efficiency Testing Surface Correction Factors for an existing device model, or F-Q-1806-3, Shield Profile Worksheet for One meter acceptance limit.
2. The 30cm readings are only required when specifically requested.
3. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.
4. Attach auto profiler print out to this sheet if used.

Appendix B: Test Data Sheets

Test Specimen & Equipment Documentation

Test Specimen

Model #	Drawing Number	Serial Number	Weight (lbs.)	Attach TMI/~~RG~~	Attach IIR	Attach NCR
976A	TP214-NCB	TP214-NCB-1	274.5	976	NA	NA
976A	TP214-NCB	TP214-NCB-2	274.5	976	NA	NA
976A	TP214-NCB	TP214-NCB-3	274.5	976	NA	NA
976A	TP214-NCB	TP214-NCB-4	274.5	976	NA	NA
976A	TP214-ASB	TP214-ASB-1	279.5	983	NA	NA
976A	TP214-FSB	TP214-FSB-1	276	984	NA	NA

Tools & Equipment

Tool Description	Enter the Model and Serial Number Mark NA when not used.	Attach Inspection Report or Calibration Certificate
Drop Surface	T10740, S/N 001	Yes
Puncture Billet	T10119, SN01	Yes
Weight Scale	QSA 215	Yes
Temperature gage	150163	Yes.

Signature/Date

Engineering:	Regulatory:	Quality Assurance:
S. Gr[illegible] 12/19/17	[signature] 3/16/18	[signature] 3-21-18

1.2-Meter Drop Test Data Sheet

Step	Instruction	Test Data	
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA	
2	Record test date & time.	Date: 12/19/2017	Time: 9:07 AM
3	Record test specimen serial number.	TP214-NCB-1	
4	Record Model 855 serial number.	10	
5	Measure test specimen weight.	274.5 LB	Scale S/N: QSA 215
6	Measure the ambient temperature (°C):	6.4	Instrument S/N: 150163
7	Record actual drop height.	4 FT 4 INCH	
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓		
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓		
10	Begin the video recorder ✓		
11	Release the test specimen. ✓		
12	Stop the video recorder. ✓		
13	Was the point of impact achieved?		Yes or No
14	Photograph the test specimen immediately after the drop. ✓		
15	Record the damage to the test specimen.	NONE	
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?	Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.	Yes or No
		Can testing continue for this specimen?	Yes or No

Test witnessed by (Signature/Date) 12-19-17

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Grami 12/19/17	3/16/18	21 MAR 18

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017		Time: 9:18 AM	
3	Record test specimen serial number.	TP214-NCB-1			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	6.2	Instrument S/N:	150163	
7	Record actual drop height.	32 FT 9 IN			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No (Yes circled)
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	BASE (IMPACT SURFACE) PUSHED UP SLIGHTLY - BOTTOM OF DRUM HAS MINOR CRUSH.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No (Yes circled)
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No (No circled)
		Can testing continue for this specimen?			Yes or No (Yes circled)

Test witnessed by (Signature/Date) [signature] 12-19-17

Engineering:	Regulatory Affairs:	Quality Assurance:
S. G[signature] 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Puncture Drop Test Data Sheet

Step	Instruction	Test Data		
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA		
2	Record test date & time.	Date: 12/19/2017	Time: 9:30 AM	
3	Record test specimen serial number.	TP214-NCB-1		
4	Record Model 855 serial number.	10		
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215
6	Measure the ambient temperature (°C):	5.9	Instrument S/N:	150163
7	Record actual drop height.	44 inches		
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓			
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓			
10	Begin the video recorder ✓			
11	Release the test specimen. ✓			
12	Stop the video recorder. ✓			
13	Was the point of impact achieved?			Yes or No (Yes circled)
14	Photograph the test specimen immediately after the drop. ✓			
15	Record the damage to the test specimen.	Bottom of drum shows a slight compressed area at low end.		
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?		Yes or No (Yes circled)
		Were there any changes in the planned drop orientation? If yes, then explain.		Yes or No (No circled)

Test witnessed by (Signature/Date) [signature] 12-19-17

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Gian[signature] 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Post Test Inspection Data Sheet	
Test Specimen Serial No.: TP214-NCB-1	Last Test Performed: PUNCTURE DROP

1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.:

DRUM OUTER DIAMETER SLIGHTY CRUSHED INWARD AT THE LOWER (IMPACT) END OF PACKAGE.

ALL COVER BOLTS INTACT AND SECURE.

NO GAP BETWEEN COVER AND DRUM MATING SURFACES.

2. Describe the condition and position of the simulated source wire assembly.

NO CHANGE COMPARED TO PRE-TEST CONDITION AND POSITION.

3. 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.

4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806.

5. 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.

6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No

7. If radiography is performed, describe any damage or failures found.

NA.

Completed by: S. Greni	Date: 12/19/2017

1.2-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017		Time: 9:49 AM	
3	Record test specimen serial number.	TP214-NCB-3			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	6	Instrument S/N:	150163	
7	Record actual drop height.	4 FT 4 IN			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	NONE			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S Gr 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA
2	Record test date & time.	Date: 12/19/2017 Time: 9:57 AM
3	Record test specimen serial number.	TP214-NCB-3
4	Record Model 855 serial number.	10
5	Measure test specimen weight.	274.5 LB — Scale S/N: QSA 215
6	Measure the ambient temperature (°C):	5.9 — Instrument S/N: 150163
7	Record actual drop height.	32 FT 9 IN
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓	
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓	
10	Begin the video recorder ✓	
11	Release the test specimen. ✓	
12	Stop the video recorder. ✓	
13	Was the point of impact achieved?	Yes or No (Yes circled)
14	Photograph the test specimen immediately after the drop. ✓	
15	Record the damage to the test specimen.	MINOR COMPRESSION OF DRUM DIAMETER AT LOWER END (IMPACT END)
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan? Yes or No (Yes) Were there any changes in the planned drop orientation? If yes, then explain. Yes or No (No) Can testing continue for this specimen? Yes or No (Yes)

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
[signature] 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Puncture Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017	Time: 10:11 AM		
3	Record test specimen serial number.	TP214-NCB-3			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	6.1	Instrument S/N:	150163	
7	Record actual drop height.	44 IN			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	NO CHANGE AFTER 9-METER DROP.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No

Test witnessed by (Signature/Date)		
Engineering: S. G[illegible] 12/19/17	Regulatory Affairs: [signature] 3/16/18	Quality Assurance: [signature] 21 MAR18

Post Test Inspection Data Sheet	
Test Specimen Serial No.: TP214-NCB-3	Last Test Performed: PUNCTURE DROP

1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.:

DRUM OUTER DIAMETER SHOWS MINOR DEFORMATION AT the LOWER (impact) END OF Specimen.

All Cover Bolts intact AND Secure.

NO GAP Between Cover AND DRUM.

2. Describe the condition and position of the simulated source wire assembly.

NO Change Compared to Pre-test Condition AND Position.

3. 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.

4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806.

5. 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.

6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No

7. If radiography is performed, describe any damage or failures found.

NA

Completed by: S. Gun	Date: 12/19/17

1.2-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017	Time: 10:31 AM		
3	Record test specimen serial number.	TP214-NCB-2			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	6.5	Instrument S/N:	150163	
7	Record actual drop height.	4 FT 4 IN			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	IMPACT EDGE OF DRUM DENTED IN ABOUT 3/4 INCH.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Gra 12/19/17.	3/16/18	21 MAR18

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017	Time: 10:41 AM		
3	Record test specimen serial number.	TP214-NCB-2			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	6.3	Instrument S/N:	150163	
7	Record actual drop height.	32 FT 9 IN.			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	IMPACT EDGE OF DRUM CRUSHED IN ABOUT 2-3 INCHES.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S-Gri 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Puncture Drop Test Data Sheet				
Step	Instruction	Test Data		
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA		
2	Record test date & time.	Date: 12/19/2017	Time: 10:52 AM	
3	Record test specimen serial number.	TP214-NCB-2		
4	Record Model 855 serial number.	10		
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215
6	Measure the ambient temperature (°C):	6.6	Instrument S/N:	150163
7	Record actual drop height.	44 IN.		
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓			
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓			
10	Begin the video recorder ✓			
11	Release the test specimen. ✓			
12	Stop the video recorder. ✓			
13	Was the point of impact achieved?			Yes or No
14	Photograph the test specimen immediately after the drop. ✓			
15	Record the damage to the test specimen.	MINOR ADDITIONAL DENTS TO DRUM		
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?		Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.		Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Gr 12/19/17	3/16/18	21 MAR18

Post Test Inspection Data Sheet	
Test Specimen Serial No.: TP214-NCB-2	Last Test Performed: PUNCTURE DROP
1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.: DRUM COVER EDGE CRUSHED INWARD ABOUT 2 to 3 INCHES ALL COVER BOLTS INTACT AND SECURE. NO GAP BETWEEN COVER AND DRUM MATING SURFACES.	
2. Describe the condition and position of the simulated source wire assembly. NO CHANGE COMPARED TO PRE-TEST CONDITION AND POSITION.	
3. 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. 4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806. 5. 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.	
6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No	
7. If radiography is performed, describe any damage or failures found. NA	
Completed by: S. Gren	Date: 12/19/17

1.2-Meter Drop Test Data Sheet

Step	Instruction	Test Data		
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA		
2	Record test date & time.	Date: 12/19/2017	Time: 11:13 AM	
3	Record test specimen serial number.	TP214-NCB-4		
4	Record Model 855 serial number.	10		
5	Measure test specimen weight.	274.5	Scale S/N:	QSA 215
6	Measure the ambient temperature (°C):	7.4	Instrument S/N:	150163
7	Record actual drop height.	4 FT 4 IN.		
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓			
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓			
10	Begin the video recorder ✓			
11	Release the test specimen. ✓			
12	Stop the video recorder. ✓			
13	Was the point of impact achieved?			Yes or No
14	Photograph the test specimen immediately after the drop. ✓			
15	Record the damage to the test specimen.	NONE		
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?		Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.		Yes or No
		Can testing continue for this specimen?		Yes or No

Test witnessed by (Signature/Date)		
Engineering: S. Greni 12/19/17	Regulatory Affairs: [signature] 3/16/18	Quality Assurance: [signature] 21 MAR 18

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017	Time: 11:25 AM		
3	Record test specimen serial number.	TP214-NCB-4			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	7.7	Instrument S/N:	150163	
7	Record actual drop height.	32 FT 9 IN			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	IMPACT SURFACE CRUSHED IN ABOUT 3-4 INCHES.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Green 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Puncture Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017		Time: 11:34 AM	
3	Record test specimen serial number.	TP214-NCB-4			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	274.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	8.1	Instrument S/N:	150163	
7	Record actual drop height.	44 IN.			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No (Yes circled)
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	SUPERFICIAL DENT OUTLINE OF PUNCTURE BILLET ON DRUM OD.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No (Yes circled)
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No (No circled)

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Gomi 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Post Test Inspection Data Sheet

Test Specimen Serial No.: TP214-NCB-4	Last Test Performed: PUNCTURE DROP

1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.:

DRUM OUTSIDE DIAMETER FLATTENED Along the LONGITUDINAL Length. DIAMETER DEFORMED INWARD ABOUT 3-4 INCHES.

All Cover Bolts intact AND Secure.

NO GAP Between Cover AND DRUM.

2. Describe the condition and position of the simulated source wire assembly.

NO Change Compared TO Pre-test CONDITION AND POSITION.

3. 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.

4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806.

5. 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.

6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No

7. If radiography is performed, describe any damage or failures found.

NA.

Completed by: S. Gre	Date: 12/19/17

1.2-Meter Drop Test Data Sheet

Step	Instruction	Test Data		
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA		
2	Record test date & time.	Date: 12/19/2017	Time: 11:50 AM	
3	Record test specimen serial number.	TP214-FSB-1		
4	Record Model 855 serial number.	10		
5	Measure test specimen weight.	276	Scale S/N:	QSA215
6	Measure the ambient temperature (°C):	9.4	Instrument S/N:	150163
7	Record actual drop height.	4 FT 4 IN		
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓			
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓			
10	Begin the video recorder ✓			
11	Release the test specimen. ✓			
12	Stop the video recorder. ✓			
13	Was the point of impact achieved?			Yes or No
14	Photograph the test specimen immediately after the drop. ✓			
15	Record the damage to the test specimen.	IMPACT EDGE CRUSHED IN ABOUT 1 INCH.		
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?		Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.		Yes or No
		Can testing continue for this specimen?		Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Green 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017	Time: 11:59 AM		
3	Record test specimen serial number.	TP214-FSB-1			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	276	Scale S/N:	QSA215	
6	Measure the ambient temperature (°C):	10	Instrument S/N:	150163	
7	Record actual drop height.	32 FT 9 IN.			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	IMPACT EDGE CRUSHES IN ABOUT 3-4 INCHES, 3/4 INCH GAP BETWEEN DEFORMED COVER AND DRUM LIP ON TWO SIDES - 3 INCHES LONG.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Green 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Puncture Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017	Time: 12:08 PM		
3	Record test specimen serial number.	TP214-FSB-1			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	276	Scale S/N:	QSA215	
6	Measure the ambient temperature (°C):	9.4	Instrument S/N:	150163	
7	Record actual drop height.	44 IN.			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	NO OR MINOR ADDITIONAL DENTS TO DRUM.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Green 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Post Test Inspection Data Sheet

Test Specimen Serial No.: TP214-FSB-1	Last Test Performed: PUNCTURE DROP

1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.:

DRUM COVER EDGE CRUSHED INWARD ABOUT 3 TO 4 INCHES.

ALL COVER BOLTS INTACT AND SECURE.

TWO SMALL GAPS APPEAR BETWEEN COVER AND DRUM - ONE ON EACH SIDE OF IMPACT POINT. LARGEST GAP IS 3/4 INCH WIDE (MAX) AND TAPERS DOWN TO NO GAP. TOTAL LENGTH OF TAPER IS 3 INCHES. OTHER GAP IS SIMILAR BUT SMALLER.

2. Describe the condition and position of the simulated source wire assembly.

NO CHANGE COMPARED TO PRE-TEST CONDITION AND POSITION.

3. 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.

4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806.

5. 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.

6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No

7. If radiography is performed, describe any damage or failures found.

NA

Completed by: S. Gu[illegible]	Date: 12/19/17

1.2-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017		Time: 12:34 PM	
3	Record test specimen serial number.	TP214-ASB-1			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	279.5	Scale S/N:	QSA215	
6	Measure the ambient temperature (°C):	9.7	Instrument S/N:	150163	
7	Record actual drop height.	4 FT 4 IN			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	MINOR DENT AT RING IMPACT POINT.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Green 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

9-Meter Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017		Time: 12:44 PM	
3	Record test specimen serial number.	TP214-AS3-1			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	279.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	9.9	Instrument S/N:	150163	
7	Record actual drop height.	32 FT 9 IN.			
8	Place the specimen on the drop surface and position it in the planned drop orientation. ✓				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes. ✓				
10	Begin the video recorder ✓				
11	Release the test specimen. ✓				
12	Stop the video recorder. ✓				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop. ✓				
15	Record the damage to the test specimen.	COVER CRUSHED IN ABOUT 3-4 INCHES.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No
		Can testing continue for this specimen?			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Green 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Puncture Drop Test Data Sheet

Step	Instruction	Test Data			
1	Record test location.	QSA Global, Inc. 40 North Ave, Burlington, MA			
2	Record test date & time.	Date: 12/19/2017		Time: 12:52 PM	
3	Record test specimen serial number.	TP 214 - ASB-1			
4	Record Model 855 serial number.	10			
5	Measure test specimen weight.	279.5 LB	Scale S/N:	QSA 215	
6	Measure the ambient temperature (°C):	11.1	Instrument S/N:	150163	
7	Record actual drop height.	44 IN.			
8	Place the specimen on the drop surface and position it in the planned drop orientation.				
9	Raise the specimen slightly and photograph the set-up in at least two perpendicular planes.				
10	Begin the video recorder				
11	Release the test specimen.				
12	Stop the video recorder.				
13	Was the point of impact achieved?				Yes or No
14	Photograph the test specimen immediately after the drop.				
15	Record the damage to the test specimen.	ONLY MINOR ADDITIONAL DENTS TO DRUM.			
16	Engineering, Regulatory Affairs and Quality Assurance make a preliminary assessment relative to 10 CFR 71.	Was the test performed in accordance with 10 CFR 71, IAEA TS-R-1, and this plan?			Yes or No
		Were there any changes in the planned drop orientation? If yes, then explain.			Yes or No

Test witnessed by (Signature/Date)

Engineering:	Regulatory Affairs:	Quality Assurance:
S. Grein 12/19/17	[signature] 3/16/18	[signature] 21 MAR 18

Post Test Inspection Data Sheet

Test Specimen Serial No.: TP214-ASB-1	Last Test Performed: PUNCTURE DROP

1. Describe and measure (if appropriate) any damage, permanent strain, deformation and/or broken parts, etc.:

DRUM COVER EDGE CRUSHED INWARD ABOUT 3 TO 4 INCHES.

All COVER BOLTS INTACT AND SECURE.

NO GAP Between COVER AND DRUM.

RING intact.

2. Describe the condition and position of the simulated source wire assembly.

NO change COMPARED TO Pre-test CONDITION AND POSITION.

3. 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.

4. Measure and record a radiation profile of the test specimen in accordance with QSA Global Work Instruction WI-Q-1806.

5. 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.

6. Is a radiograph required to inspect for hidden component damage or failure? Yes or No

7. If radiography is performed, describe any damage or failures found.

NA

Completed by: S. Gr[illegible]	Date: 12/19/17

Appendix E: Standard Clamp Band Drawing

[redacted]

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

QSA GLOBAL

40 NORTH AVE, BURLINGTON, MA 01803

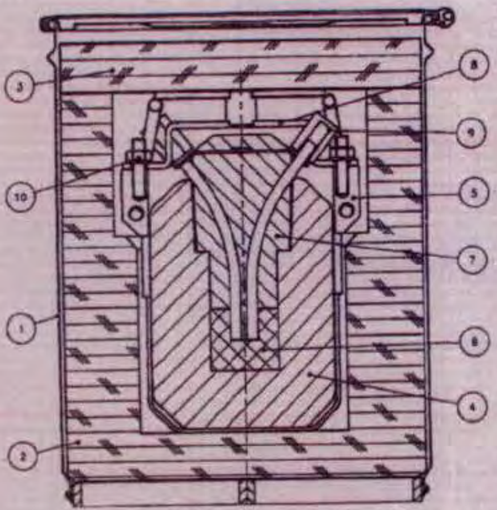
DESCRIPTIVE DRAWING

TITLE	CLAMP BAND		
SIZE A	DWG. NO. RCLM011		REV A
	SCALE: NONE	SHEET 1 OF 1	

Appendix F: Reference - Test Plan 163 Thermal Test Assessment

Section 5.5 Thermal Assessments

Thermal testing was performed for a similar, but smaller, drum design to support approval of a Type B container in Great Britain (See Figure 33). The tested drum measured 32.5 cm in diameter by 40.5 cm tall with minimum cork thickness on the bottom of 4 cm, on the top of 4.5 cm and on the sides of 5 cm. In contrast the Model 976 package measures 50 cm in diameter by 54 cm tall. The Model 976 Series packages have a minimum cork thickness, which is based on the Model 976A configuration containing the least cork material, of 5 cm on the bottom, 12.7 cm on the top and 8.3 cm on the sides.



Item	Description	Material	No off
1	DRUM	STEEL	1
2	PACKING INSERT	CORK	1
3	PACKING SPACER	CORK	1
4	LEAD POT	LEAD	1
5	POT CRADLE	CARBON STEEL	1
6	CORE SHIELD	TUNGSTEN ALLOY / DEPLETED URANIUM	1
7	SHIELDING INSERT	LEAD	1
8	RETAINING STRAP	CARBON STEEL	1
9	TUBE CAP	BRASS	4
10	M10 COMB NUT	STAINLESS STEEL	2

FIGURE 33 – TEST SPECIMEN CONFIGURATION FOR TEST NUMBER 1835

Test Number 1835 (see Appendix F) documents testing of a Model 3018 inner shield container (lead shielded device) inside of a cork lined steel drum assembly. The cork used in these test units was purchased to the same specification as the cork used for the test specimens under this Test Plan Report, however, the overall cork thickness is greater in the Model 976 style packages than was used in the specimens tested under Test Number 1835.

Testing included 9 m drop tests and puncture tests in similar orientations as were performed for the test specimens under this test plan report. The test specimens under Test Number 1835 were tested at ambient temperature and were not cooled to -40°C prior to the 9 m and puncture drop tests.

As was seen with the Model 976 style test specimens, the test units described under Test Number 1835 also experienced drum deformation but no loss of the lid from the drum base. Though cracking of the cork was not specifically referenced on the sides of the cork liners in the test units from Test Number 1835, cracking of the bottom cork inserts was noted. The bottom of the cork cavity was cracked around the circumference and across diagonals in line with the drum reinforcement bars.

Thermal testing of the specimens under Test Number 1835 placed the specimens into a furnace maintained at an ambient temperature between 800°C - 820°C for a period of 30 minutes. The test specimens did not contain any radioactive contents during the thermal testing performed under Test Number 1835. The test specimens were allowed to cool for at least 18 hours before disassembly and evaluation.

Upon evaluation it was found that the top cork inserts exhibited slight charring (e.g. 22-25 mm depth) with a 26 mm thickness of the insert remaining intact. In both cases the lead shield container was undamage, exhibiting only the

presence of a resin condensate and soot on the lead pot exterior. For both test specimens, the maximum temperature recorded by temperature strips on the exterior surface of the lead pot was 82°C. This temperature rise was less than 1/4 of that necessary to reach the melting point of the lead pot (300°C). Therefore no melting or slumping of the lead shielding occurred.

Upon inspection of the test specimens under this test plan it was observed that TP163(C) exhibited the largest cork cracking on the side inserts. This test unit contained jagged cracks up to ¼" in width in the sides of the cork inserts (see Figures 28 and 29). The presence of these cracks introduces the possibility of a different result in the thermal test if performed. The three thermal transport mechanisms are conduction, convection and radiation. Each will be addressed in the following assessment.

The shield containers used in the Model 976 drum assembly are of two general types: (1) those which use depleted uranium for their primary shielding (e.g., 855 and 3078), and (2) those that use lead for their primary shielding with supplemental materials as part of the inner assembly shielding design (e.g., 3015, 3018, 3056 and 1911). All shield container exteriors are a steel weldment which does not melt below 1,427 °C. The melting point of depleted uranium is 1,130°C.

Section 5.5.1 Conduction Contribution

A calculation of the worst case, steady state conduction through the cork insulation that could be created in TP163(C) is as follows:

$$Q_X = \frac{k\,A(T_1 - T_2)}{L}$$

(Reference Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and Dewitt, page 5.)

Where: Q_x = the heat transfer rate in Watts
k = coefficient of thermal conductivity, 0.0314 W/m K for air at 370°K; 0.039 W/ m K for cork[1]
A = cross sectional area of material (~2 cracks, ¼" wide = 0.00635 m, each 0.5 m long) = 0.00635 m^2
T_1 = Drum Wall Temperature (assumed to be thermal test temperature = 800°C or 1,027°K)
T_2 = Shield Container Initial External Temperature (assumed to be = 97°C or 370°K from 5.5.3)
L = minimum thickness of the outer and inner cork liners (located on the sides) = 0.08m + 0.04m = 0.12 m

Reference 1: Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and DeWitt, Appendix A.

For the thermal test, regardless of the cork condition, A, T_2, T_1 and L will be the same. The only difference will be the variation in the coefficient of thermal conductivity between air and cork. As indicated above, the coefficient for air is less than the coefficient for cork, therefore the heat transfer rate in air through the crack will be less than is experienced through the cork.

Calculation of the maximum conduction through the solid cork is based on the maximum outer area divided by the minimum cork thickness. The drum outer surface is 0.52 m in diameter and 0.54 m high for a maximum cross sectional area of 1.31 m^2. The minimum cork thickness at the bottom of the drum is 0.08 m. Therefore the maximum heat transfer rate is 420 Watts.

Section 5.5.2 Convection Contribution

There is a limited air gap between the cork and the inner surface of the drum. As such, movement of the air around the cork inside the drum to produce convection heating will be insignificant when compared to the conductive heat transferred directing from the drum to the cork. If the crack in the cork is approximated as a solid air volume between the inner drum surface and the outer shield container, then a worst case approximation of the conductive heat transfer

can be made in this limited air volume. Similar to steady state conduction, the under steady state conditions, the local heat transfer rate can be calculated as follows:

$$q_X = (T_1 - T_2) \int h \, dA_s$$

(Reference Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and Dewitt, page 327.)

Where: q_x = the heat transfer rate in Watts
h = convection coefficient for air = 10 Watts/m^2 °K (Reference IAEA TS-G-1.1 (ST-2))
dA_s = cross sectional area of material (~1 cracks, ¼" wide = 0.00635 m, each 0.5 m long)
T_1 = Drum Wall Temperature (assumed to be thermal test temperature = 800°C or 1,027°K)
T_2 = Shield Container Initial External Temperature (assumed to be = 97°C or 370°K from Section 5.5.3)

Estimating the air volume between the inner drum wall and outer shield surface as a vertical cylinder produces the following equation.

$$q_X = h \, 2 \pi \, r \, l (T_1 - T_2)$$

Where: r = the radius of the cylinder (crack) = 0.0032 m
l = length of the crack = 0.305 m

Solving for q_x produces a worst case heat transfer rate from convection of 43 Watts along the inner surface of the cork crack.

Section 5.5.3 Radiant Heat Contribution

The jagged path of the crack through the cork prevents any radiation from the drum wall directly contacting the shield container. Without direct contact, the radiative heat transfer to the shield container surface will be insignificant in comparison to the other heat transfer contributions.

Assuming heat contribution to the inner shield from the radioactive contents produces a worst case transfer rate as follows:

The Specific heat output of Ir-192 is 8.6 mW/Ci assuming a decay energy of 1.46 MeV/decay and that 100% of the radioactive decay is transferred to thermal energy. The maximum source content for the package is 1,000 Ci. Actual content to output activity varies based on the capsule configuration as well as variations in isotope self-absorption. A factor of 2.3 was used to convert output activity to content activity as this factor reflects the worst case variation for Ir-192 sources transported in these packages. Therefore the total content activity would be 2,300 Ci and the total heat output assuming a conservative 100% decay during the thermal test is:

8.6 mW/Ci x 2,300 Ci = 19,780 mW = 19.78 Watts

Even assuming complete decay of the Ir-192 during the thermal test produces a heat transfer rate that is insignificant when compared with heat transfer from conduction.

Calculation for the Model 1911 inner shield (smallest shield diameter/wall thickness and largest source term) based on a thermal analysis from "Fundamentals of Heat and Mass Transfer", F.P. Incropera, 5th Edition, 2002 is as follows:

$$Q_{in} = Q_{radiated} = Q_{decay} = 19.78 \ watts$$

Where:

$Q_{radiated}$ = heat radiated = B E A_{ts} [$(T_w + 273)^4 - (T_m + 273)^4$]

(This equation assumes no conduction or convection from all surfaces and radiative heat losses from the top and side surfaces only).

A_{ts} = Area of the top and sides = 0.174 m^2 based on:

$$A_{ts} = \left(\left[\frac{diameter}{2}\right]^2 \pi\right) + (diameter)(height)\pi$$

T_a = ambient temperature = 20°C
T_w = shield maximum equilibrium temperature
T_m = shield median temperature = $(T_a + T_w)/2$
B = Stefan Boltzmann Constant = 5.670 x 10^{-8}
E = emissivity for rough stainless steel surface between 300 and 400°K = 0.3

Iteration for T_w balancing the heat in to the heat radiated produces a value of 97°C for the maximum temperature at the surface of the inner shield prior to the start of the thermal test.

Section 5.5.4 Thermal Contribution Summary

To raise the temperature of the 1911 lead shield container to the melting point of lead would require a significant amount of energy. The specific heat of lead, C_p = 0.15 kJ/kg-°K. From this relation, calculation of the required heat transfer rate is as follows:

$$Q_{Input} = C_p M (T_2 - T_1)$$

Where Q_{Input} = Minimum heat input to melt the lightest lead container (Model3015)
C_p = Specific Heat of Lead
M = Mass of the shield container = 104 lbs or 47 kg for the Model 3015
T_2 = Melting temperature of lead = 573°K (or 300°C, Smithells, Colin J. Smithells Metals Reference Book, Seventh Edition, Butterworth-Heinemann Ltd, Oxford 1992)
T_1 = Ambient shield temperature = 370°K (see section 5.5.3)

Therefore the required heat transfer rate to cause lead melting in the shield is 1,431 kJ or 1.43 x 10^6 Watts/sec. To achieve this in the 30 minutes (1,800 sec) of the thermal test requires a heat input of 795 Watts. Even when combining all the worst case thermal contribution factors, the required heat input in the most vulnerable area along the cork crack is less than 60% of the actual heat input that would melt the lead shield and will therefore be insufficient to degrade the lead shielding.

Section 5.5.5 Additional Factors for Consideration

In the case of the depleted uranium shield containers, there was no breach or weld cracking of the shield container which would allow oxygen to reach the inner depleted uranium shield. Without the presence of a continuing source of oxygen, these shields will remain intact during the thermal test. As seen in testing performed on the Model 650L (Reference USNRC CoC USA/9269/B(U)-85, Test Plan 80 Report Revision 1) thermal testing of this device where cracking to allow air to the shield had occurred resulted in production of only a small amount of depleted uranium oxide. With an air path and air circulation during the thermal test, the radiation dose rate at one meter from this unit increases by approximately 10% remaining less than 3% of the regulatory limit.

Without sufficient oxygen provided to the interior of the depleted uranium shield containers (e.g., welds intact) there will be no appreciable oxidation of the depleted uranium shield inside the steel container housings, and the 800°C temperature is well below the melting point of depleted uranium (1,130°C) therefore the shield will retain its original shape throughout the thermal test.

The thermal test will not adversely effect the structural integrity of the shield containers. The Model 855 and Model 1911 containers were physically undamaged after the 9 m and puncture drop testing. The other shield containers (e.g., Models 3015, 3018, 3056 and 3078) are lighter than the Models 855 and 1911 and would therefore be expected to sustain less damage in the drop configurations than was seen for these package assemblies. For shield containers incorporating lead, again the exterior shield temperature will not exceed 82°C. The testing performed under Test Number 1835 took drum assemblies at ambient temperature prior to subjecting them to the thermal test condition. In actual practice the 976 package assemblies would have been thermally tested immediately after the puncture test and would still have been at a temperature below 0°C introducing a further temperature difference to be overcome before the shield container would be susceptible to a melting temperature.

For the Model 976 Series packages, performance of the thermal test would not produce a condition sufficient to reduce the shielding efficiency or containment efficiency of the shield containers within the 976 drum assembly. In addition the temperature increase in the shield container surfaces will be well below the melting temperature of the lead which will preclude any shielding configuration change or lead slumping in the shield containers. By assessment, the Model 976 Series package designs would therefore meet the thermal test requirements.

Section 3 - THERMAL EVALUATION

3.1 Description of Thermal Design

The Model 976 Series transport packages are completely passive thermal devices having no mechanical cooling system or relief valves. All cooling of the transport package is through free convection and radiation. The maximum output activity for this package is 1,250 Ci of Ir-192. Accounting for source absorption, this equals a maximum content activity of 2,875 Ci of Ir-192. The corresponding decay heat generation rate for the content activity is approximately 25 Watts (See Table 1.2d).

3.1.1 Design Features

The Model 976 is a series of transport packages based on a previously designed, tested and approved Type B(U) transport package. The package design was approved in the United Kingdom under Type B certificate GB/3605B/B(U)-85 and was revalidated by the USDOT for Type B(U) import and export under certificate USA/0592/B(U)-85. the Model 976 Series packages are described in Section 1. The United Kingdom package design was thermal tested and the results of that testing are contained in Appendix F of Test Plan 163 Report in Section 2.12.3. The thermal tested drum measured 32.5 cm in diameter by 40.5 cm tall. In comparison, the Model 976 packages measure 50 cm in diameter by 54 cm tall. Features uniquely relevant to thermal performance are detailed below.

3.1.1.1 Cork Inserts

The inserts serve as a thermal insulator during the fire test (Hypothetical Accident). Although the cork chars during the test, due to the composition of this cork, the rate of charring is relatively slow. During an actual thermal test, the maximum depth of charring was 1 inch (25 mm) (See Appendix F of Test Plan 163 Report in Section 2.12.3).

The drum configuration which was thermal tested as described in Appendix F of Test Plan 163 Report (Section 2.12.3) had a minimum cork thickness on the bottom of 4 cm, on the top of 4.5 cm and on the sides of 5 cm. In contrast the Model 976 packages have minimum cork thickness, based on the Model 976A configuration which contains the least cork material, of 5 cm on the bottom, 12.7 cm on the top and 8.3 cm on the sides.

In all dimensions, the cork present in the Model 976 packages and surrounding the inner shield containers is greater than the cork that was present in the container design that was thermal tested as described in

Appendix F of Test Plan 163 Report in Section 2.12.3.

3.1.1.2 Thin Walled Stainless Steel Drum, Lid, Lid closure band and Lid Closure Bolts

The thin walls of the drum components exhibit almost no thermal gradient. During a fire test, the entire drum will very quickly heat to a uniform temperature, eliminating stresses induced by thermal differentials within the material. Further, the drum will move and flex easily, thus relieving any thermal expansion stress without rupture.

3.1.1.3 Un-gasketed Lid

Upon charring of the cork, gasses evolve. This drum design does not use a gasket under the lip of the lid. This permits these gasses to escape and not significantly increase the pressure within the package.

3.1.1.4 Shield Containers

All shield containers are retained within the drum/cork overpack assembly, thus limiting their temperature to well below the shield container material melting points. Those shield containers using depleted uranium shielding have the depleted uranium fully enclosed in a welded steel structure. This construction prevents oxidation by severely limiting oxygen from reaching the depleted uranium shield.

3.1.2 Content's Decay Heat

From Table 1.2d, a maximum of 25 Watts of energy is available to be absorbed by the package.

3.1.3 Summary Tables of Temperatures

Table 3.1.3.a: Summary Table of Temperatures

Surface Temperature Condition	Model 976 Series Packages	Cork Insets	Shield Container Models	Comments
Insolation (38°C in full sun)	90.3°C (195°F)	90.3°C to 109.4°C (195°F to 229°F)[3]	109.4°C (229°F)	Sections 3.4.1.1. & 3.5.2.4
Decay Heating (38°C in shade)	42.7°C (109°F)	42.7°C to 109.4°C (109°F to 229°F)[3]	109.4°C (229°F)	Sections 3.4.1.2 & 3.5.2.4
Fire Test During	90.3°C to 800°C[4] (195°F to 1,472°F)	109.4°C to 800°C[5] (229°F to 1,472°F)	109.4°C to 159°C[2] (229°F to 318°F)	Section 3.5.2.4
Post-Fire (Maximum Temperature)	800°C[1] (1,472°F)	800°C[1] (1,472°F)	159°C[2] (318°F)	

1 – From actual testing of similar packages. Reference Section 2.12.2 and Section 2.12.3.

2 – Maximum temperature based on thermal increase of 50°C seen in actual package testing (See section 5.5 of Test Plan 163 Report – Section 2.12.3).

3 – Temperature of Cork Inserts assumed to be bounded by the external surface reading of the Model 976 package and the exterior surface temperature calculated for the Shield Container within the package.

4 – Maximum initial temperature of the package assumed to be bounded by the external surface reading of the Model 976 package in full sun (insolation).

5 Maximum initial temperature of the cork inserts assumed to be bounded by the calculated external surface temperature of the shield container for the package.

3.1.4 Summary Tables of Maximum Pressures

All outer drum components are vented to atmosphere. As such, no pressure will build up in the units under either Normal or Hypothetical Accident conditions. However, the Model 855 shield container does have a small gasketed cavity. As noted below, it will not develop sufficient internal pressure to detrimentally effect the device.

Table 3.1.4.a: Summary Table of Maximum Pressures

Package Configuration	Void Volume IN^3	Normal Conditions 88°C (190°F) Pressure Developed	Fire Conditions 800°C (1,472°F) Pressure Developed	Comments
976A	285	8 psi[2]	14 psig[1,2]	¼" welded steel sides for cavity. Cover retained with (8) 3/8" bolts
976C	0	0 psig[2]	0 psig[2,3]	J-Tubes without sealed cover
976F	21	0 psig[2,3]	0 psig[2,3]	4 mm steel cover retained by (4) M8 bolts

1 – Pressure at 177°C (350°F). After which the gasket will burn and allow release of any pressure.

2 – Initial temperature taken to be -40°C as a worst case scenario.

3 – No gasket to seal void, pressure equal to ambient.

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

Table 3.2a lists the relevant thermal properties of the important materials in the transport package. The sources referred to in the last column are listed below the table.

Table 3.2a: Thermal Properties of Principal Transport Package Materials

Material	Density (lb/in^3)	Melting/Combustion Temperature	Thermal Expansion	Source
Depleted Uranium	0.68	1,130°C (2,066°F)	8μin/in°F	Reference #1, p. 6-11 and Reference #2
Copper	0.32	1,082°C (1,980°F)	9.2μin/in°F	Reference #1, p. 6-7 and 6-11
Steel (nominal)	0.28	1,510°C (2,750°F)	6.3μin/in°F	Reference #1, p. 6-7 and 6-11
Stainless Steel-Type 304	0.29	1,427°C (2,600°F)	9.9μin/in°F	Reference #1, p. 6-11
Tungsten	0.70	3,370°C (6,098°F)	2.4μin/in°F	Reference #1, p. 6-51
Cork	0.01	~230°C (~450°F)	NA	Reference #3
Lead (4% Sb)[1]	0.40	300°C (572°F)	15.4 μin/in°F	Reference #4, p. 11-420

[1]Note: 4% Sb Lead is used in subsequent thermal calculations in this Section as its melting point is lower than pure Lead which melts at 327°C (622°F) – ref: www.matweb.com for "Lead, Pb".

Resource references:

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

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

3. Amersham International plc RMR 214 Issue C.

4. Smithells, Colin J., *Smithells Metals Reference Book*, Seventh Edition, Butterworth-Heinemann Ltd, Oxford., 1992

3.2.2 Component Specifications

All components are specified and described on the Descriptive drawings included in the Section 1.3.

3.3 General Considerations

3.3.1 Evaluation by Analysis

Evaluations by analysis are described in the section they apply to in this Safety Analysis Report or when applicable in documents contained in Appendix 2.12 and 5.5

3.3.2 Evaluation by Test

Evaluations by direct testing are documented in the testing documents contained in Appendix 2.12 or are described in the section they apply to in this Safety Analysis Report.

3.4 Thermal Evaluation for Normal Conditions of Transport

3.4.1 Heat and Cold

3.4.1.1 <u>Insolation and Decay Heat</u>

This analysis determines the maximum surface temperature produced by solar heating of the Model 976 Series transport package loaded at maximum activity in accordance with 10 CFR 71.71(c)(1) and IAEA No. TS-R-1. This will be compared to the Normal Transport test conditions temperature range to determine which is the most onerous for thermal stress considerations.

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

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

b. The transport package is assumed to undergo free convective heat transfer from the top and sides, as airflow to the bottom of the package will most likely be blocked by the ground and/or a pallet.

c. To maximize the temperature of the stainless steel drum surface temperature, the inside transport package faces are considered perfectly insulated so there is no conduction into the transport package. In use, the inside transport package will act as a heat sink during daylight

hours and a heat source during the night, but this will be ignored for this calculation.

d. The transport package is approximated as a right cylinder with dimensions, 19 ¾ inches (0.52 m) in diameter (conservatively using the maximum lid diameter – the drum diameter is only 18 3/16 inches (0.46 m) except where it has stiffening ribs) and 21¼ inches (0.54m) high.

e. The surfaces of the transport package are assumed to be solid. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.

f. The worst case decay heat load (25 Watts) is added to the solar heat input load.

g. The emissivity coefficient of the stainless steel transport package is assumed to be 0.3, while the absorptivity coefficient is assumed to be 0.8.

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

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

Heat Input:

The solar heat input is the combined solar heating of the top horizontal surface and the vertical side surface. The insolation data, provided in 10 CFR 71.71(c)(1), is found in Table 3.4.1a.

Table 3.4.1.a: Insolation Data

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

Top surface heat input: $Q_{IT} = 800\ W/m^2 \times 0.212\ m^2 = 170\ W$

Side surface heat input: $Q_{IS} = 400\ W/m^2 \times 0.880\ m^2 = 352\ W$

Decay heat input: $Q_{DT} = 25\ W$

Absorptivity coefficient: $A_c = 0.8$

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

Total heat input: $Q_{IN} = A_c\,(Q_{IT} + Q_{IS}) + Q_{DT} = 443$ W

Heat Output:

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

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

Where:

B	=	5.67×10^{-8} W/m² K⁴ (Stefan-Boltzmann Constant)
E	=	0.3 (Emissivity of rough stainless steel @ 300°K)
A_{TS}	=	1.048 m^2 (top and side surface area)
T_W	=	The maximum surface temperature of the package (°C)
T_A	=	38°C (ambient temperature, per 10 CFR 71.71(c)(1))

Therefore:

$$Q_R = 1.78 \times 10^{-8}\{(T_W + 273)^4 - (311)^4\} = 1.78 \times 10^{-8}\,(T_W + 273)^4 - 166.76 \quad \text{(Equation 1)}$$

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

Where:

A_T	=	0.1976 m^2 (the top surface area)
H_T	=	The free convection coefficient for a flat horizontal surface

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

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

Where:

g	=	9.8 m/s^2

β	=	0.003215 ($1/(T_A + 273)$)
L	=	0.13 m (Area / Perimeter)
ν	=	18.9×10^{-6} m^2/s
α	=	26.9×10^{-6} m^2/s
K	=	28.52×10^{-3} W/mK

Therefore:

$$Q_T = 0.450\,(T_W - 38)^{1.25} \qquad \text{(Equation 3)}$$

Side surface convection: $$Q_S = H_S\, A_S\, (T_W - T_A) \qquad \text{(Equation 4)}$$

Where:

A_S	=	0.8506 m^2 (the total surface area of sides)
H_S	=	The free convection coefficient for a flat vertical surface

As stated in "Heat Transfer", Fourth Edition by Alan J. Chapman (1984), in the case of a vertical cylinder, calculations for a vertical plate may be applied to the case of the vertical cylinder as long as the circumferential curvature of the cylinder is not great, basically that:

$$\frac{D}{L} > \frac{35}{Gr_L^{1/4}}$$

Where:

D = Diameter of cylinder = 0.50 m
L = Characteristic Length = Height cylinder = 0.54 m
Gr_L = Grashof number for the plate length which is equal to:

$$Gr_L = \frac{L^3\, g\, \beta\, \Delta t}{\nu}$$

Where:

g = 9.8 m/s^2
β = 0.003215 ($1/(T_A + 273)$)
$\Delta t = (t_s - t_f) = 40°C\ (40°K)$
$\nu^2 = 18.90 \times 10^{-6}$ @ t_m from Chapman Appendix Table A.6.

For the Model 976 drum assemblies, this calculates to the following:

$$\frac{D}{L} > \frac{35}{Gr_L^{1/4}}$$
$$0.93 > 0.22$$

Therefore in the case of the Model 976 drum assemblies, vertical plane calculations are acceptable for use in convection calculations for a vertical cylinder as used in the following calculations.

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

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

Where:

L = 0.201 m (Area / Perimeter)

Therefore:

$$Q_S = 0.082\ (T_W - 38) + 1.65\ (T_W - 38)^{1.25} \qquad \text{(Equation 5)}$$

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

Total heat input: $Q_{IN} = Q_R + Q_T + Q_S + Q_{DT} = 443$ W

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

$$443 \text{ Watts} = 1.78 \times 10^{-8}\,(T_W + 273)^4 + 0.082\ (T_W - 38) + 2.101\ (T_W - 38)^{1.25} - 166.76$$

Iteration of this relationship yields a maximum wall temperature (T_W) of 90.3°C (195°F). This temperature would constitute the most onerous Normal Transport thermal condition. Based on the package materials of construction, this temperature will not be sufficient to adversely affect the package containment or shielding integrity. As such the package complies with the requirements of this section.

3.4.1.2 Still Air (shaded) Decay Heating

This analysis calculates the maximum surface temperature of the Model 976 Series Transport package in the shade (i.e., no insolation effects), assuming an ambient temperature of 38°C (100°F), per 10 CFR 71.43(g).

The same assumptions from Section 3.4.1.1 are used:

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

$$Q_D = Q_R + Q_T + Q_S \qquad \text{(Equation 6)}$$

Where:

Q_D	=	25 Watts (decay heat deposited on the surface)
Q_R	=	Heat radiated from surface of package
Q_T	=	Heat convected from top of package
Q_S	=	Heat convected from side of package

From Section 3.4.1.1,

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

Where:

B	=	5.67×10^{-8} W/m^2 K^4 (Stefan-Boltzmann Constant)
E	=	0.3 (Emissivity of rough stainless steel @ 300°K)
A_{TS}	=	1.048 m^2 (top and side surface area)
T_W	=	The maximum surface temperature of the package (°C)
T_A	=	38°C (ambient temperature, per 10 CFR 71.43(g))

Therefore:

$$Q_R = 1.78 \times 10^{-8}\{(T_W + 273)^4 - (311)^4\} = 1.78 \times 10^{-8}(T_W + 273)^4 - 166.76 \qquad \text{(Equation 7)}$$

Also from Section 3.4.1.1,

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

Where:

g	=	9.8 m/s^2

β	=	$0.003215\ (1/(T_A + 273))$
L	=	0.13 m (Area / Perimeter)
ν	=	$18.9 \times 10^{-6}\ m^2/s$
α	=	$26.9 \times 10^{-6}\ m^2/s$
K	=	28.52×10^{-3} W/mK
A_T	=	$0.1976\ m^2$ (the top surface area)

Therefore:

$Q_T = 0.4497\ (T_W - 38)^{1.25}$ (Equation 8)

Also from Section 3.4.1.1,

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

Where:

L	=	0.201 m (Area / Perimeter)
A_S	=	$0.8506\ m^2$ (the total surface area of sides)

Therefore:

$Q_S = 0.082\ (T_W - 38) + 1.651\ (T_W - 38)^{1.25}$ (Equation 9)

Substituting Equations 7, 8, and 9 into Equation 6:

$$25 \text{ Watts} = 1.78 \times 10^{-8} (T_W + 273)^4 + 2.101\ (T_W - 38)^{1.25} + 0.082\ (T_W - 38) - 166.76$$

Iteration of this relationship yields a maximum wall temperature (T_W) of 42.7°C (109°F), which is less than the maximum 50°C (122°F) allowed by 10 CFR 71.43(g).

3.4.1.3 Cold Effected Materials

The carbon steel components of the Model 976 Series (internal shields on the 976A and 976C) are most affected by the low Normal Transport temperature (-40°C). During testing, shock induced stresses could cause the steel to fail in brittle fracture. As such, all shock inducing testing (i.e. drops, punctures and penetrations) was carried out at the lower temperatures. Outer drums and cork inserts absorbed the majority of the energy and the carbon steel was not damaged during testing.

Cork used for the drum inserts also exhibits some brittle tendencies at lower temperatures. Again, all cork inserts were kept at or below (-40°C). The inserts exhibited cracking to varying degrees, but provided adequate protection for all of the specimens tested.

All materials exhibit some contraction due to lower temperatures. However in this limited temperature range, the Model 976 was not adversely effected as all specimens passed the Normal and Hypothetical Accident drop, puncture and compression testing.

3.4.2 Temperatures Resulting in Maximum Thermal Stresses

The temperature and pressure variations described in Sections 3.4.1 and 3.4.2 will not adversely affect the transport package during normal transport since the melting temperatures of all safety critical components are well above these temperatures and the pressures calculated are insufficient to cause package failure. It its therefore concluded that the Model 976 transport package will maintain its structural integrity and shielding effectiveness under the normal transport thermal stress conditions.

3.4.3 Maximum Normal Operating Pressure

All outer drum components are vented to the atmosphere. As such, pressure will not build up in the packages during Normal Transport conditions. This condition is not time dependent once steady state is achieved. However, the Model 855 shield container does have a small gasketed cavity. If the cavity is sealed under the lowest temperatures (-40°C) and then allowed to heat up to the highest (88°C from Section 3.4.1.1) a small pressure differential will be created.

Using the Ideal Gas Law and equating for two standard scenarios we get:

$$P_1/T_1 = P_2/T_2 \qquad \text{(Equation 13)}$$

Where: P_1 = Ambient pressure at sealing = 14.7 psi

T_1 = -40°C (233°K)
P_2 = Pressure at temperature (88°C) (361°K)
T_2 = 88°C (361°K)

Substituting into Equation 13 we get a pressure of:

P_2 = 22.8 psi

Which is a pressure differential of 8 psi. Containers with no gasket sealed cavities will exhibit a pressure differential of 0 psi as they are vented to the atmosphere with no means for creating a pressure differential. No other contributing gas sources are present.

3.5 Thermal Evaluation Under Hypothetical Accident Conditions

3.5.1 Initial Conditions

Frequently it is difficult to determine which damaged container would be the worst case. As such multiple containers were tested. This was also the case for the fire tests performed on the Models 3605B and Model 650L (See Section 2.12.3 for Test Plan 163 Report and reference section 5.4 for an assessment of the Model 976 Series containers based on the testing performed on the Models 3605B and 650L).

Since the Model 976 Series container is symmetrical along its axis, orientation would have little effect on the thermal response of the package. Additionally, all thermal gradient calculations assume a starting temperature of –40°C, as this is the worst case scenario for gas pressure build up.

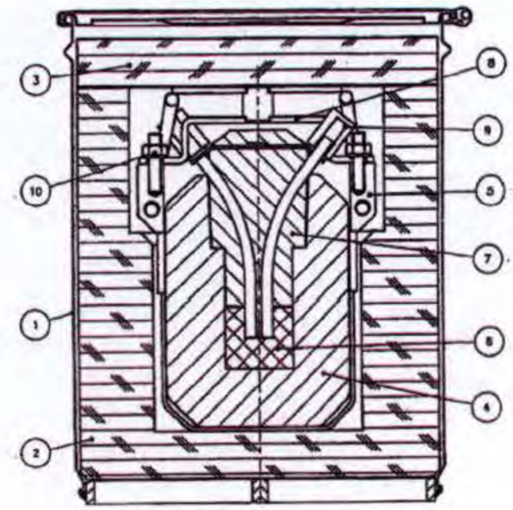
3.5.2 Fire Test Conditions

The response of the package, in its various configurations, to the thermal test of 10 CFR 71.73(c)(4) is assessed from previous satisfactory thermal tests performed on the Model 3605B and the Model 650L (See Section 2.12.3 for Test Plan 163 Report and reference section 5.4).

Damage to the test units under Test Plan 163 Report (Section 2.12.3) was external. All test specimens retained closure between the lid and drum base and no air gaps were created that could allow charring of the cork greater than was observed in the thermal tests performed on the Model 3605B (Test 1835 located in Appendix F of Test Plan 163 Report in Section 2.12.3). No damage was induced in any of the inner shield containers and there was no cracking of any welds in the inner shield containers after the Hypothetical Accident drop testing.

3.5.2.1 General Considerations

Thermal testing was performed for a similar, but smaller, drum design the Model 3605B (See Figure 3.5.2a). The tested drum measured 32.5 cm in diameter by 40.5 cm tall with minimum cork thickness on the bottom of 4 cm, on the top of 4.5 cm and on the sides of 5 cm. In contrast the Model 976 package measures 50 cm in diameter by 54 cm tall. The Model 976 Series packages have a minimum cork thickness, which is based on the Model 976A configuration containing the least cork material, of 5 cm on the bottom, 12.7 cm on the top and 8.3 cm on the sides.



Item	Description	Material	No. off
1	DRUM	STEEL	1
2	PACKING INSERT	CORK	1
3	PACKING SPACER	CORK	1
4	LEAD POT	LEAD	1
5	POT CRADLE	CARBON STEEL	1
6	CORE SHIELD	TUNGSTEN ALLOY DEPLETED URANIUM	1
7	SHIELDING INSERT	LEAD	1
8	RETAINING STRAP	CARBON STEEL	1
9	TUBE CAP	BRASS	4
10	M10 COMBI NUT	STAINLESS STEEL	2

FIGURE 3.5.2a – TEST SPECIMEN CONFIGURATION FOR TEST NUMBER 1835

Test Number 1835 (see Appendix F of Test Plan 163 Report in Section 2.12.3) documents testing of a Model 3018 inner shield container (lead shielded device) inside of a cork lined steel drum assembly. The cork used in these test units was purchased to the same specification as the cork used for the test specimens under Test Plan 163 Report, however, the overall cork thickness is greater in the Model 976 style packages than was used in the specimens tested under Test Number 1835.

Testing included 9 m drop tests and puncture tests in similar orientations as were performed for the test specimens under Test Plan 163 Report. The test specimens under Test Number 1835 were tested at ambient temperature and were not cooled to -40°C prior to the 9 m and puncture drop tests as were the drop test units under Test Plan 163 Report.

As was seen with the Model 976 style test specimens, the test units described under Test Number 1835 also experienced drum deformation but no loss of the lid from the drum base. Though cracking of the cork was not specifically referenced on the sides of the cork liners in the test units from Test Number 1835, cracking of the bottom cork inserts was noted. The bottom of the cork cavity was cracked around the circumference and across diagonals in line with the drum reinforcement bars.

Thermal testing of the specimens under Test Number 1835 placed the specimens into a furnace maintained at an ambient temperature between 800°C - 820°C for a period of 30 minutes. The test specimens did not contain any radioactive contents during the thermal testing performed under Test Number 1835. The test specimens were allowed to cool for at least 18 hours before disassembly and evaluation.

Upon evaluation it was found that the top cork inserts exhibited slight charring (e.g. 22-25 mm depth) with a 26 mm thickness of the insert remaining intact. In both cases the inner lead shield container was undamaged, exhibiting only the presence of a resin condensate and soot on the lead pot exterior. For both test specimens, the maximum temperature recorded by temperature strips on the exterior surface of the lead pot was 82°C. This temperature rise was less than ¼ of that necessary to reach the melting point of the lead pot (300°C). Therefore no melting or slumping of the lead shielding occurred.

Upon inspection of the test specimens under Test Plan 163 it was observed that TP163(C) exhibited the largest cork cracking on the side inserts. This test unit contained jagged cracks up to ¼" in width in the sides of the cork inserts (see Figures 28 and 29 in Test Plan 163 Report contained in Section 2.12.3). The presence of these cracks introduces the possibility of a different result in the thermal test if performed. The three thermal transport mechanisms are conduction, convection and radiation. Each will be addressed in the following assessment.

3.5.2.2 Conduction Contribution During Fire Test

The shield containers used in the Model 976 drum assembly are of two general types: (1) those which use depleted uranium for their primary shielding (e.g., 855), and (2) those that use lead for their primary shielding with supplemental materials as part of the inner assembly shielding design (e.g., 3056 and 1911). All shield container exteriors are a steel weldment which does not melt below 1,427°C. The melting point of depleted uranium is 1,130°C.

A calculation of the worst case, steady state conduction through the cork insulation that could be created in TP163(C) is as follows:

$$Q_X = \frac{k\,A(T_1 - T_2)}{L}$$

(Reference Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and Dewitt, page 5.)

Where:

Q_x = the heat transfer rate in Watts

k = coefficient of thermal conductivity, 0.0314 W/m°K for air (at 370°K); 0.039 W/ m °K for cork (Reference: Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and DeWitt, Appendix A)

A = cross sectional area of material (~2 cracks, ¼" wide = 0.00635 m, each 0.5 m long) = 0.00635 m^2

T_1 = Drum Wall Temperature (assumed to be thermal test temperature = 800°C or 1,027°K)

T_2 = Shield Container Initial External Temperature (assumed to be = 97°C or 370°K from Section 3.5.2.4)

L = minimum thickness of the outer and inner cork liners (located on the sides) = 0.08m + 0.04m = 0.12 m

For the thermal test, regardless of the cork condition, A, T_2 , T_1 and L will be the same. The only difference will be the variation in the coefficient of thermal conductivity between air and cork. As indicated above, the coefficient for air is less than the coefficient for cork, therefore the heat transfer rate in air through the crack will be less than is experienced through the cork.

Calculation of the maximum conduction through the solid cork is based on the maximum outer area divided by the minimum cork thickness. The drum outer surface is 0.52 m in diameter and 0.54 m high for a maximum cross sectional area of 1.31 m^2. The minimum cork thickness at the bottom of the drum is 0.08 m. Therefore the maximum heat transfer rate from conduction is 420 Watts.

3.5.2.3 Convection Contribution During Fire Test

There is a limited air gap between the cork and the inner surface of the drum. As such, movement of the air around the cork inside the drum to produce convection heating will be insignificant when compared to the conductive heat transferred directing from the drum to the cork. If the

crack in the cork is approximated as a solid air volume between the inner drum surface and the outer shield container, then a worst case approximation of the conductive heat transfer can be made in this limited air volume. Similar to steady state conduction, the under steady state conditions, the local heat transfer rate can be calculated as follows:

$$q_X = (T_1 - T_2) \int h \, dA_s$$

(Reference Fundamentals of Heat and Mass Transfer, 5th Edition, by Incropera and Dewitt, page 327.)

Where:
q_x = the heat transfer rate in Watts
h = convection coefficient for air = 10 Watts/m^2 °K (Reference IAEA TS-G-1.1 (ST-2))
dA_s = cross sectional area of material (~1 cracks, ¼" wide = 0.00635 m, each 0.5 m long)
T_1 = Drum Wall Temperature (assumed to be thermal test temperature = 800°C or 1,027°K)
T_2 = Shield Container Initial External Temperature (assumed to be = 97°C or 370°K from Section 3.5.2.4)

Estimating the air volume between the inner drum wall and outer shield surface as a vertical cylinder produces the following equation.

$$q_X = h 2 \pi r l (T_1 - T_2)$$

Where:

r = the radius of the cylinder (crack) = 0.0032 m
l = length of the crack = 0.305 m

Solving for q_x produces a worst case heat transfer rate from convection of 43 Watts along the inner surface of the cork crack.

3.5.2.4 <u>Radiant Heat Contribution During the Fire Test</u>

The jagged path of the crack through the cork prevents any radiation from the drum wall directly contacting the shield container. Without direct contact, the radiative heat transfer to the shield container surface will be insignificant in comparison to the other heat transfer contributions.

Assuming heat contribution to the inner shield from the radioactive contents produces a worst case transfer rate as follows:

The Specific heat output of Ir-192 is 8.6 mW/Ci assuming a decay energy of 1.46 MeV/decay and that 100% of the radioactive decay is transferred to thermal energy. The maximum source content for the package is 1,250 Ci. The maximum decay heat for Ir-192 in table 1.2d has been adjusted to account for content activity of the source. Actual content to output activity varies based on the capsule configuration as well as variations in isotope self-absorption. A factor of 2.3 was used to convert output activity to content activity as this factor reflects the worst case variation for Ir-192 sources transported in these packages. Therefore the total content activity would be 2,875 Ci and the total heat output assuming a conservative 100% decay during the thermal test is:

8.6 mW/Ci x 2,875 Ci = 24,725 mW = 24.73 Watts

Even assuming complete decay of the Ir-192 during the thermal test produces a heat transfer rate that is insignificant when compared with heat transfer from conduction and convection. Calculation for the Model 1911 inner shield (smallest shield diameter/wall thickness and largest source term) based on a thermal analysis from "Fundamentals of Heat and Mass Transfer", F.P. Incropera, 5th Edition, 2002 is as follows:

$$Q_{in} = Q_{radiated} = Q_{decay} = 24.73\ watts$$

Where:

$Q_{radiated}$ = heat radiated = B E A_{ts} [$(T_w + 273)^4 - (T_m + 273)^4$]

(This equation assumes no conduction or convection from all surfaces and radiative heat losses from the top and side surfaces only).

A_{ts} = Area of the top and sides = 0.174 m^2 based on:

$$A_{ts} = \left(\left[\frac{diameter}{2}\right]^2 \pi\right) + (diameter)(height)\pi$$

T_a = ambient temperature = 20°C
T_w = shield maximum equilibrium temperature
T_m = shield median temperature = $(T_a + T_w)/2$
B = Stefan Boltzmann Constant = 5.670×10^{-8}
E = emissivity for rough stainless steel surface between 300 and 400°K = 0.3

Iteration for T_w balancing the heat in to the heat radiated produces a value of 109.4°C (229°F) for the maximum temperature at the surface of the inner

shield prior to the start of the thermal test.

3.5.2.5 Thermal Contribution Summary During the Fire Test

To raise the temperature of the shield containers with lead to the melting point of lead would require a significant amount of energy. The specific heat of lead, C_p = 0.15 kJ/kg-°K. From this relation, calculation of the required heat transfer rate is as follows:

$$Q_{Input} = C_p\, M\,(T_2 - T_1)$$

Where

Q_{Input} = Minimum heat input to melt the lightest lead container (Model 3015)

C_p = Specific Heat of Lead

M = Mass of the shield container = 114 lbs or 52 kgs for Model 3056 (Lightest shield)

T_2 = Melting temperature of lead = 573°K (300°C, see Table 3.2a)

T_1 = Ambient shield temperature = 370°K (See Section 3.5.2.4)

Therefore the required heat transfer rate to cause lead melting in the shield is 1,569 kJ or 1.569 x 10^6 Watts/sec. To achieve this in the 30 minutes (1,800 sec) of the thermal test requires a heat input of 872 Watts. Even when combining all the worst case thermal contribution factors, the required heat input in the most vulnerable area along the cork crack is less than 60% of the actual heat input that would melt the lead shield and will therefore be insufficient to degrade the lead shielding.

3.5.2.6 Additional Factors for Consideration During the Fire Test

In the case of the depleted uranium shield containers, there was no breach or weld cracking of the shield container which would allow oxygen to reach the inner depleted uranium shield. Without the presence of a continuing source of oxygen, these shields will remain intact during the thermal test. As seen in testing performed on the Model 650L (Reference USNRC CoC USA/9269/B(U)-85, Test Plan 80 Report Revision 1) thermal testing of this device where cracking to allow air to the shield had occurred resulted in production of only a small amount of depleted uranium oxide. With an air path and air circulation during the thermal test, the radiation dose rate at one meter from this unit increases by approximately 10% remaining less than 3% of the regulatory limit.

Without sufficient oxygen provided to the interior of the depleted uranium shield containers (e.g., welds intact) there will be no appreciable oxidation of

the depleted uranium shield inside the steel container housings, and the 800°C temperature is well below the melting point of depleted uranium (1,130°C) therefore the shield will retain its original shape throughout the thermal test.

3.5.2.7 Thermal Assessment Summary

The thermal test will not adversely effect the structural integrity of the shield containers. The Model 855 and Model 1911 containers were physically undamaged after the 9 m and puncture drop testing. The 3056 shield container is lighter than the Models 855 and 1911 and would therefore be expected to sustain less damage in the drop configurations than was seen for these package assemblies (See Section 5.4 of Test Plan 163 Report in Section 2.12.3).

For shield containers incorporating lead, the exterior shield temperature will not exceed 109.4°C. The testing performed under Test Number 1835 took drum assemblies at ambient temperature prior to subjecting them to the thermal test condition. In actual practice the 976 package assemblies would have been thermally tested immediately after the puncture test and would still have been at a temperature below 0°C introducing a further temperature difference to be overcome before the shield container would be susceptible to a melting temperature.

For the Model 976 Series packages, performance of the thermal test would not produce a condition sufficient to reduce the shielding efficiency or containment efficiency of the shield containers within the 976 drum assembly. In addition, the temperature increase in the shield container surfaces will be well below the melting temperature of the lead which will preclude any shielding configuration change or lead slumping in the shield containers. By assessment, the Model 976 Series package designs would therefore meet the thermal test requirements.

3.5.3 Maximum Temperatures and Pressure

All outer drum components are vented to the atmosphere. As such, pressure will not build up in the packages during Normal Transport conditions. This condition is not time dependent once steady state is achieved. However, the Model 855 shield container does have a small gasketed cavity. If the cavity is sealed under the lowest temperatures (-40°C) and then allowed to heat up until the gasket is burned away allowing release of any pressure build up at a temperature of 177°C a small pressure differential will be created.

Using the Ideal Gas Law and equating for two standard scenarios we get:

$$P_1/T_1 = P_2/T_2 \qquad \text{(Equation 13)}$$

Where: P_1 = Ambient pressure at sealing = 14.7 psi
T_1 = -40°C
P_2 = Pressure at temperature (177°C)
T_2 = 177°C

Substituting into Equation 13 we get a pressure of:

$$P_2 = 28 \text{ psi}$$

Which is a pressure differential of 14 psi. Containers with no gasket sealed cavity will exhibit a pressure differential of 0 psi as they are vented to the atmosphere with no means for creating a pressure differential. No other contributing gas sources are present. See Section 2.7.4.3.

3.5.4 Temperatures Resulting in Maximum Thermal Stresses

The temperature and pressure variations described in Sections 3.4.1 and 3.4.3 will not adversely affect the transport package during normal transport since the melting temperatures of all safety critical components are well above these temperatures and the package will experience no pressures sufficient to cause package failure. The thermal stresses introduced under the hypothetical accident condition criteria were evaluated in Section 3.5.3 and again demonstrated to be insufficient to cause package failure. It is therefore concluded that the Model 976 Series transport packages will maintain their structural integrity and shielding effectiveness under the hypothetical accident condition transport thermal stress conditions.

3.5.5 Fuel/Cladding Temperatures for Spent Nuclear Fuel

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

3.5.6 Accident Conditions for Fissile Material Packages for Air Transport

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

3.6 Appendix

Not Applicable.

Section 4 – CONTAINMENT

4.1 Description of the Containment System

The containment system consists of the Model 976 Series transport packages and the radioactive source capsule(s). See Section 1.2.1.4 and Table 1.2c for details related to source securement in the Model 976 Series packages. The source capsule(s) shall be qualified as Special Form radioactive material under 49 CFR 173 and IAEA No. TS-R-1 (2009).

4.1.1 Special Requirements for Damaged Spent Nuclear Fuel

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

4.2 Containment Under Normal Conditions of Transport

As demonstrated in Test Plan 90 Report and assessed under Test Plan 163 Report (Sections 2.12.2 and 2.12.3 respectively), performance of the normal conditions of transport testing caused no breach of the source capsules contained in the package. Since the source capsules are the primary containment of the radioactive contents and no release from the source capsules occurred, the Model 976 Series packages meet the requirements of this section.

4.3 Containment Under Hypothetical Accident Conditions

As demonstrated in Test Plan 90 Report, Test Plan 163 Report and Test Plan 214 Report (See Section 2.12), after performance of the hypothetical accident conditions of transport testing, the radiation level at one meter from the surface of the package did not exceed 1 R/hr. The Model 976 Series packages therefore meet the requirements of this section.

4.4 Leakage Rate Tests for Type B Packages

The primary containment for the radioactive material in the Model 976 Series transport packages are the radioactive source capsules. All source capsules authorized for Type B transport in the Model 976 Series packages are certified as special form radioactive material under 10 CFR Part 71, 49 CFR Part 173 IAEA No. TS-R-1 (2009). After manufacture and again once every six months thereafter prior to transport, the source capsule is leak tested in accordance with ISO9978:1992(E) (or more recent editions) to ensure that containment of the source does not allow release of more than 0.005 μCi of radioactive material. These fabrication and periodic tests ensure that contamination release from the package does not exceed the regulatory limits.

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

4.5 Appendix

Not Applicable.

Section 5 - SHIELDING EVALUATION

5.1 Description of Shielding Design

5.1.1 Design Features

The principal shielding in the Model 976 Series transport packages are depleted uranium, tungsten or lead shield assemblies used in the shield containers. Dimensional information for the individual shield containers is contained in the shield drawings included in Section 1.3. Table 3.2a lists the material densities of the packaging.

5.1.2 Summary Table of Maximum Radiation Levels

Table 5.1a includes radiation profile data obtained from the 976 Series package that was tested to the Normal Conditions of Transport under Test Plan 90 (see Section 2.12.2). Note that radiation survey results from this package were obtained after the package had also been subjected to the Hypothetical Accident Condition testing.

Table 5.1a: Model 976A with 855 sn 9 - TP90A
Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use) After Normal and Hypothetical Accident Transport Condition Testing Under Test Plan 90 Report

(Ref: Profile Sheet "855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan 90 Report and Pre-Test Results under Test Plan Report 163". Copy of profile sheet located in Appendix D of Test Plan 90 Report (Section 2.12.2) and Appendix D of Test Plan Report 163 (Section 2.12.3))

Normal Conditions of Transport	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
	Top	Side	Bottom	Top	Side	Bottom
Total (Gamma Only)	1.41 (141)	0.38 (38)	0.75 (75)	0.019 (1.9)	0.003 (0.3)	0.008 (0.8)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)
Hypothetical Accident Conditions						
Total (Gamma Only)				0.019 (1.9)	0.003 (0.3)	0.008 (0.8)
10 CFR 71.51(a)(2) Limit				10 (1000)	10 (1000)	10 (1000)

[1]Transport Index may not exceed 10. The Transport Index is equivalent to the 1 meter reading in mRem per hour (i.e., 5 mRem per hour at 1 meter = a Transport Index of 5.0).
[2]All packages accepted and released for shipment under this Model designation will have a Transport Index less than or equal to 10.

NOTE: Survey results in Test Plan 90 Report both before and after hypothetical accident conditions were obtained from the Model 855 outside of the drum and cork components. This produced dose rates which would be higher than the Model 855 if it had been placed inside the test drum and cork components. Values after hypothetical accident conditions are measured 1 meter from the surface of the Model 855.

Tables 5.1b through 5.1.d includes radiation profile data obtained from the 976 Series packages that were tested to the Hypothetical Conditions of Transport under Test Plan 163 (see Section 2.12.3). Notes 1 through 3 apply to Tables 5.1b through 5.1.l. Note 4 applies to Tables 5.1.b and 5.1.c only.

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

Note 2: All packages accepted and released for shipment under this Model designation will have a Transport Index less than or equal to 10.

Note 3: Dose rates under exclusive use conditions for the package identified in the Table will not exceed the maximum package surface dose rate on the vehicle surface. In addition, the maximum dose rate in the Occupied Position of the vehicle will not exceed 0.02 mSv/hr (2 mrem/hr).

Note 4: Survey results in Test Plan 163 Report both before and after hypothetical accident conditions were obtained from the Model 855 outside of the drum and cork components. This produced dose rates which would be higher than the Model 855 if it had been placed inside the test drum and cork components. Values after hypothetical accident conditions are measured 1 meter from the surface of the Model 855.

Table 5.1b: Model 976A with 855 sn 8 - TP163(A)
Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use) After Hypothetical Accident Transport Condition Testing Under Test Plan 163 Report

(Ref: Profile Sheet "855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan Report 163 (SN 8)". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.021 (2.1)	0.006 (0.6)	0.029 (2.9)
Neutron	NA	NA	NA
Total	0.021 (2.1)	0.006 (0.6)	0.029 (2.9)
10 CFR 71.51(a)(2) Limit	10 (1000)	10 (1000)	10 (1000)

Table 5.1c: Model 976A with 855 sn 9 – TP163(B)
Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use) After Hypothetical Accident Transport Condition Testing Under Test Plan 163 Report

(Ref: Profile Sheet "855 Device Profile (Without 976 drum/cork overpack) Used for Post Test Results under Test Plan Report 163 (SN 9)". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.028 (2.8)	0.006 (0.6)	0.010 (1.0)
Neutron	NA	NA	NA
Total	0.028 (2.8)	0.006 (0.6)	0.010 (1.0)
10 CFR 71.51(a)(2) Limit	10 (1000)	10 (1000)	10 (1000)

Table 5.1d: Model 976F with 1911 sn 013 – TP163(C)
Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use) After Hypothetical Accident Transport Condition Testing Under Test Plan 163 Report

(Ref: Profile Sheet "976F (1911 w/Depleted Uranium Insert Device Capacity Profile with 976 drum/cork overpack) Performed After Testing under Test Plan 163 – Test Specimen TP163C". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.006 (0.6)	0.015 (1.5)	0.006 (0.6)
Neutron	NA	NA	NA
Total	0.006 (0.6)	0.015 (1.5)	0.006 (0.6)
10 CFR 71.51(a)(2) Limit	10 (1000)	10 (1000)	10 (1000)

Tables 5.1e through 5.1l include radiation profile data used to demonstrate that all shield and package configurations will meet the external radiation level requirements for non-exclusive use transport when loaded to capacity for that package configuration.

Table 5.1e: Model 976A with 855 sn 9 – Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use)

(Ref: Profile Sheet "976A (855 Device Profile With 976 drum/cork overpack)". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Normal Conditions of Transport	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
	Top	Side	Bottom	Top	Side	Bottom
Total (Gamma Only)	0.29 (29)	0.10 (10)	0.22 (22)	0.011 (1.1)	0.003 (0.3)	0.005 (0.5)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)
Hypothetical Accident Conditions						
Total (Gamma Only)				0.019 (1.9)	0.003 (0.3)	0.008 (0.8)
10 CFR 71.51(a)(2) Limit				10 (1000)	10 (1000)	10 (1000)

Table 5.1f: Model 976C with 3056 sn P0745-060 – Summary Table of External Radiation Levels Extrapolated to Capacity of 1,250 Ci Ir-192 (Non-Exclusive Use)

(Ref: Profile Sheet "976C Modified Insert Configuration – Performed 11 Jan 06. Copy of profile sheet located in Section 5.5.2)

Normal Conditions of Transport	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
	Top	Side	Bottom	Top	Side	Bottom
Total (Gamma Only)	0.78 (78)	1.46 (146)	1.69 (169)	0.046 (4.6)	0.053 (5.3)	0.055 (5.5)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)
Hypothetical Accident Conditions						
Total (Gamma Only)				0.046 (4.6)	0.053 (5.3)	0.055 (5.5)
10 CFR 71.51(a)(2) Limit				10 (1000)	10 (1000)	10 (1000)

Table 5.1g: Model 976F with 1911 sn 013 with Depleted Uranium Insert Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use)

(Ref: Profile Sheet "976F (1911 w/Depleted Uranium Insert Device Capacity Profile With 976 drum/cork overpack) Performed Before Testing under Test Plan 163 – Test Specimen TP163C". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Normal Conditions of Transport	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
	Top	Side	Bottom	Top	Side	Bottom
Total (Gamma Only)	0.11 (11)	0.049 (49)	0.018 (18)	0.007 (0.7)	0.011 (1.1)	0.007 (0.7)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)
Hypothetical Accident Conditions						
Total (Gamma Only)				0.007 (0.7)	0.011 (1.1)	0.007 (0.7)
10 CFR 71.51(a)(2) Limit				10 (1000)	10 (1000)	10 (1000)

Table 5.1h: Model 976F with 1911 sn 013 with Tungsten Insert – Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use)

(Ref: Profile Sheet "976F (1911 w/Tungsten Insert Device Capacity Profile With 976 drum/cork overpack)". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Normal Conditions of	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
Transport	Top	Side	Bottom	Top	Side	Bottom
Total (Gamma Only)	0.63 (63)	0.062 (6.2)	0.042 (4.2)	0.045 (4.5)	0.023 (2.3)	0.013 (1.3)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)
Hypothetical Accident Conditions						
Total (Gamma Only)				0.045 (4.5)	0.023 (2.3)	0.013 (1.3)
10 CFR 71.51(a)(2) Limit				10 (1000)	10 (1000)	10 (1000)

Table 5.1i: Model 976F with 1911 sn 013 with Lead Insert – Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci Ir-192 (Non-Exclusive Use)

(Ref: Profile Sheet "976F (1911 w/Lead Insert Device Capacity Profile With 976 drum/cork overpack)". Copy of profile sheet located in Appendix D of Test Plan 163 Report (Section 2.12.3))

Normal Conditions of	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
Transport	Top	Side	Bottom	Top	Side	Bottom
Total (Gamma Only)	0.73 (73)	1.27 (127)	1.12 (112)	0.034 (3.4)	0.052 (5.2)	0.034 (3.4)
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)
Hypothetical Accident Conditions						
Total (Gamma Only)				0.034 (3.4)	0.052 (5.2)	0.034 (3.4)
10 CFR 71.51(a)(2) Limit				10 (1000)	10 (1000)	10 (1000)

Tables 5.1a through 5.1i include radiation profile data used to demonstrate that the Model 976 style package configurations will meet the external radiation level requirements for non-exclusive use transport when loaded to capacity for Ir-192.

The photon energies and quantities from both Se-75 and Yb-169 are less than Ir-192. The materials providing effective shielding for contents in the 976 style packages are lead, depleted uranium and steel. An evaluation of transmission factors for Se-75 and Yb-169 when compared to Ir-192 in these materials is shown in Table 5.1m

Table 5.1j: Radionuclide Transmission Shielding Assessment

Nuclide	Calculation Activity (Ci)	Γ (R m^2/hr Ci)	Transmission Ratio Steel Relative to Ir-192	Transmission Ratio Lead Relative to Ir-192	Transmission Ratio Depleted Uranium Relative to Ir-192
Ir-192	1	0.48	1	1	1
Se-75	1	0.203	0.422	0.088	0.019
Yb-169	1	0.125	0.160	0.006	5.5E-4

Transmission exposure rates were determined using Microshield V5 (See Section 5.5.3). Transmission values were calculated through a unit material thickness of 1 cm for each of the shielding materials and were calculated for a unit activity of 1 Ci of each radionuclide. The shielding material densities used in the Microshield calculations were as follows: steel (7.86 g/cm^3), lead (11.34 g/cm^3) and depleted uranium (18.7 g/cm^3).

The relative shielding reduction per shielding material for each radionuclide confirms that for a unit quantity of 1 Ci of Ir-192, the dose rate from an equivalent unit quantity of 1 Ci of either Se-75 or Yb-169 will allow a significantly lower transmission of radiation through the material for both Se-75 and Yb-169 when compared to Ir-192. In addition, the relative radiation rate in air for Se-75 and Yb-169 are over ½ that which would be expected from the same activity of Ir-192.

Since each shielding material will effectively shield Se-75 and Yb-169 to a greater extent than it will shield Ir-192 and since the maximum activity of Se-75 or Yb-169 does not exceed the maximum rated capacity for the package when loaded with Ir-192 for any 976 package, the package radiation dose rates for each Model 976 design can be bounded by results performed to demonstrate the package shielding is effective to shield the maximum capacity of Ir-192 authorized in the package design.

Also, since all shielding materials will effectively shield Se-75 and Yb-169 to a greater extent than they will shield Ir-192, any combination of sources containing either Ir-192, Se-75 or Yb-169 will also not exceed the maximum package surface and 1 meter radiation dose limits specified in the regulations if the contents of a package loaded with multiple isotopes meets the following condition:

$$\sum \frac{q_i}{Q_{CoC,i}} \leq 1,$$

Where q_i is the amount of radioisotope i loaded in the Model 976 Series package and

$Q_{CoC,i}$ is the maximum amount of radioisotope i allowed in the Model 976 Series package as specified in the Certificate of Compliance (CoC).

Since the content activity for both Se-75 and Yb-169 are equal to or less than the content activity of Ir-192 in all cases, by the preceding assessment the Model 976 package configurations will also meet the external radiation level requirements for non-exclusive use when loaded to capacity for Se-75 or Yb-169 or when loaded with more than one different radionuclide so long as the sum of the activity ratios as described above is ≤ 1.

5.2 Source Specification

5.2.1 Gamma Source

The gamma sources allowed for transport in the Model 976 Series transport package specified in Sections 1.2.3 and 2.10.

5.2.2 Neutron Source

Not Applicable. The Model 976 Series transport packages are not used for the transportation of neutron emitting sources.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

A shielding model was not used as the primary justification for these packages. Shielding justification was based on direct measurement. However, a estimate of the calculated shielding efficiency for the Model 976C package configuration was performed using Microshield V5.05 (see Section 5.5.1). Comparison of the estimated shielding results for the bottom of this package configuration against the measured radiation dose were in good agreement (calculated dose rate of 141 mR/hr versus measured dose rate of 169 mR/hr). See Table 5.3.1a

Table 5.3.1a: Microshield Comparison Calculations for the Model 976C Package

Case #	DU Insert	Lead on Bottom of 3056	Steel strap of 3056 (This Gap is Assumed to be air for worst case Assessment)	Inner Cork Insert Bottom	Outer Cork Insert Bottom	Drum Bottom	Microshield Calculated Surface Dose Rate
1	Density = 18 g/cc Thickness = 1 in	Density = 11.34 g/cc Thickness = 1.4 in	Density = 0.00122 g/cc Thickness = 0.1 in	Not Included in Calculation. Dose Calculated on Surface of 3056	Not Included in Calculation. Dose Calculated on Surface of 3056	Not Included in Calculation. Dose Calculated on Surface of 3056	1,614 mR/hr
2	Density = 18 g/cc Thickness = 1 in	Density = 11.34 g/cc Thickness = 1.4 in	Density = 0.00122 g/cc Thickness = 0.1 in	Assumed to be Air Density = 0.00122 g/cc Thickness = 1.25 in	Assumed to be Air Density = 0.00122 g/cc Thickness = 2 in	Steel Density = 7.82 g/cc Thickness = 0.06 in	141 mR/hr

The surface reading at the bottom for the Model 976C package from Table 5.1.g is 169 mR/hr. If the distance and shielding provided by the drum and cork inserts are not considered in the calculations, a significantly higher dose rate is obtained using Microshield. However, Microshield produces a calculated dose rate very close to the value listed in Table 5.1g if the shielding model incorporates the actual distance from the Model 3056 shield to the drum surface, and if it accounts for the presence of the cork. As shown in test Case 2 in Table 5.3.1a, a surface dose rate of 141 mR/hr is calculated for a package which assumes the dose rate is measured on the surface of the drum and the cork has a density equivalent to air.

5.3.2 Material Properties

Not Applicable. A shielding model was not used in the justification for these packages. Shielding justification was based on direct measurement.

5.4 Shielding Evaluation

5.4.1 Methods

Shielding justification was based on direct measurement. See Test Plan 163 Report (see Section 2.12.3) for results of radiation surveys of the 976 Series transport packages. Note there was no physical testing of the package configuration using the Model 3056 under Test Plan 163 Report (Ref: Section 2.12.3). Radiation survey information for this package configuration in Test Plan 163 Report (Ref: Section 2.12.3) was performed to document shielding capacity of this package configuration. Assessment of this package configuration under the normal and hypothetical accident condition testing is provided in Test Plan 163 Report Sections 5.4 and 5.5 (See Section 2.12.3).

5.4.2 Input and Output Data

Radiation measurements included in this Section were adjusted to the maximum activity capacity for the package (e.g., activity correction factor) and the surface measurements were also adjusted to correct for off-set of the survey meter probe from the true surface of the package.

Activity correction factors (CF_A) were obtained by using the following relationship:

$$CF_A = \frac{Maximum Package Activity Capacity\ (A_C)}{Actual\ \mathrm{Pr}\, ofile Activity\ (A_P)}$$

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

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

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

Radiation measurements at the surface of the container were also adjusted to compensate for the off-set of the survey meter probe from the true surface of the package.

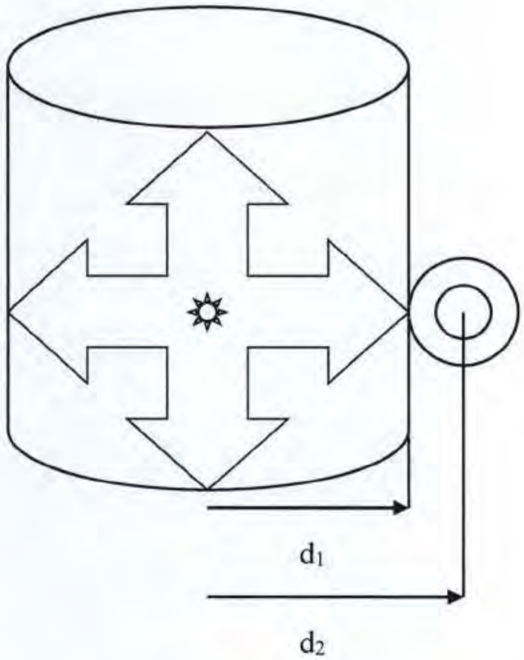
Surface correction factors (SCF) were obtained by using the following relationship:

$$SCF = \frac{d_2}{d_1} \text{ where } d_1 \text{ and } d_2 \text{ are determined as shown in Figure 5.a.}$$

$$\text{For Example, if } d_1 = 9 \text{ inches and } d_2 = 9.5 \text{ inches, then}$$

$$SCF = \frac{9.5\,inches}{9\,inches} = 1.06$$

Therefore in the example shown, all original surface profile measurements located along the side of the drum shown in Figure 5.a would also be multiplied by a factor of 1.06 to account for surface correction of the detector to the drum. Different SCF's would be calculated for the any dimension of the container where the minimum distance from the center of the activity to the center of the radiation probe is different.



d_1 =	distance from activity center to surface of container.
d_2 =	distance from activity center to surface of container plus radius of the survey meter probe.

FIGURE 5.a. SAMPLE SURFACE CORRECTION FACTOR DISTANCE CRITERIA

The radiation profile data showed no increase in radiation dose after testing beyond normal measurement variations. All test specimens met the regulatory requirements.

5.4.3 Flux-to-Dose-Rate Conversion

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

5.4.4 External Radiation Levels

Radiation surveys for all 976 Series configurations showed maximum surface and 1 meter radiation levels from the transport packages within regulatory limits. Radiation surveys of 976 Series transport packages after undergoing normal and accident condition transport testing were also well within the regulatory limits.

5.5 Appendix

5.5.1 Microshield V5.05 Calculations for the Model 976C with 3056,
1,250 Curies of Ir-192, Profile of Bottom, Case 1 and Case 2

5.5.2 Profile Sheet "976C Modified Insert Configuration – Performed 11 Jan 06.

5.5.3 Microshield V5.05 Transmission for Various Nuclides and Materials

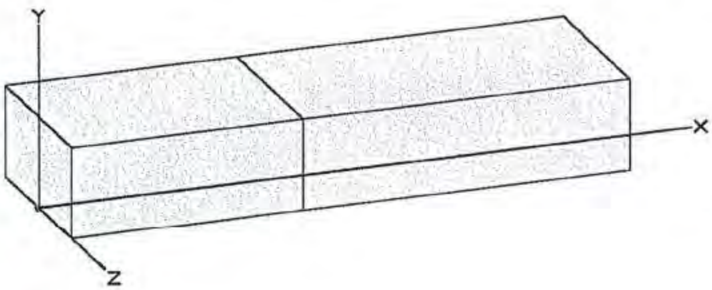
Section 5.5.1 Appendix: **Microshield V5.05 Calculations for the Model 976C with 3056, 1,250 Curies of Ir-192, Profile of Bottom, Case 1 and Case 2**

MicroShield v5.05 (5.05-00160)
AEA Technology QSA, Inc.

Page : 1
DOS File: 3056.MS5
Run Date: May 4, 2005
Run Time: 2:12:36 PM
Duration: 00:00:00

File Ref: Case 1
Date:
By:
Checked:

Case Title: Model 3056 Shield
Description: 800 Curies of Ir-192, Profile of Bottom of 3056 Shield Only
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	6.1214 cm	0 cm	0 cm
	2.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	2.54 cm	Uranium	18
Shield 2	3.556 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ir-192	8.0000e+002	2.9600e+013

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0615	3.352e+11	8.414e-189	4.217e-19	1.622e-191	8.129e-22
0.063	5.788e+11	2.031e-176	7.507e-19	3.807e-179	1.408e-21
0.0651	7.800e+11	5.633e-161	1.054e-18	1.021e-163	1.910e-21
0.0668	1.338e+12	1.164e-149	1.867e-18	2.059e-152	3.302e-21
0.0714	2.486e+11	2.462e-125	3.766e-19	4.134e-128	6.324e-22
0.0757	5.824e+11	3.775e-106	9.483e-19	6.123e-109	1.538e-21
0.1363	5.346e+10	1.835e-98	5.978e-05	2.949e-101	9.610e-08
0.2013	1.383e+11	2.933e-33	9.690e-19	5.184e-36	1.713e-21
0.2058	9.730e+11	2.491e-30	6.813e-18	4.424e-33	1.210e-20
0.2833	7.740e+10	1.801e-11	2.813e-11	3.390e-14	5.294e-14
0.296	8.588e+12	9.447e-08	1.480e-07	1.789e-10	2.802e-10
0.3085	8.785e+12	2.530e-06	3.997e-06	4.815e-09	7.609e-09
0.3165	2.452e+13	4.574e-05	7.285e-05	8.733e-08	1.391e-07
0.3745	2.150e+11	6.279e-03	1.080e-02	1.218e-05	2.096e-05
0.4165	1.967e+11	4.472e-01	8.112e-01	8.733e-04	1.584e-03
0.4231	2.359e+10	9.361e-02	1.711e-01	1.830e-04	3.343e-04
0.4681	1.422e+13	1.293e+03	2.462e+03	2.537e+00	4.830e+00
0.4846	9.362e+11	2.134e+02	4.110e+02	4.189e-01	8.067e-01
0.4891	1.179e+11	3.393e+01	6.551e+01	6.659e-02	1.286e-01
0.5886	1.354e+12	1.777e+04	3.579e+04	3.472e+01	6.993e+01
0.6044	2.428e+12	4.932e+04	9.995e+04	9.622e+01	1.950e+02
0.6125	1.579e+12	3.954e+04	8.041e+04	7.709e+01	1.568e+02

'age : 2
)OS File: 3056.MS5
Run Date: May 4, 2005
Run Time: 2:12:36 PM
)uration: 00:00:00

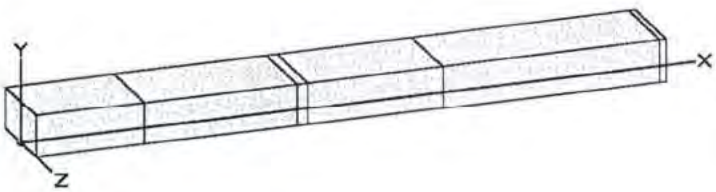
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.8717	2.918e+10	4.290e+04	9.527e+04	8.074e+01	1.793e+02
0.8845	8.927e+10	1.483e+05	3.302e+05	2.786e+02	6.202e+02
TOTALS:	6.820e+13	2.994e+05	6.446e+05	5.704e+02	1.227e+03

MicroShield v5.05 (5.05-00160)
AEA Technology QSA, Inc.

?age : 1
)OS File: 976C.MS5
Run Date: May 4, 2005
Run Time: 2:14:11 PM
)uration: 00:00:00

File Ref: Case 2
Date: ______
By: ______
Checked: ______

Case Title: 976C with 3056
Description: 800 Curies of Ir-192, Profile of Bottom of 976C with 3056
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	14.7828 cm	0 cm	0 cm
	5.8 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	2.54 cm	Uranium	18
Shield 2	3.556 cm	Lead	11.34
Shield 3	.254 cm	Air	0.00122
Shield 4	3.175 cm	Air	0.00122
Shield 5	5.08 cm	Air	0.00122
Shield 6	.152 cm	Iron	7.82
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ir-192	8.0000e+002	2.9600e+013

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0615	3.352e+11	4.070e-190	7.232e-20	7.845e-193	1.394e-22
0.063	5.788e+11	1.062e-177	1.287e-19	1.991e-180	2.413e-22
0.0651	7.800e+11	3.247e-162	1.807e-19	5.884e-165	3.275e-22
0.0668	1.338e+12	7.197e-151	3.201e-19	1.273e-153	5.662e-22
0.0714	2.486e+11	1.779e-126	6.457e-20	2.987e-129	1.084e-22
0.0757	5.824e+11	3.059e-107	1.626e-19	4.961e-110	2.637e-22
0.1363	5.346e+10	2.456e-99	1.025e-05	3.949e-102	1.648e-08
0.2013	1.383e+11	4.263e-34	1.662e-19	7.536e-37	2.937e-22
0.2058	9.730e+11	3.631e-31	1.168e-18	6.448e-34	2.075e-21
0.2833	7.740e+10	2.707e-12	4.228e-12	5.094e-15	7.958e-15
0.296	8.588e+12	1.424e-08	2.232e-08	2.697e-11	4.226e-11
0.3085	8.785e+12	3.824e-07	6.045e-07	7.279e-10	1.151e-09
0.3165	2.452e+13	6.926e-06	1.104e-05	1.322e-08	2.107e-08
0.3745	2.150e+11	9.605e-04	1.654e-03	1.863e-06	3.208e-06
0.4165	1.967e+11	6.879e-02	1.249e-01	1.343e-04	2.440e-04
0.4231	2.359e+10	1.441e-02	2.637e-02	2.817e-05	5.153e-05
0.4681	1.422e+13	2.001e+02	3.816e+02	3.925e-01	7.485e-01
0.4846	9.362e+11	3.308e+01	6.381e+01	6.493e-02	1.252e-01

)OS File: 976C.MS5
Run Date: May 4, 2005
Run Time: 2:14:11 PM
)uration: 00:00:00

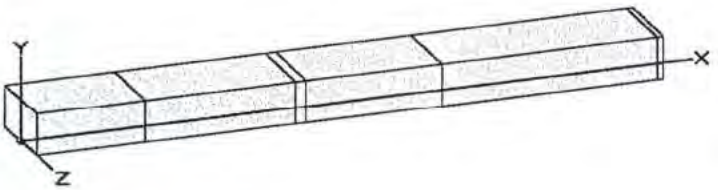
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.4891	1.179e+11	5.260e+00	1.017e+01	1.033e-02	1.997e-02
0.5886	1.354e+12	2.778e+03	5.608e+03	5.428e+00	1.096e+01
0.6044	2.428e+12	7.719e+03	1.568e+04	1.506e+01	3.059e+01
0.6125	1.579e+12	6.193e+03	1.262e+04	1.207e+01	2.461e+01
0.8717	2.918e+10	6.814e+03	1.519e+04	1.282e+01	2.859e+01
0.8845	8.927e+10	2.357e+04	5.269e+04	4.427e+01	9.895e+01
TOTALS:	6.820e+13	4.731e+04	1.022e+05	9.012e+01	1.946e+02

MicroShield v5.05 (5.05-00160)
AEA Technology QSA, Inc.

Page : 1
DOS File: 976C.MS5
Run Date: May 4, 2005
Run Time: 2:13:08 PM
Duration: 00:00:00

File Ref: Case 3
Date:
By:
Checked:

Case Title: 976C with 3056
Description: 800 Curies of Ir-192, Profile of Bottom of 976C with 3056
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	14.7828 cm	0 cm	0 cm
	5.8 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	2.54 cm	Uranium	18
Shield 2	3.556 cm	Lead	11.34
Shield 3	.254 cm	Air	0.00122
Shield 4	3.175 cm	Air	0.24~Cork
Shield 5	5.08 cm	Air	0.24~Cork
Shield 6	.152 cm	Iron	7.82
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ir-192	8.0000e+002	2.9600e+013

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0615	3.352e+11	2.870e-190	7.232e-20	5.532e-193	1.394e-22
0.063	5.788e+11	7.513e-178	1.287e-19	1.409e-180	2.413e-22
0.0651	7.800e+11	2.308e-162	1.807e-19	4.182e-165	3.275e-22
0.0668	1.338e+12	5.132e-151	3.201e-19	9.077e-154	5.662e-22
0.0714	2.486e+11	1.278e-126	6.457e-20	2.147e-129	1.084e-22
0.0757	5.824e+11	2.213e-107	1.626e-19	3.589e-110	2.637e-22
0.1363	5.346e+10	1.872e-99	1.025e-05	3.009e-102	1.648e-08
0.2013	1.383e+11	3.351e-34	1.662e-19	5.922e-37	2.937e-22
0.2058	9.730e+11	2.858e-31	1.168e-18	5.077e-34	2.075e-21
0.2833	7.740e+10	2.185e-12	3.416e-12	4.113e-15	6.428e-15
0.296	8.588e+12	1.154e-08	1.809e-08	2.185e-11	3.426e-11
0.3085	8.785e+12	3.108e-07	4.916e-07	5.916e-10	9.358e-10
0.3165	2.452e+13	5.640e-06	8.993e-06	1.077e-08	1.717e-08
0.3745	2.150e+11	7.922e-04	1.366e-03	1.537e-06	2.649e-06
0.4165	1.967e+11	5.719e-02	1.041e-01	1.117e-04	2.032e-04
0.4231	2.359e+10	1.200e-02	2.199e-02	2.344e-05	4.298e-05
0.4681	1.422e+13	1.678e+02	3.208e+02	3.291e-01	6.292e-01
0.4846	9.362e+11	2.781e+01	5.379e+01	5.458e-02	1.056e-01

'age : 2
)OS File: 976C.MS5
lun Date: May 4, 2005
lun Time: 2:13:08 PM
)uration: 00:00:00

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.4891	1.179e+11	4.425e+00	8.583e+00	8.685e-03	1.685e-02
0.5886	1.354e+12	2.368e+03	4.798e+03	4.626e+00	9.375e+00
0.6044	2.428e+12	6.591e+03	1.344e+04	1.286e+01	2.623e+01
0.6125	1.579e+12	5.293e+03	1.083e+04	1.032e+01	2.112e+01
0.8717	2.918e+10	5.961e+03	1.338e+04	1.122e+01	2.518e+01
0.8845	8.927e+10	2.064e+04	4.646e+04	3.876e+01	8.726e+01
TOTALS:	6.820e+13	4.105e+04	8.930e+04	7.817e+01	1.699e+02

Section 5.5.2 Appendix: **Profile Sheet "976C Modified Insert Configuration – Performed 11 Jan 06.**

AEA TECHNOLOGY QSA

SHIELDING PROFILE AND INSPECTION FORM (SPIF)

F-Q-1806-2

976C Modified insert Configuration

Sheet 1 of 1

Shield Data

Model: 976 C	Serial # 21	Radionuclide: Ir-192	Max. Capacity 1200 Ci
Shield P/N: 3056 SN P0745-060	Shield Heat # NA		Lot # NA

Profile Process Data

Source Model: 424-9	Source Ser. # see attached	Radionuclide: Ir-192	Activity: 1135.9 Ci
Survey Inst. E-600	Serial # 2750	Date Cal. 5/2/05	Date Due: 5/2/06
Inst. Uncertainty:		Capacity Correction Factor: 1.06	

	Measured Dose Rate mR/hr				Adjusted Dose Rate mR/hr				
Location	At Surface	Surface Corr. Factor	At 30 Cm [Note 1]	At one Meter	1250 Cap	At Surface	At 30 Cm [Note 1]	1250 Cap.	At one Meter
Top	63	1.13		4.1	78	75		4.6	4.4
Right	100	1.20		4.7	132	127		5.2	~~4.9~~ 5.0
Front	107	1.20		4.8	142	136		5.3	5.~~0~~1
Left	110	1.20		4.7	146	140		5.2	5.0
Rear	109	1.20		4.7	145	139		5.2	5.0
Bottom	126	1.21		5.0	169	162		5.5	5.3
				Acceptance Criteria:		≤200	NA		10.0 ~~≤2.0~~
			Result: (Check one)	Accept		✓	Reject		

Inspector: [signature] Date: 11 JAN 06 NCR # ______

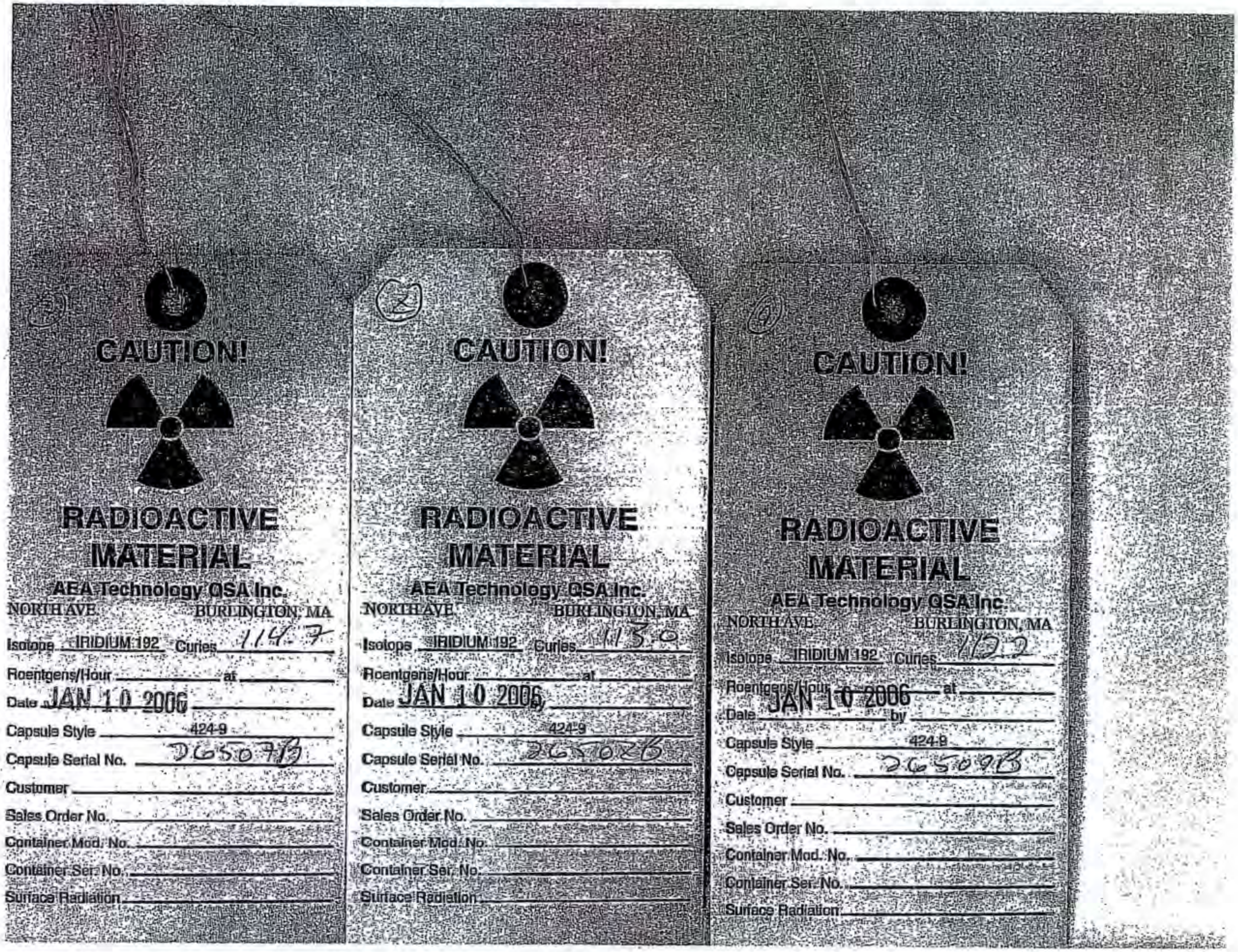
Comments

1) Shield container raised 2" by extra cork donut placed below inner cork insert.

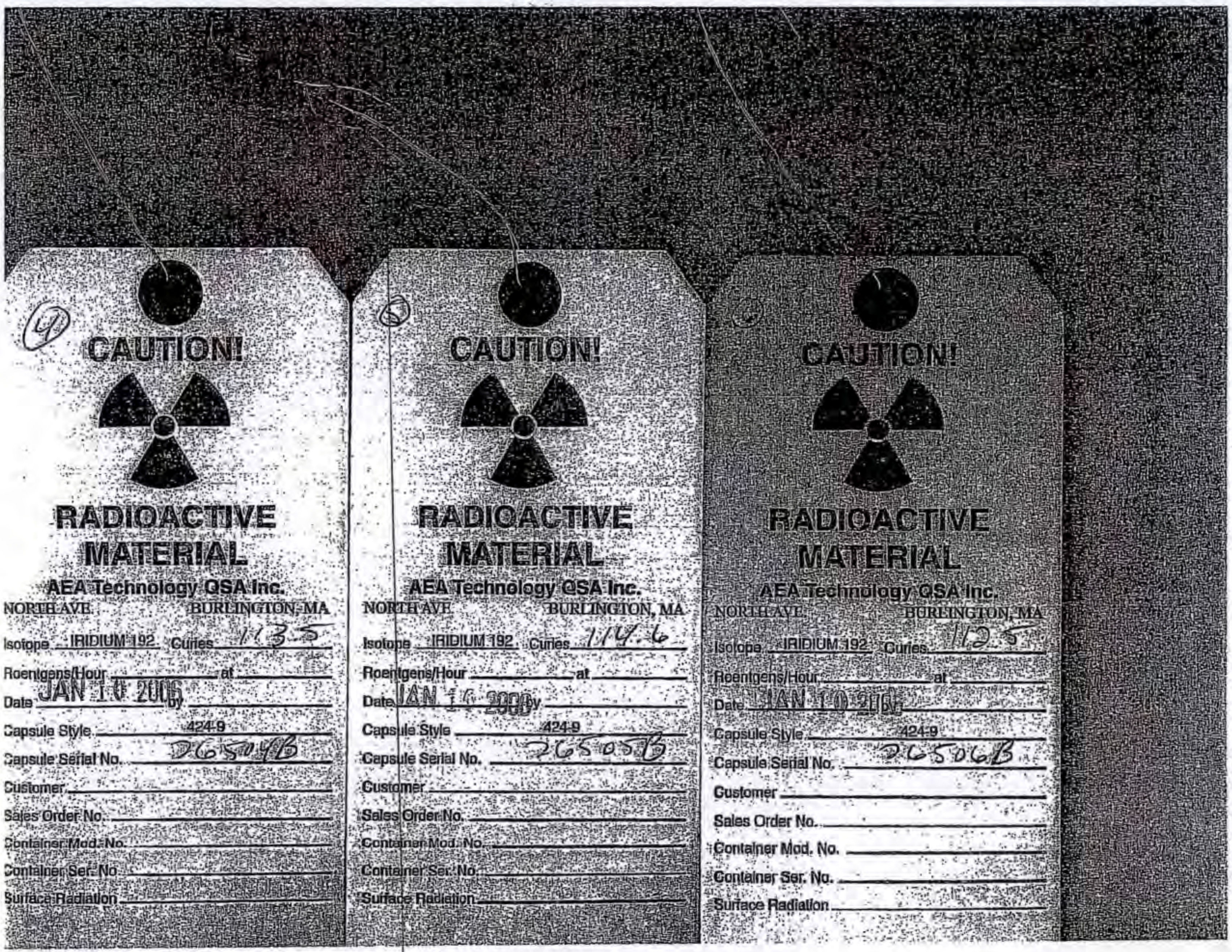
2) Top cork insert not in place.

Notes: 1. The 30cm readings are only required when specifically requested.

2. Additional sheets may be used to describe results or indicate reading locations using sketches. Number all sheets and indicate total number of sheets. Make sure shield Identification is included on each sheet.



CAUTION!
RADIOACTIVE MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 114.7
Roentgens/Hour at
Date JAN 10 2006
Capsule Style 424-9
Capsule Serial No. D6507B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation
CAUTION!
RADIOACTIVE MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 113.0
Roentgens/Hour at
Date JAN 10 2006 by
Capsule Style 424-9
Capsule Serial No. D6502B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation
CAUTION!
RADIOACTIVE MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 112.2
Roentgens/Hour at
Date JAN 10 2006 by
Capsule Style 424-9
Capsule Serial No. D6509B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation


(4)
CAUTION!
RADIOACTIVE
MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 113.5
Roentgens/Hour at
Date JAN 10 2006 by
Capsule Style 424-9
Capsule Serial No. 26504B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation
(5)
CAUTION!
RADIOACTIVE
MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 114.6
Roentgens/Hour at
Date JAN 10 2006 by
Capsule Style 424-9
Capsule Serial No. 26505B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation
CAUTION!
RADIOACTIVE
MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 112.5
Roentgens/Hour at
Date JAN 10 2006
Capsule Style 424-9
Capsule Serial No. 26506B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation


③
CAUTION!
RADIOACTIVE MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 113.3
Roentgens/Hour at
Date JAN 10 2006
Capsule Style 424-9
Capsule Serial No. 76503B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation
①
CAUTION!
RADIOACTIVE MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 115.3
Roentgens/Hour at
Date JAN 10 2006
Capsule Style 424-9
Capsule Serial No. 76501B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation
②
CAUTION!
RADIOACTIVE MATERIAL
AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA
Isotope IRIDIUM 192 Curies 114.5
Roentgens/Hour at
Date JAN 10 2006
Capsule Style 424-9
Capsule Serial No. 76502B
Customer
Sales Order No.
Container Mod. No.
Container Ser. No.
Surface Radiation

(10)

CAUTION!

RADIOACTIVE MATERIAL

AEA Technology QSA Inc.
NORTH AVE. BURLINGTON, MA

Isotope IR-192 112.3 Curies

Date JAN 10 2006 By

Capsule Style 87703

Capsule Serial No. 24805B

Customer

Sales Order No.

Container Mod. No.

Container Ser. No.

Surface Radiation

Transport Index

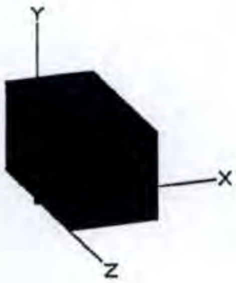
Section 5.5.3 Appendix: Microshield V5.05 Transmission for Various Nuclides and Materials

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

age : 1
OS File: IRDU.MS5
un Date: May 23, 2007
un Time: 9:09:15 AM
uration: 00:00:00

File Ref: ____
Date: ____
By: ____
Checked: ____

Case Title: Ir-192 Transmission
Description: 1 Ci Ir-192 thru 1 cm Depleted Uranium
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Uranium	18.7
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Ir-192	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

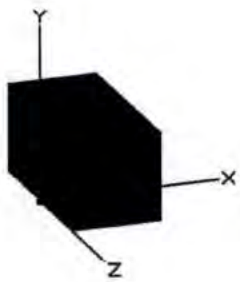
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.032e+09	0.000e+00	2.124e-20	0.000e+00	1.822e-21
0.06	3.958e+09	3.778e-46	1.810e-19	7.504e-49	3.596e-22
0.08	1.093e+09	1.037e-18	1.214e-18	1.641e-21	1.921e-21
0.1	4.265e+07	3.514e-09	4.343e-09	5.376e-12	6.645e-12
0.15	6.682e+07	6.100e-15	4.901e-06	1.004e-17	8.070e-09
0.2	1.405e+09	2.292e-03	4.116e-03	4.045e-06	7.264e-06
0.3	5.248e+10	1.382e+05	1.878e+05	2.621e+02	3.562e+02
0.4	5.900e+08	1.128e+05	1.570e+05	2.199e+02	3.060e+02
0.5	1.900e+10	2.360e+07	3.350e+07	4.632e+04	6.575e+04
0.6	6.689e+09	2.317e+07	3.291e+07	4.522e+04	6.425e+04
0.8	1.137e+08	1.189e+06	1.694e+06	2.261e+03	3.222e+03
1.0	2.115e+07	4.087e+05	5.760e+05	7.533e+02	1.062e+03
1.5	4.598e+05	1.986e+04	2.647e+04	3.341e+01	4.454e+01
TOTALS:	8.749e+10	4.863e+07	6.905e+07	9.507e+04	1.350e+05

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

'age : 1
OS File: SEDU.MS5
un Date: May 23, 2007
un Time: 9:10:49 AM
uration: 00:00:00

File Ref: ____
Date: ____
By: ____
Checked: ____

Case Title: Se-75 Transmission
Description: 1 Ci Se-75 thru 1 cm Depleted Uranium
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Uranium	18.7
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Se-75	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.093e+10	0.000e+00	2.188e-19	0.000e+00	1.876e-20
0.02	9.451e+06	0.000e+00	1.317e-22	0.000e+00	4.562e-24
0.06	4.088e+08	3.902e-47	1.870e-20	7.750e-50	3.714e-23
0.08	3.077e+06	2.919e-21	3.417e-21	4.618e-24	5.407e-24
0.1	7.846e+09	6.465e-07	7.991e-07	9.891e-10	1.223e-09
0.15	2.242e+10	2.046e-12	1.644e-03	3.370e-15	2.708e-06
0.2	5.567e+08	9.084e-04	1.631e-03	1.603e-06	2.879e-06
0.3	3.178e+10	8.367e+04	1.137e+05	1.587e+02	2.157e+02
0.4	4.203e+09	8.039e+05	1.119e+06	1.566e+03	2.180e+03
0.5	2.086e+05	2.590e+02	3.677e+02	5.084e-01	7.218e-01
0.6	1.560e+07	5.405e+04	7.678e+04	1.055e+02	1.499e+02
0.8	4.835e+04	5.054e+02	7.202e+02	9.612e-01	1.370e+00
TOTALS:	8.817e+10	9.424e+05	1.310e+06	1.832e+03	2.547e+03

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: YBDU.MS5
Run Date: May 23, 2007
Run Time: 9:09:58 AM
Duration: 00:00:00

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: Yb-169 Transmission
Description: 1 Ci Yb-169 thru 1 cm Depleted Uranium
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Uranium	18.7
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Yb-169	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.678e+10	0.000e+00	1.754e-19	0.000e+00	1.504e-20
0.02	8.767e+07	0.000e+00	1.222e-21	0.000e+00	4.232e-23
0.05	5.399e+10	1.662e-77	1.979e-18	4.429e-80	5.271e-21
0.06	2.927e+10	2.794e-45	1.339e-18	5.549e-48	2.659e-21
0.1	8.105e+09	6.678e-07	8.255e-07	1.022e-09	1.263e-09
0.15	4.254e+09	3.883e-13	3.120e-04	6.394e-16	5.137e-07
0.2	2.159e+10	3.523e-02	6.325e-02	6.217e-05	1.116e-04
0.3	4.280e+09	1.127e+04	1.532e+04	2.137e+01	2.905e+01
0.4	6.509e+05	1.245e+02	1.733e+02	2.426e-01	3.376e-01
0.5	2.326e+06	2.888e+03	4.100e+03	5.670e+00	8.049e+00
0.6	3.617e+06	1.253e+04	1.780e+04	2.445e+01	3.474e+01
0.8	9.564e+04	9.996e+02	1.424e+03	1.901e+00	2.709e+00
TOTALS:	1.384e+11	2.781e+04	3.881e+04	5.364e+01	7.488e+01

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

'age : 1
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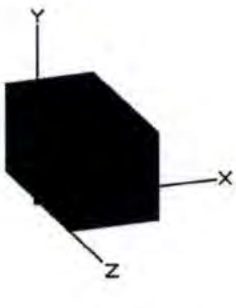
.un Date: May 23, 2007
.un Time: 9:08:17 AM
'uration: 00:00:00

File Ref: ______
Date: ______
By: ______
Checked: ______

Case Title: Ir-192 Transmission
Description: 1 Ci Ir-192 thru 1 cm Steel
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Ir-192	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

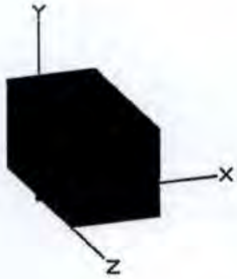
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.032e+09	6.701e-187	2.145e-20	5.748e-188	1.840e-21
0.06	3.958e+09	2.604e+03	3.656e+03	5.173e+00	7.261e+00
0.08	1.093e+09	9.157e+04	1.460e+05	1.449e+02	2.310e+02
0.1	4.265e+07	2.299e+04	3.974e+04	3.517e+01	6.079e+01
0.15	6.682e+07	1.894e+05	3.602e+05	3.119e+02	5.932e+02
0.2	1.405e+09	7.539e+06	1.454e+07	1.331e+04	2.566e+04
0.3	5.248e+10	5.428e+08	9.909e+08	1.030e+06	1.880e+06
0.4	5.900e+08	9.112e+06	1.564e+07	1.776e+04	3.047e+04
0.5	1.900e+10	3.943e+08	6.401e+08	7.740e+05	1.256e+06
0.6	6.689e+09	1.756e+08	2.722e+08	3.428e+05	5.313e+05
0.8	1.137e+08	4.294e+06	6.222e+06	8.168e+03	1.183e+04
1.0	2.115e+07	1.054e+06	1.454e+06	1.942e+03	2.680e+03
1.5	4.598e+05	3.745e+04	4.764e+04	6.301e+01	8.015e+01
TOTALS:	8.749e+10	1.135e+09	1.942e+09	2.188e+06	3.739e+06

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: SESTL.MS5
Run Date: May 23, 2007
Run Time: 9:06:32 AM
Duration: 00:00:00

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: Se-75 Transmission
Description: 1 Ci Se-75 thru 1 cm Steel
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Se-75	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

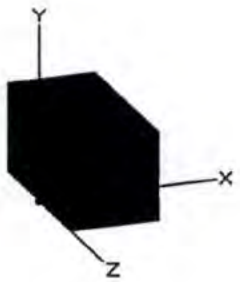
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.093e+10	6.903e-186	2.210e-19	5.921e-187	1.895e-20
0.02	9.451e+06	1.223e-82	1.568e-22	4.236e-84	5.432e-24
0.06	4.088e+08	2.690e+02	3.776e+02	5.343e-01	7.499e-01
0.08	3.077e+06	2.577e+02	4.108e+02	4.078e-01	6.500e-01
0.1	7.846e+09	4.230e+06	7.311e+06	6.471e+03	1.119e+04
0.15	2.242e+10	6.355e+07	1.208e+08	1.047e+05	1.990e+05
0.2	5.567e+08	2.988e+06	5.762e+06	5.274e+03	1.017e+04
0.3	3.178e+10	3.288e+08	6.002e+08	6.237e+05	1.138e+06
0.4	4.203e+09	6.491e+07	1.114e+08	1.265e+05	2.171e+05
0.5	2.086e+05	4.328e+03	7.026e+03	8.496e+00	1.379e+01
0.6	1.560e+07	4.096e+05	6.350e+05	7.995e+02	1.239e+03
0.8	4.835e+04	1.826e+03	2.645e+03	3.473e+00	5.032e+00
TOTALS:	8.817e+10	4.649e+08	8.461e+08	8.673e+05	1.577e+06

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

?age : 1
)OS File: YBSTL.MS5
?un Date: May 23, 2007
?un Time: 9:07:19 AM
)uration: 00:00:00

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: Yb-169 Transmission
Description: 1 Ci Yb-169 thru 1 cm Steel
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Iron	7.86
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Yb-169	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.678e+10	5.534e-186	1.771e-19	4.747e-187	1.519e-20
0.02	8.767e+07	1.135e-81	1.455e-21	3.930e-83	5.039e-23
0.05	5.399e+10	1.008e+02	1.307e+02	2.684e-01	3.482e-01
0.06	2.927e+10	1.926e+04	2.703e+04	3.825e+01	5.370e+01
0.1	8.105e+09	4.369e+06	7.552e+06	6.684e+03	1.155e+04
0.15	4.254e+09	1.206e+07	2.293e+07	1.986e+04	3.776e+04
0.2	2.159e+10	1.159e+08	2.235e+08	2.045e+05	3.944e+05
0.3	4.280e+09	4.428e+07	8.082e+07	8.399e+04	1.533e+05
0.4	6.509e+05	1.005e+04	1.725e+04	1.959e+01	3.362e+01
0.5	2.326e+06	4.826e+04	7.835e+04	9.474e+01	1.538e+02
0.6	3.617e+06	9.495e+04	1.472e+05	1.853e+02	2.873e+02
0.8	9.564e+04	3.612e+03	5.233e+03	6.870e+00	9.953e+00
TOTALS:	1.384e+11	1.768e+08	3.350e+08	3.154e+05	5.975e+05

MicroShield v5.05 (5.05-00161)
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Page : 1
DOS File: YBTRANS.MS5
Run Date: May 23, 2007
Run Time: 9:12:41 AM
Duration: 00:00:00

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: Yb-169 Transmission
Description: 1 Ci Yb-169 thru 1 cm Lead
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Yb-169	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

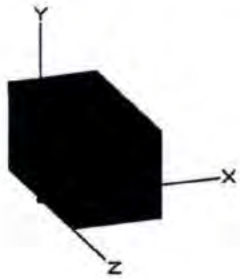
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.678e+10	0.000e+00	1.754e-19	0.000e+00	1.504e-20
0.02	8.767e+07	0.000e+00	1.222e-21	0.000e+00	4.232e-23
0.05	5.399e+10	5.751e-29	2.050e-18	1.532e-31	5.462e-21
0.06	2.927e+10	4.710e-15	5.340e-15	9.356e-18	1.061e-17
0.1	8.105e+09	2.733e-19	2.294e-02	4.182e-22	3.509e-05
0.15	4.254e+09	1.758e-02	5.322e-02	2.894e-05	8.764e-05
0.2	2.159e+10	7.779e+03	1.052e+04	1.373e+01	1.857e+01
0.3	4.280e+09	1.418e+06	1.851e+06	2.690e+03	3.512e+03
0.4	6.509e+05	1.765e+03	2.367e+03	3.438e+00	4.612e+00
0.5	2.326e+06	1.662e+04	2.250e+04	3.263e+01	4.417e+01
0.6	3.617e+06	4.541e+04	6.118e+04	8.863e+01	1.194e+02
0.8	9.564e+04	2.330e+03	3.094e+03	4.431e+00	5.885e+00
TOTALS:	1.384e+11	1.492e+06	1.951e+06	2.833e+03	3.704e+03

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

'age : 1
)OS File: IRTRANS.MS5
:un Date: May 23, 2007
:un Time: 9:11:22 AM
)uration: 00:00:00

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: Ir-192 Transmission
Description: 1 Ci Ir-192 thru 1 cm Lead
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Ir-192	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

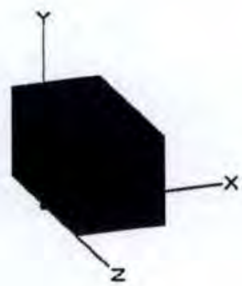
Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.032e+09	0.000e+00	2.124e-20	0.000e+00	1.822e-21
0.06	3.958e+09	6.370e-16	7.222e-16	1.265e-18	1.434e-18
0.08	1.093e+09	2.128e-04	2.564e-04	3.367e-07	4.057e-07
0.1	4.265e+07	1.438e-21	1.207e-04	2.200e-24	1.847e-07
0.15	6.682e+07	2.761e-04	8.360e-04	4.546e-07	1.377e-06
0.2	1.405e+09	5.061e+02	6.846e+02	8.933e-01	1.208e+00
0.3	5.248e+10	1.739e+07	2.270e+07	3.298e+04	4.305e+04
0.4	5.900e+08	1.600e+06	2.146e+06	3.117e+03	4.181e+03
0.5	1.900e+10	1.358e+08	1.838e+08	2.666e+05	3.608e+05
0.6	6.689e+09	8.398e+07	1.132e+08	1.639e+05	2.209e+05
0.8	1.137e+08	2.770e+06	3.679e+06	5.268e+03	6.997e+03
1.0	2.115e+07	7.745e+05	1.006e+06	1.428e+03	1.854e+03
1.5	4.598e+05	3.077e+04	3.763e+04	5.177e+01	6.330e+01
TOTALS:	8.749e+10	2.423e+08	3.265e+08	4.733e+05	6.378e+05

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

'age : 1	File Ref: ______
)OS File: SETRANS.MS5	Date: ______
!un Date: May 23, 2007	By: ______
!un Time: 9:12:08 AM	Checked: ______
)uration: 00:00:00	

Case Title: Se-75 Transmission
Description: 1 Ci Se-75 thru 1 cm Lead
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1 cm	0 cm	0 cm
	0.4 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.0 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : ICRP-38

Nuclide	curies	becquerels
Se-75	1.0000e+000	3.7000e+010

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.093e+10	0.000e+00	2.188e-19	0.000e+00	1.876e-20
0.02	9.451e+06	0.000e+00	1.317e-22	0.000e+00	4.562e-24
0.06	4.088e+08	6.578e-17	7.458e-17	1.307e-19	1.481e-19
0.08	3.077e+06	5.989e-07	7.216e-07	9.477e-10	1.142e-09
0.1	7.846e+09	2.646e-19	2.221e-02	4.048e-22	3.397e-05
0.15	2.242e+10	9.263e-02	2.805e-01	1.525e-04	4.619e-04
0.2	5.567e+08	2.006e+02	2.713e+02	3.540e-01	4.789e-01
0.3	3.178e+10	1.053e+07	1.375e+07	1.997e+04	2.608e+04
0.4	4.203e+09	1.139e+07	1.528e+07	2.220e+04	2.978e+04
0.5	2.086e+05	1.491e+03	2.018e+03	2.926e+00	3.961e+00
0.6	1.560e+07	1.959e+05	2.639e+05	3.824e+02	5.152e+02
0.8	4.835e+04	1.178e+03	1.564e+03	2.240e+00	2.975e+00
TOTALS:	8.817e+10	2.212e+07	2.930e+07	4.256e+04	5.638e+04

Section 6 - CRITICALITY EVALUATION

All parts of this section are not applicable. The Model 976 Series transport packages are not used for shipment of Type B quantities of fissile material.

Section 7 – Package Operations

Operation of the Model 976 Series transport packages must be in accordance with the operating instructions supplied with the transport package, per 10 CFR 71.87 and 71.89.

7.1 Package Loading

7.1.1 Preparation for Loading

The Model 976 Series packages must be loaded and closed in accordance with the following written procedures. Shipment of Type B quantities of radioactive material are authorized for sources specified in Section 7.1.1.1. Maintenance and inspection of the Model 976 Series packaging is in accordance with the requirements specified in Section 7.1.1.2.

7.1.1.1 Authorized Package Contents

Table 7.1.1a: Model 976 Series Package Information

Identification	Inner Shield(s)	Nuclide	Form	Maximum Capacity[1,2]	Maximum Weight
976A	855	Ir-192	Special Form Sources	1,000 Ci	136 kg (300 lb)
		Se-75		1,000 Ci	
		Yb-169		865 Ci	
976C	3056	Ir-192	Special Form Sources	1,250 Ci	86 kg (190 lb)
		Se-75		1,250 Ci	
		Yb-169		1,000 Ci	
976F	1911	Ir-192	Special Form Sources	1,000 Ci	119 kg (263 lb)
		Se-75		1,000 Ci	
		Yb-169		1,000 Ci	

[1]For Iridium-192, the maximum capacity is based on the output curies which are determined by measuring the source output at 1 meter and expressing its activity in curies derived from the following: 0.48 R/hr-Ci Iridium-192 at 1 meter. (Ref: American National Standard N432-1980, "Radiological Safety for the Design and Construction of Apparatus for Gamma Radiography."). For Selenium-75 and Yb-169 the maximum capacity is based on the content curies contained in the radioactive source(s).

[2] For shipments of multiple radioisotopes in a single package, the sum of the ratios of the curie quantity of each loaded isotope to the maximum allowed curie quantity of that isotope (were that isotope the only contents of the package) must be less than or equal to unity.

7.1.1.2 Packaging Maintenance and Inspection Prior to Loading

7.1.1.2.a Instructions for the 855 Shield Container

1. Ensure all markings are legible.

2. Inspect the container for signs of significant degradation. Ensure all welds are intact, the container is free of heavy rust and cracks/damage to the steel housing which breaches the container.

3. Ensure the lid eyebolt is straight and undamaged, and that the seal gasket is present and intact.

4. Ensure that the 3/8 inch cover bolts are present and there is no visible signs of damage to bolt heads. After removal of the cover, examine the external surfaces of the cover bolts for any signs of fatigue cracking or thread damage. The bolts must be replaced prior to further transport, if they are no longer fit for use (e.g., threads stripped, unable to fully thread, signs of cracking, etc.).

5. Inspect the lock holder assemblies and ensure these are securely attached to the container body and that the seal wires on the lock holder mechanisms are present and intact. Ensure the lock plungers operate from the lock to the open positions using the lock plunger key.

6. Insert the source check gauge into the source tubes and ensure the gauge can be fully inserted, without obstruction, to the mark on the source check gauge for all source tubes.

7. If the container fails any of the inspections in steps 7.1.1.2.a.1-6, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.1.2.b Instructions for the 3056 Shield Container

1. Ensure all markings are legible.

2. Inspect the container for signs of significant degradation. Ensure all welds are intact, the container is free of heavy rust and cracks/damage to the steel bracing. Examine the lead and ensure the shield pot has not been damaged in a way that significantly reduces the container shielding.

3. Ensure the source tube caps can be fully threaded onto the source tubes.

4. Ensure that the M12 x 1.75 mm retaining nut can be fully threaded onto the container threaded rods and secure the lid to the container without gaps. Ensure that the M10 x 20 mm socket head screws can be full threaded onto the container. Examine the external surfaces of the screws/retaining nut for any signs of fatigue cracking or thread damage. The hardware must be replaced prior to further transport, if they are no longer fit for use (e.g., threads stripped, unable to fully thread, signs of cracking, etc.).

5. Insert the source check gauge into the source tubes and ensure the gauge can be fully inserted, without obstruction, to the mark on the source check gauge for all source tubes.

6. If the container fails any of the inspections in steps 7.1.1.2.b.1-5, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.1.2.c Instructions for the 1911 Shield Container

1. Ensure all markings are legible.

2. Inspect the container for signs of significant degradation. Ensure all welds are intact, the container is free of heavy rust and cracks/damage to the steel housing which breaches the container.

3. Ensure the lid eyebolt is undamaged and that it threads freely into the shield container lid.

4. Ensure that the M8 cover bolts engage in the container threaded holes and secure the lid to the container body. Examine the cover bolts for any visible signs of damage. After removal of the cover, examine the external surfaces of the bolts for any signs of fatigue

cracking or thread damage. The cover bolts must be replaced prior to further transport, if they are no longer fit for use (e.g., threads stripped, unable to fully thread, signs of cracking, etc.).

5. Inspect the shield insert plug and ensure that it inserts freely over the lower shield insert and allows attachment of the shield container lid after insertion. Inspect the lower shield insert and ensure that the insert cavity is free of foreign objects, sources and obstruction.

6. If the container fails any of the inspections in steps 7.1.1.2.c.1-5, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.1.2.d Instructions for the Drum and Cork Inserts

1. Ensure all markings are legible.

2. Inspect the drum, lid and lid closure band for signs of significant degradation. Ensure all welds are intact, the container is free of heavy rust and cracks/damage to the steel.

3. Ensure the cork inserts are intact and no damage that would allow significant shield container movement during transport.

4. Ensure that lid closure band hardware is undamaged (e.g. there is no visible signs of damage to bolt/nut). Examine the external surfaces of the bolt for any signs of fatigue cracking or thread damage. The bolts must be replaced prior to further transport, if it is no longer fit for use (e.g., threads stripped, unable to fully thread, signs of cracking, etc.). Ensure the lid closure band can fit around the lid and drum when these components are assembled.

5. After removal of the drum lid, ensure the four 3/8-16 x ¾ inch long lid closure bolts are present and there are no visible signs of damage. Examine the external surfaces of the lid bolts for any signs of fatigue cracking or thread damage. The bolts must be replaced prior to further transport, if they are no longer fit for use (e.g., threads stripped, unable to fully thread, signs of cracking, etc.). Ensure that the lid bolts can be inserted through the drum body sides into the lid closure blocks/floating nuts (as applicable) and that the bolts fully thread into the lid closure blocks/floating nuts (as applicable).

6. If the container fails any of the inspections in steps 7.1.1.2.d.1-5, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.2 Loading of Contents

NOTE: ***These loading operations apply to "dry" loading only. None of the shield configurations for the Model 976 Series packages are approved for wet loading.***

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

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

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

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

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

   All necessary safety precautions and regulations must be observed to ensure safe transfer of the radioactive material.

2. Model 855 Shield Container

   i. Using remote handling techniques, load the source assemblies so that they are fully inserted into the source tubes with the active end of the source assembly inserted first. Once loaded ensure the plunger lock(s) are depressed, the key removed and the source hold down cap(s) installed.

ii. Secure the shield cover to the container using eight 3/8-16 by ¾ inch long hex head screws. Tighten the screws so that no gap exists between the screw heads, lid or container.

3. Model 3056 Shield Container

i. Using remote handling techniques, load the source assemblies so that they are fully inserted into the source tubes with the active end of the source assembly inserted first. Attach the tube caps over the source assemblies by fully threading the caps onto the source tubes. Tighten the tube caps by light finger pressure only.

ii. Secure the shield cover lid to the container using the M12 x 1.75 mm retaining nut. Tighten the retaining nut so that no gap exists between the retaining nut, lid or container.

4. Model 1911 Shield Container

i. Identify the shield insert configuration required for shielding of the sources to be loaded into the container (contact the manufacturer if unsure on the appropriate shield insert configuration for use with the special form sources to be transported) and confirm that the shield container is configured with the proper shield insert (e.g., depleted uranium, tungsten or lead).

ii. Using remote handling techniques, load the source(s) within the shield cavity.

iii. Insert the shield plug fully into the shield cavity so that the bottom of the shield plug rests on the top of the shield insert.

iv. Secure the shield lid to the container using the four M8 x 25 mm long hex head bolts. Tighten the hex head bolts so that no gap exists between the bolt, lid or container.

7.1.2.1.d Load the shield into the 976 drum and applicable bottom cork inserts. See drawings for the applicable cork inserts for the specific shield container to be transported in the 976 drum.

7.1.2.1.e Insert the applicable top cork inserts into the 976 drum. See drawings for the applicable cork inserts for the specific shield container to be transported in the 976 drum.

7.1.2.1.f Place the drum lid onto the drum. Insert the four 3/8-16 x ¾ inch long lid closure bolts through the drum body sides into the lid closure blocks/floating nuts (as applicable). Tighten the lid closure bolts so that no gap exists between the bolt and the drum. Secure the lid to the drum using the drum lid closure band.

7.1.3 Preparation for Transport

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

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

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

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

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

7.2 Package Unloading

7.2.1 Receipt of Package from Carrier

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

7.2.1.2 Upon receipt of a transport package of radioactive material:

7.2.1.2.a Survey the transport package with a survey meter as soon as possible, preferably at the time of pick-up and no more than three hours after it was received during normal working hours. Radiation levels should not exceed 200 mR/hr at the surface of the transport package, nor 10 mR/hr at a distance of 1 meter from the surface.

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

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

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

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

7.2.2 Removal of Contents

7.2.2.1 Unload the Model 976 in accordance with the applicable licensing provisions for the user's facility related to radioactive material handling.

7.2.2.2 Remove the inner shield container from the Model 976 drum and cork inserts.

7.2.2.3 Place the shield container in a shielded cell/enclosure capable of holding the maximum isotope capacity of this container. (Note: Transfer of source wire assemblies for the Model 855 and 3056 style shields may be performed outside of shielded cells/enclosures using radiographic controls and guide tubes if authorized under the approval of a licensing authority.)

7.2.2.4 Individual Container Instructions for Unloading

7.2.2.4.a Model 855 Shield Container

1. Remove the eight 3/8-16 by ¾ inch long hex head cover screws and remove the cover lid from the container.

2. Use remote handling techniques to unload each source tube and transfer the source to an alternate, shielded storage location. Prior to source transfer, remove the source hold down cap and unlock the plunger lock on the lock block assembly for the source tube to be unloaded.

3. Repeat Step 7.2.2.4.a.2 for all sources in the shield container.

7.2.2.4.b Model 3056 Shield Container

1. Remove the M12 x 1.75 mm retaining nut from the container lid. Remove the M10 screws.

2. Use remote handling techniques to unload each source tube and transfer the source to an alternate, shielded storage location. Prior to source transfer, remove the source tube cap for the source tube to be unloaded.

3. Repeat Step 7.2.2.4.b.2 for all sources in the shield container.

7.2.2.4.c Model 1911 Shield Container

1. Install the M10 eyebolt into the lid. Remove the M8 x 25 mm hex head lid screws and remove the container lid.

2. Use remote handling techniques to remove the shield plug from the container cavity. Remotely unload each source and transfer the source to an alternate, shielded storage location.

7.3 Preparation of Empty Package for Transport

In the following instructions, an *empty* transport package refers to a Model 976 Series transport package without an active source contained within the shielded container. To ship an empty transport package:

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

7.3.1.1 For Model 1911

7.3.1.1.a Place the shield container in a shielded cell/enclosure capable of holding the maximum isotope capacity of this container. Remove the cover. Remove any shield plugs used in that shield container and visually inspect the container for any source capsules.

7.3.1.1.b Use remote manipulators, mirrors, and radiation monitors if necessary, inspect the container to verify that it is empty.

7.3.1.1.c Once the shield cavity is determined to be empty, place all shield plugs/inserts back into the container and install the cover.

7.3.1.2 For Models 855 and 3056

7.3.1.2.a Remove all source tube caps and visually inspect the source tubes for the presence of a source assembly.

7.3.1.2.b For the Model 855, unlock the lock plungers and insert the source check gauge into each source tube. If the source check gauge cannot be inserted past the indicator mark on the gauge, the source tube may not be empty. Contact QSA Global, Inc. for further assistance after securing the source tube.

7.3.1.2.c Once the source tubes are determined to be empty, place all shield caps back onto the source tubes. For the Model 855, engage the plunger lock assemblies. Install the shield container covers on all model containers.

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

7.3.3 Assure that the levels of removable radioactive contamination on the inside surface of the shield container does not exceed 400 Bq/cm^2 (when averaged over 300 cm^2).

7.3.4 When it is confirmed that the Model 976 Series transport package is empty, prepare the transport package for shipment. Survey the assembled package to ensure the external surface radiation level does not exceed 5 μSv/h.

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

7.4 Other Operations

7.4.1 Package Transportation By Consignor

Persons transporting the Model 976 Series transport package in their own conveyances should comply with the following:

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

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

7.4.2 Emergency Response

In the event of a transport emergency or accident involving this package, follow the guidance contained in "2016 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident", or equivalent guidance documentation.

Reference: "2016 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident"

7.5 Appendix

Not Applicable.

Section 8 - ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspections and Measurements

8.1.1.1 New Fabrication

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

   i. The transport package was assembled properly to the applicable drawing.

   ii. Evaluate each shield container for shielding integrity when used in the applicable Model 976 Series assembly to ensure the transport dose rate requirements are met when the container is loaded to capacity.

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

   iv. The relevant labels are attached, contain the required information, and are marked in accordance with 10 CFR 20.1904, 10 CFR 40.13(c)(6)(i), 10 CFR 34, and 10 CFR 71 or equivalent Agreement State regulations.

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

8.1.1.2 Dedication of Pre-existing Shield Components

a. Evaluate all 855, 3056, and 1911 shield containers prior to first use in a Model 976 Series package to assure the following:

   i. Shield containers comply with the applicable drawing. (This evaluation will be performed to assess all components not requiring disassembly of the shield container such as external construction, overall dimensions, hardware compliance, weld integrity, etc. All items critical to safety are specified under the QSA Global, Inc. USNRC approved QA Program.)

ii. Evaluate each shield container for shielding integrity when used in the applicable Model 976 Series assembly to ensure the transport dose rate requirements are met when the container is loaded to capacity.

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

8.1.2 Weld Examinations

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

8.1.3 Structural and Pressure Tests

Prior to first use as part of a 976 Series transport package, container structural conformance will be evaluated in accordance with the applicable drawings requirements and in accordance with QSA Global, Inc.'s USNRC approved Quality Assurance Program No. 0040. The containment system is not designed to require increased or decrease operating pressures to maintain containment during transport, therefore pressure tests of package components prior to first use is not required.

8.1.4 Leakage Tests

The source capsules (primary containment) are wipe tested for leakage of radioactive contamination upon initial manufacture. The removable contamination must be less than 0.005 microcuries. The source capsules will also be subjected to leak tests under ISO9978:1992(E) (or more recent editions). The source capsules are not used if they fail any of these tests.

8.1.5 Component and Material Tests

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

8.1.6 Shielding Tests

The radiation levels at the surface of the transport package and at 1 meter from the surface are evaluated prior to first transport. In the case of the Model 976A container (which uses the 855 inner shield assembly), these surveys were performed in a low background area and involved a slow scan survey of the entire surface area as well as one meter from the surface of the 855 inner shield container. In the case of the Model 976C and 976F packages, these surveys are performed in a low background area and involved a slow scan survey of the dedicated 3056 or 1911 inside its respective Model 976 style drum/cork assembly. Survey measurements are taken at the surface and one meter from the surface of the Model 976 style drum/cork assembly with the appropriate 3056 or 1911 container inside the package. This survey is used to identify any significant void volumes or shield porosity which could prevent the finished Type B(U) transport package, from complying with the dose limits in 10 CFR 71.47.

The radiation profile survey is made with the radiation detector housing in contact with the surface of the device/package (as applicable). The maximum radiation levels, when extrapolated to the rated capacity of the transport package, can not exceed 200 mR/hr at the surface, nor 10 mR/hr at 1 meter from the surface of the transport package.

Failure of this radiation profile tests for any assembly identifies the potential of significant shielding porosity which causes the rejection of the inner shield container. Inner shield containers which do not comply with the construction requirements on its respective drawing (e.g., R85590, R3056 or R1911) or any inner shield container which does not comply with the radiation profile requirements described in this section are not distributed and are therefore prevented from use as part of a Model 976 series Type B(U) package.

8.1.7 Thermal Tests

Not applicable. The source content of the Model 976 Series packages has minimal effect on the package surface temperature and therefore no additional testing is necessary to evaluate thermal properties of the packaging.

8.1.8 Miscellaneous Tests

Not applicable.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Not applicable. Material certification is obtained for Safety Class A components used in the transport package prior to their initial use. Based on the construction of the design, no additional structural testing during the life of the package is necessary if the container shows no signs of defect when prepared for shipment in accordance with the requirements of Section 7 of the SAR. The 976 Series packaging system is not designed to require increased or decrease operating pressures to maintain containment during transport, therefore pressure tests of package components prior to individual shipment is not required.

8.2.2 Leakage Tests

As described in Section 8.1.4, "Leakage Tests," the radioactive source assembly is leak-tested at manufacture. In addition, the sources are leak tested in accordance with that Section at least once every six months thereafter if being transported to ensure that removable contamination is less than 0.005 microcuries. Also a contamination wipe is performed of the source J-tubes of the Model 855 and 3056 shields whenever the shield is returned to the manufacturer (typically the shield is shipped to a customer with new sources and returned directly to the manufacturer with decayed sources for disposition).

8.2.3 Component and Material Tests

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

8.2.4 Thermal Tests

Not applicable. The source content of the Model 976 Series packages has minimal effect on the package surface temperature and therefore no additional testing is necessary to evaluate thermal properties of the packaging prior to shipment.

8.2.5 Miscellaneous Tests

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

8.3 Appendix

Not applicable.

Section 9 – Quality Assurance

9.1 U.S. Quality Assurance Program Requirements

All component fabrication (including assembly) is controlled under the QSA Global, Inc. Quality Assurance program approved by the USNRC (approval number 0040) and ISO 9001.

9.2 Canada Quality Assurance Program Requirements

Not applicable. This package is originally submitted for certification in the United States and complies with the criteria in Section 9.1.