QSA GLOBAL

QSA Global, Inc.
40 North Avenue
Burlington, MA 01803
Telephone: (781) 272-2000
Toll Free: (800) 815-1383
Facsimile: (781) 273-2216

15 April 2010

Pierre Saverot, Project Manager
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
One White Flint
Rockville, MD 20852

Docket No. 71-9027 (Model 741-OP Type B Package)
TAC Nos. L24366

Dear Mr. Saverot:

The following is submitted in response to your 17 March 2010 letter requesting additional information in support of our renewal request for the Model 741-OP package.

1-1 Enclosed is Revision J to drawing R741-OP. This revision corrects note 9 on page 2 to read "0.230 – 1.000 Thick, ASTM A1018, Hot Rolled Steel Sheet, CS Type A or B". Reference to Type "C" has been removed as this was included in error on Revision L of the drawing.

1-2 The steel brackets shown on page 5 of drawing R741-OP do not aid in the attachment or security of the overpack lid to the overpack body. The only function of these brackets is to support the lid arms to hold the lid open during loading and unloading of the overpack. These components are not used to secure the lid or the inner device during transport. From a transportation standpoint, the steel brackets and the lid arm components are not important to safety (NITS).

The hinge shown on page 7 of the drawing is not designated as NITS and is considered by us, and as noted in your letter, to be important to safety (ITS) as it does aid in retaining the lid to the overpack box during transport. This component is purchased as a commercial grade hinge as was originally used on the test unit box design. It is currently specified on drawing R741-OP to the level of detail available for the commercially available component.

The hinge on the metal overpack box used for this package design has been unchanged since the package configurations were tested in 1998. Therefore, the results of testing performed on these packages remains fully representative and applicable for evaluation/comparison purposes.

Analysis of this package relates to how lid hinge failure could adversely impact the package ability to meet the requirements of 10 CFR 71.51.

- For Normal Transport there must be no loss or dispersal of radioactive material, no significant increase in surface dose rates and no substantial reduction in package effectiveness.

- For Hypothetical Accident Conditions of transport there must be no radioactive material loss exceeding the A_2 Quantity in 1 week and no external dose rate above 1 Rem/hr at 1 meter from the package.

Under Normal Conditions of Transport, lid failure due to damage or drop will have no impact on the radioactive material containment within the special form capsule. Therefore there will be no loss or dispersal of radioactive material since shell weld failure cannot adversely impact the special form capsule integrity.

The inner device has demonstrated the ability to withstand a 1 m drop onto a puncture bar after sustaining a 9 m drop within the overpack box. Radiation profiles of the device after testing demonstrated its ability to maintain source shielding with no significant increase in surface dose rates or substantial reduction in package effectiveness, therefore the hinge specification is not critical to ensure the package meets the normal transport test conditions.

The inner device is required to measure no more than 200 mR/hr at the surface and 5 mR/hr at one meter from the surface of the device to ensure its compliance for use as an industrial radiography device. These device limits, along with the overpack protection prior to the normal transport testing, will ensure that the inner device never measures above the normal transport limits of 200 mR/hr at the surface and 10 mR/hr at one meter from the surface.

Physical testing, to the normal and hypothetical accident conditions of transport, has demonstrated that so long as the inner device is contained within the transport box prior to impact on the 9 m drop test, any subsequent hypothetical accident testing is insufficient to cause failure of the device outside the regulatory limits.

As was seen repeatedly in the actual testing performed, the test conditions of 10 CFR 71.73 are not sufficient to cause multiple failures of the secondary securing systems related to shield retention or source containment since the 741 inner container maintained its shielding integrity for all test units.

The lid attachment on the transport box is necessary such that the box is capable of holding the internal wood in place around the inner device during transport. The wood and rigid polyurethane foam surrounding the device acts as a shock absorber under impact conditions. As was again seen in testing, so long as the package is intact upon impact, the inner device can withstand the subsequent accident testing outside of the protective overpack without adversely impacting the radioactive material containment.

Further as demonstrated since the institution of the overpack box design since 1999, the hinge closure on the box is adequate to withstand, without failure, the stress related in normal lifting and transport of the package. From this it is clear that the current level of specification for the lid hinge is sufficient to ensure that it retains the overpack box closure intact around the inner package contents during normal transport conditions and up until impact in a 9 m drop test condition. This will ensure that the 741-OP package will continue to meet the minimum containment requirement of this package design as it relates to ensuring the overall package will meet the requirements of 10 CFR 71.

1-3 Drawings R741-OP and R74190 have been revised to add indication of visual weld inspection requirements for the package welds. Based on the package construction, a visual inspection is considered adequate for all welds on this package.

Like the overpack box hinge described in response to Item 1-2, the welds of the overpack box are necessary to maintain the internal wood in place around the inner device during transport and are considered sacrificial to the package after the 9 m drop impact. These welds are not important beyond maintaining the inner package wood intact around the inner projector during normal transport and up till the point of impact on the 9 m hypothetical accident drop test. As demonstrated since the institution of the overpack box design since 1999, the welds on the box are adequate to withstand, without failure, the stress related in normal lifting and transport of the package.

The inner projector manufacture incorporates a weld on the device shell in two places. These welds hold the two halves of the shell together and allow attachment of the side frames prior to filling the empty volume of the device interior with polyurethane foam to solidify the package construction. The shell welds are not important to safety during transport since:

- Failure of these welds during normal transport will not cause failure of the package integrity or elevate radiation dose rates from the package in excess of the regulatory limits and

- The device is protected by the overpack assembly during the 9 m drop and testing has proven that this hypothetical accident drop test is insufficient to cause failure of the shell welds. Impact of the inner device on the puncture bar is inadequate to cause failure of the shell welds such that an air gap could be created to allow pyrolization of the polyethylene foam and/or burning of the inner depleted uranium shield. As demonstrated through testing and by package design, the device will maintain the shielding integrity around the radioactive source under the hypothetical accident condition testing as the device welds are not critical to the safety/integrity of the radioactive package contents.

1-4 The ASTM material standards referenced on the drawings for carbon steel used on this package, do not all require adherence to minimum mechanical properties. Based on the material use in the package and its importance to safety, adherence to minimum mechanical properties is not necessary in all cases. The thinner steel components, which are obtained to "Typical" mechanical properties, is sufficient to ensure package integrity under normal and hypothetical accident conditions of transport.

ASTM A1008 specifies the material properties as "Typical" and "(Nonmandatory)" as the values are provided to assist in selection of a suitable steel for a given application. As indicated in Technical Report 159:

"The Overpack box is a Quality Class B, 'sacrificial' container intended to absorb an impact rather than transmitting it to the packages 741/741 inner device. The design assumes that, during the 30 ft drop test, the steel container will crush and the inner packaging (wood and foam) will protect the 741/741 from significant impact damage that could cause containment failure during subsequent accident condition testing. In the Type B testing these assumptions proved to be true, because the box damage prevented significant damage to the 741 device after the hypothetical accident condition testing...

The variations in alloy (AISI/SAE 1008-1012) and CRS vs HRS should have no effect on the results of the hypothetical accident condition testing since these properties are well within the Commercial Steel range originally and currently used for fabrication of these containers (See Table 1). The primary material concerns related to the overpack box construction would be the weldability, formability (cracking when bent) and cold temperature properties of the materials used...use of any of these materials in the construction of the overpack box would produce results similar to those seen in the actual testing performed..."

Additionally, ASTM A1011 Table 3 also provides "Typical Ranges of Mechanical Properties" for CS designated materials. These steels do not provide structural support to package containment under the normal or hypothetical accident test conditions and use of typical mechanical property ranges is sufficient to meet the intended performance requirements for the package.

The material specifications for the thickest steel range covered by ASTM A1018 are required mechanical properties. The thickest material on the inner device (shell and side frames along with support braces within the device structure) are controlled by ASTM A1018, therefore the minimum mechanical properties are adequately controlled based on drawings R741-OP and R74190.

The SAR is revised to clarify, for components manufactured to ASTM A1008 and ASTM A1011, that the mechanical properties listed in Table 2.2.A are "Typical" and not mandatory. Based on the evaluation contained in Technical Report 159, this level of material specification is sufficient for the safety importance of the overpack box metal components.

1-5 Only the fasteners attaching the rear plate to the 741 device from sheet 2 of drawing R74190 are ITS as these have direct impact on the containment of the radioactive source assembly inside the device shielding. The current fasteners in service also require the rear plate screws meet the following physical properties: 70,000 psi minimum ultimate tensile strength, 45,000 psi minimum 0.2% offset yield strength and 30% minimum elongation in 2 inches. This information has been added to drawing R74190 Revision K as required criteria for the rear plate screws.

Section 7.1.1.2.a of the SAR requires that the package user assure all bolts and fasteners (hardware) required for assembly of the package and as specified on the drawings referenced on the Type B transport certificate are fit for use. Fasteners with associated mechanical properties will be specified on the drawings referenced on the Type B transport certificate. This SAR section also requires the replacement of any bolts/fasteners that are no longer fit for use and that replacement hardware meet the applicable specifications on the drawings referenced under the Type B transport certificate. We believe this section addresses the concern raised in Item 1-8 of your request for information letter.

1-6 The only transport related safety critical component on the lock assembly are the retaining screws which hold the lock assembly to the rear plate of the device. These are noted as compliant to ASTM A837 on the current drawing. All other posilock assembly components are considered not important to safety, under transport conditions, based on the analysis provided in response to Item 1-6 of this letter.

The enclosed Revision 10 to the SAR is provided with all pages except for the documents referenced in Appendix 2. These documents are unchanged from Revision 9 of the SAR previously provided to your office and can be inserted directly into Revision 10 of the SAR in the same locations they had in Revision 9 of the SAR.

Should you have any questions on this letter or its enclosure, please feel free to contact me to discuss.

Sincerely,

Lori Podolak
Senior Regulatory Affairs Specialist
Regulatory Affairs Department
Ph: (781) 505-8241
Fax: (781) 359-9191
Email: Lori.Podolak@qsa-global.com

RA/QA Approval	15 Apr 2010 Date
Engineering Approval	15 Ap-10 Date

Enclosures:

- R741-OP Revision J
- R74190 Revision K
- SAR Rev 10 (minus Appendix 2 documents)

Safety Analysis Report

QSA Global, Inc.

Model 741-OP
Type B(U) - 96
Transport Package

13 April 2010

Revision 10

Contents

List of Tables

List of Figures

Section 1 - GENERAL INFORMATION

1.1 Introduction

The Model 741-OP is designed as a transport packages and storage container for Type B quantities of special form ^{60}Co radioactive material. It conforms to the Type B(U)-96 criteria for packaging in accordance 10 CFR 71, 49 CFR 173, the IAEA Regulations for the Safe Transport of Radioactive Material No. TS-R-1 (ST-1, Revised) 1996 Edition (Revised) and Canadian Nuclear Safety Commission (CNSC) PTNS Regulations SOR/2000-208. This submission is formatted in accordance with NUREG-1886 "Joint Canada – United States Guide for Approval of Type B(U) and Fissile Material Transportation Packages" dated March 2009.

1.2 Package Description

The transport package consists of an outer steel container with wood and foam inserts inside which is housed a Model 741 Series Projector (Figure 1.2.A). This transport package is constructed in accordance with descriptive drawings R74190 and R741-OP in Appendix 1.3. The Model 741-OP package may contain the following projector models; 741, 741A, 741B, 741E, 741AE, and 741BE. These models are structurally identical. All materials of construction and methods of fabrication are essentially the same. The models with the designation AE, BE and E have wires and connectors attached to the end plates for automatic source actuation when the device is in operation. All models except the 741 and 741E use a Posilok™ lock assembly. Prior to 1980, the Models 741, 741A and 741AE and 741E were manufactured with zircalloy source tubes, all other models have titanium source tubes. Throughout this evaluation, all models are considered interchangeable.

The exterior steel container is lined with polyurethane foam and wood which protects the Projector during transport. It is also fitted with wood inserts which locate and hold the projector in position within the container. The projector fits in the center of the inserts but is not mechanically fixed to the outer box. The container lid is closed by two padlock latches which are recessed into the front face of the box. The container is fitted with box section feet at each end, extending the full depth of the box enabling access underneath for mechanical lifting.

The package is constructed in accordance with descriptive drawings in Appendix A. Overall external dimensions for the 741-OP package is approximately 32" (813 mm) wide by 18 ½" (470 mm) high by 19" (483 mm) deep. The maximum weight of the package contents is 0.09 lbs (40 grams). The package weighs a maximum of 510 lbs (231 kgs) and is used for the transport of 1.22 TBq (33 Ci) of Co-60 as a special form source.

1.2.1 Packaging

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

1.2.1.1 741 Series Projectors:

The Model 741 Series Projectors are radiography devices. The overall dimensions are approximately 19 1/8" (486 mm) long, 11 3/8" (289 mm) high and 13 7/8" (352 mm) wide, with a maximum weight of 360 lbs (162 kg). The projector is shown in Figure 1.2.A and consists of the following major components.

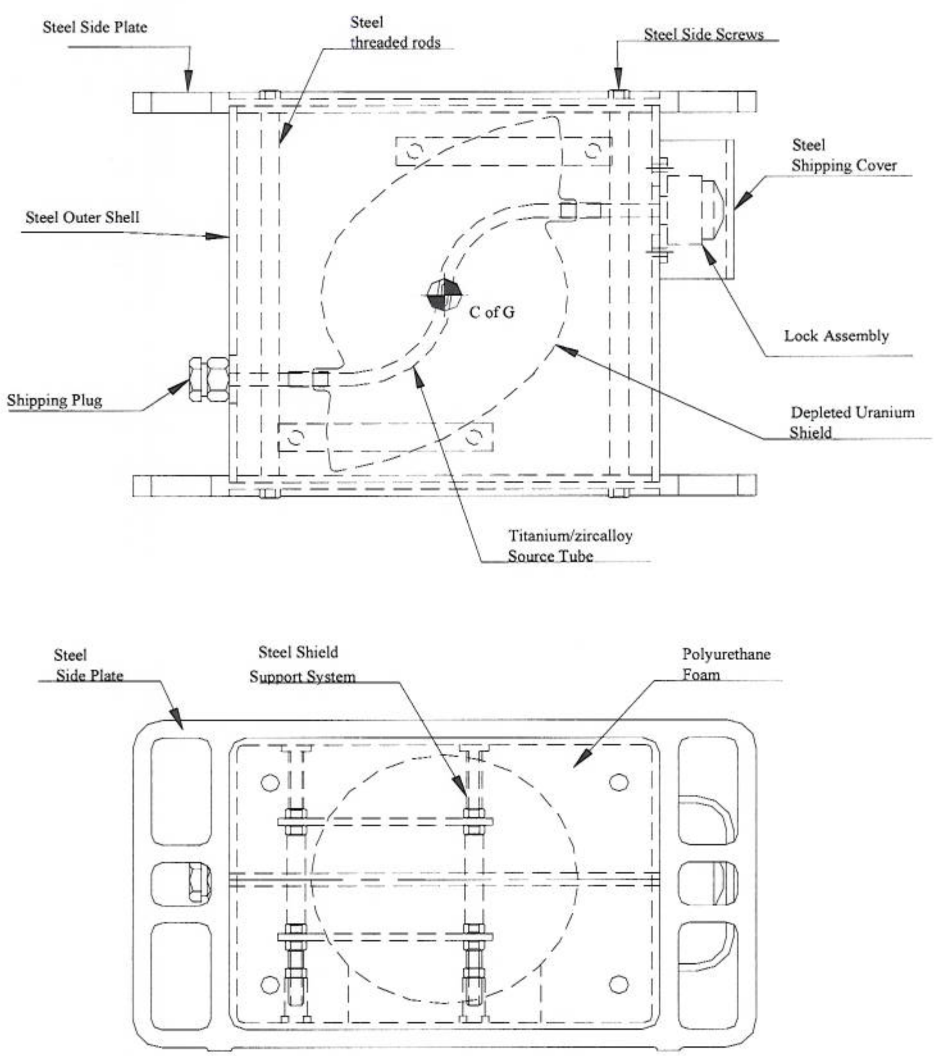


Figure 1.2.A – 741 Projector Structural Components

- Titanium or zircalloy source tube enclosed in a depleted-uranium shield
- 1/4" thick steel outer shell
- Lock assembly attached to one end of the shell
- Shipping plug assembly attached to the opposite end of the shell
- Two steel side plates which may be either machined from plate or a fabricated weldment
- Four steel connecting rods and side screws which hold the side plates to the shell.
- Steel support system locating the shield within the outer shell

1.2.1.2 Shield Assembly

The shield consists of a titanium or zircalloy source tube cast within the middle of depleted uranium. The depleted uranium is cast in place around the source tube.

The depleted-uranium shield is the primary radiation protection. The shield limits the projector's transmission of gamma rays to a maximum of 200 mR/hr at the surface and 10 mR/hr at one meter from the surface of the projector. In some cases, supplemental lead shielding may be added to portions of the depleted uranium shield to compensate for shield casting inconsistencies. This lead shielding is a maximum of ½" thick and the total weight of the added lead will not exceed 17 lbs (7.7 kgs). The total weight of the depleted uranium will not exceed 225 lbs (101 kgs).

1.2.1.3 741 Projector Lock Assembly

At one end of the shell is a lock assembly to prevent unauthorized use or unintentional movement of the source assembly within the projector. During shipment, the lock assembly is protected by a 1/4" thick steel shipping cover which is fixed to the outer shell with six 3/8"-24 × ¾" long hexagonal head stainless steel bolts.

The Co-60 special form source is attached to a source wire assembly. The source wire assembly is secured in the projector by either a Posilok™ or a non-Posilok™ lock assembly. (See drawings in Appendix 1.3 for general lock configuration variations between the Posilok™ or a non-Posilok™ lock assemblies.) The 741 projector uses a selector ring to change and indicate the safety state of the source. When the selector ring is rotated to the "LOCK" position, it securely holds the source wire assembly in place for transport.

The lock assembly is attached to a 1/4" steel mounting plate with four #10-32 stainless steel screws. The mounting plate is then attached to the outer shell with either four, 1/4"-20 × ¾" long stainless steel tamperproof screws or four, 1/4"-20 × ¾" long Grade 2 steel hexagonal head screws. Torque requirements for these screws are shown on the drawings in Appendix 1.3.

1.2.1.4 Shipping Plug Assembly

The other end of the shell incorporates a source guide tube connector assembly. During transport and storage, this connector assembly includes the installation of a shipping plug. The shipping plug is not protected by a shipping cover and is only removed during radiography operations

The source guide tube connector assembly includes a 1/4" steel mounting plate. The complete shipping plug assembly is then attached to the outer shell with four 1/4"-20 steel screws.

1.2.1.5 741 Projector Structural Construction

The steel shell is formed into a rectangle and welded at the top and base. The shield is restrained within the shell by a support system consisting of clamping bars attached to threaded rods. The threaded rods are in turn secured into steel cleats that are welded to the outer shell. All uranium/steel interfaces have copper separators to reduce the potential formation of a eutectic alloy.

The side frames are secured to the shell assembly using four, 5/8" diameter thread tapped, steel tubes and eight 7/16"-20 x 1" long steel hexagonal head bolts. A polyurethane foam (minimum 18 lb/ft^3) is used to fill the space around the shield within the projector housing. The foam secures the shield inside the shell and provides protection against shock and vibration.

1.2.1.6 741-OP Steel Transport Container

All versions of the 741 projectors are located inside a steel transport container that uses polyurethane foam and wood inserts to provide projector stability and protection during transport.

The exterior container is formed from 1/16" thick steel sheet which is a folded and welded construction. There are two box section feet made from 13 gauge (0.09") steel. These feet extend the full depth of the container and allow access underneath the container for mechanical lifting. The steel container measures approximately 32" (813 mm) long, 19" (483 mm) deep and 18 ½" (470 mm) high.

The steel container has a hinged lid and is closed by two lock hasps. The lock hasps are secured with padlocks which are inserted through the front face of the container and are recessed into the box.

The external surfaces of the overpack are painted black and are free from protruding features allowing ease of decontamination. As far as practicable the outer surface of the box is impermeable to water ingress. The pockets which house the padlocks can easily shed to the outside of the box any water which might fall on them.

Polyurethane foam and the fixed wood inserts locate the Model 741 Projector in the center of the container. The minimum free rise density of the foam is 8 lb/ft^3. Table 1.2.A and the descriptive drawings in the Appendix 1.3 provide a guide to the dimensions of these materials and their various positions within the container.

Table 1.2.A: Packing Materials

Location	Material	Thickness
Above the Projector	Wood	2 - 3"
Underneath the Projector	Wood	1 ½"
Front and Back of container	Wood	2-1/4"
Either end of Projector	Polyurethane Foam	3" each side
Between Foam and projector housing at both ends	Wood	Various

1.2.2 Contents

The Model 741-OP transport packages are designed to transport 1.22 TBq (33 Ci) of Co-60 as special form capsules attached to a source wire assembly. The maximum package source decay heat for Co-60 is 0.55 watts. The source capsules are loaded into the projector and secured according to the requirements in Section 7.

The maximum weight of the package contents is 0.09 lbs (40 grams). The content weight value is based on the weight of the full source wire assembly weight that can be transported in the package.

1.2.3 Special Requirements for Plutonium

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

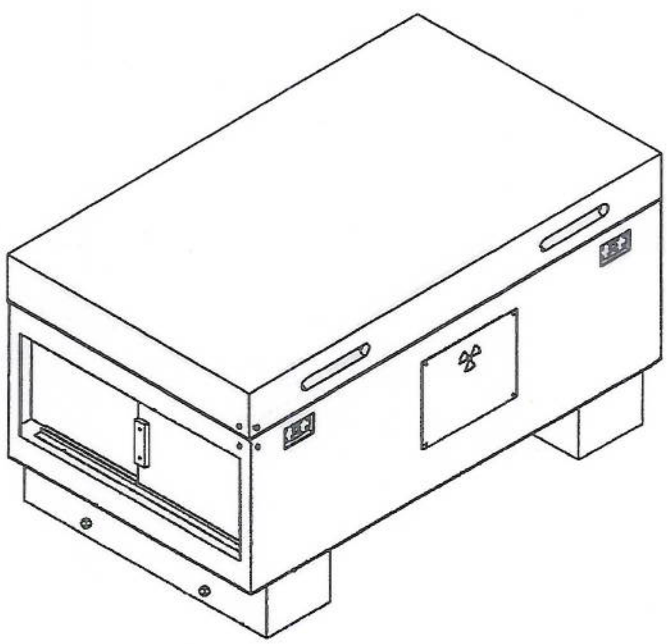
1.2.4 Operational Features

These packages do not involve complex containment systems for source securement. The sources for these packages are all special form, welded capsules. The capsules are attached to flexible handling wires which are held in place by the 741 projector lock mechanism. The projectors are inserted into the 741-OP transport container and secured as described in Section 7.

1.3 Appendix

Figure 1.3.A. shows a sketch of the Model 741-OP package as prepared for transport. Additional drawings of the Model 741-OP transport package are also enclosed in this appendix.

Figure 1.3.A – Sketch of Model 741-OP Prepared for Transport



For Transport: Package is assembled in accordance with Type B certificate and reference drawings.

Two Pad-locks are engaged for closure of the top lid and tamper indicating seals are applied to the side doors. (Note: Optional tamper indicating seal can also be applied to the top lid in addition to the padlocks which also act as tamper indicating seals.)

Section 2 - STRUCTURAL EVALUATION

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

2.1 Description of Structural Design

2.1.1 Discussion

The Model 741-OP Transport Packages are described in Section 1.2, "Package Description".

2.1.2 Design Criteria

The Model 741-OP 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 (ST-1, Revised) 1996 Edition (Revised) and CNSC PTNS SOR/2000-208. All design criteria are evaluated by a straightforward application of the appropriate section of these requirements.

2.1.3 Weight and Centers of Gravity

The transport package weighs up to 510 lbs (231 kg). The maximum weight of the Model 741 projector is 360 lbs (162 kg). The maximum weight of the projector shield is 225 lbs (101 kg). The shield may also include the addition of up to 17 lbs (7.7 kgs) of lead as supplemental shielding to the exterior surface of the shield. This lead if applied will not exceed ½ inch thick in any location on the depleted uranium shield. The center of gravity (C of G) is nominally assumed as the geometric center of the shield.

2.1.4 Identification of Codes and Standards for Package Design

See Section 2.1.2 relating to design criteria of the package. Any applicable, specific codes or standards related to the finished assemblies for these transport packages are specified on the drawings contained in Section 1.3. All component fabrication (including assembly) is controlled under the QSA Global, Inc. Quality Assurance Plan approved by the USNRC and ISO. All welding under this plan adheres to the standards referenced on the drawings in Section 1.3. All hardware meets the standards referenced on the drawings in Section 1.3. All external fabrication deemed critical to safety is either verified to equivalent in-house standards or dedicated as appropriate for use prior to release as part of this transport package.

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

2.2 Materials

2.2.1 Material Properties and Specifications

Tables 2.2.A and 2.2.B list the relevant mechanical properties (at ambient temperature) of the principal materials used in the Model 741-OP transport package. The references in the last column are listed after the tables.

Table 2.2.A: Mechanical Properties of Principal Package Materials

Material	Tensile Strength	Yield Strength	Elongation	Resource
Depleted Uranium (U-0.75 Ti)	65 ksi	30 ksi	12%	Reference #1, p. 20-35
Copper (99%)	20 ksi	-	25%	Reference #3, p6
Lead (99%)	1.7 ksi	7.9 ksi	30%	Reference #1, p. 12-3
Steel Plate & Bar	53-80 ksi	36 ksi	16-21%	ASTM A1018/A1018M-08
Cold Rolled Steel Sheet	Not Specified	20-40 ksi	30% Min	ASTM A1008/A1008M-09[1]
Hot Rolled Steel Sheet	Not Specified	30-50 ksi	25% Min	ASTM A1011/A1011M-09[1]
Titanium Tube Ti-3Ai-2.5V	90 ksi	75 ksi	10%	Reference #1, p. 9-3

[1] Mechanical properties for the referenced materials listed in this standard are considered "Typical Ranges". These materials, as used in this transport package, do not provide structural support to the package containment under normal or hypothetical accident test conditions. The use of typical material properties ranges for these materials is sufficient to meet the intended performance requirements for the package

Table 2.2.B: Compressive Strength of Non-metallic Materials

Material	Compressive Strength	Resource
Polyurethane Foam 8 lbs/ft^3 20 lbs/ft^3 *Foam Values are Nominal ± 2 lb/ft^3	Nominally 155 psi Nominally 960 psi	General Latex and Chemical Company
Wood	35 psi	Reference #2, p. 260

Resource references:

1. Howard E. Boyer and Timothy L. Gall, Editors, *Metals Handbook.* Metals Park, Ohio: American Society for Metals, 1985.

2. Lawrence H. Van Vlack, *Materials for Engineering: Concepts and Applicants.* Boston: Addison-Wesley Publishing Company, 1992.

3. Copper and Copper Alloys, Compositions and Mechanical Properties. CDA publication.

2.2.2 Chemical, Galvanic or Other Reactions

The materials used in the 741-OP outer container are steel, rigid polyurethane foam and wood. There will be no adverse chemical or galvanic reactions between any of these components.

The materials used in the construction of the 741 Projector are depleted uranium metal, lead (in some instances), steel, stainless steel, titanium or zircalloy, rigid polyurethane foam and copper. There will be no significant chemical or galvanic action between any of these components.

To prevent the possible formation of a eutectic alloy of steel and depleted uranium in the fire test, copper separators are used. The separators are positioned at all places where the steel and depleted uranium would otherwise come into contact, i.e. between the steel clamping bars and depleted uranium shield and between the shell and the hot top.

2.2.3 Effects of Radiation on Materials

Lead, depleted uranium, titanium (or zircalloy), steel, wood and polyurethane foam have been used in transport packaging for decades without degradation of the package performance over time due to irradiation from package contents.

2.3 Fabrication and Examination

2.3.1 Fabrication

Package components are procured, manufactured and inspected for use under QSA Global, Inc. NRC approved QA Program Number 0040. This QA program is based on the application of guidance contained in NUREG/CR-6407 "Classification of Transportation Packing and Dry Spent Fuel Storage System Components According to Importance to Safety (1996). Quality Class A components on the package are considered to be important to the package safety. All transport packages will be evaluated and documented for compliance to the drawings provided in Section 1.3 prior to initial use as part of a Model 741-OP transport package.

2.3.2 Examination

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

2.4 General Requirements for All Packages

2.4.1 Minimum Package Size

The package is approximately 32" (813 mm) long, 19" (483 mm) wide and 18 ½" (470 mm) high and therefore exceeds minimum package size requirements.

2.4.2 Tamper-Indicating Feature

The Model 741-OP packages incorporates a seal wire attached to either the lid closure or the side doors which, if broken during transport, serves as evidence of possible unauthorized access to the contents.

2.4.3 Positive Closure

These packages do not involve complex containment systems for source securement. The sources for these packages are all special form, welded capsules. The source wire assembly is held securely in the device by components of the rear plate assembly. One of these components, the sleeve, in conjunction with the selector ring retainer, prevents the stop ball of the source wire from being pulled through the rear of the package.

Another component of the rear plate assembly, either the lock slide or locking pins depending the lock assembly design, prevents the source assembly from being pushed out through the front of the package when in the secured position. When the 741 projector is prepared for transport, the source assembly is secured and the selector ring is rotated to the lock position preventing source movement.

A cover over the source wire connector prevents access to the source assembly until a keyed lock is actuated and the cover removed. This cover is in place during transport of the package and the 741 device is further protected during transport inside the overpack box assembly.

2.5 Lifting and Tiedown Standards for All Packages

2.5.1 Lifting Devices

The package is designed to be mechanically lifted by means of a forklift or by slinging. In both cases, lifting should be carried out between the two container feet. There are no lifting attachments on the package. For this analysis, lifting of the package is modeled as a box section dimensioned between the two overpack feet. The package in this model is assumed to measure 32 inches (813 mm) long, 19 inches (483 mm) wide, 15 inches (381 mm) deep with a steel thickness of 0.06 inches (1.5 mm). The bending moment of inertia of the package is estimated by:

$$I = \frac{t\,d^2}{6}\,(3\,b + d)$$

Reference: "Design of Welded Structures", James F. Lincoln Arc Welding Foundation, Library of Congress, Catalog # 66-23123.

Where:

t	=	steel thickness of the base = 0.06 inches
d	=	depth of the package = 15 inches
b	=	length of the package = 32 inches)

From this equation the bending moment of inertia is 250 in^4. From this the maximum stress on the package is calculated by:

$$\sigma = PLc/4I$$

Where:

P	=	The weight of the transport package 510 lbs (231 kg)
L	=	The length of the base between forks 9 inches (229 mm)
c	=	Half the thickness of the box section 7.5 inches (191 mm)
I	=	The moment of inertia 250 in^4 (10,406 cm^4)

From this relationship, the stress generated in the base is calculated to be 34 psi. With a Safety Factor of 3 applied, the maximum stress in the base is 105 psi. This is less than 1% of the ultimate yield strength of the steel base, 42,000 psi. Further, as was demonstrated in TP 72 Report (see Section 2.12.3), TP72(A) was subjected for 24 hrs to a compressive load which was six times the maximum package weight. The test unit inside the overpack was a Model 680 projector which is larger than the 741 projector with less wood protection surrounding the projector inside the overpack. The 680 was measured before and after testing in two locations: (1) the overall package height at the end of the overpack, and (2) the package centerline distance measured from the package the bottom to the ground. After testing there was no buckling or deformation of the package in these areas. By comparison since the 741 projector (and overall package) is lighter and has additional internal wood support than the tested unit, it can be further assessed that the package strength in the 741-OP configuration is sufficient to withstand the stress requirements of this section.

2.5.2 Tie-Down Devices

The Model 741-OP 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 741-OP transport package is described in Section 1.2.3. Co-60 generates approximately 15.4 milliwatts per Curie based on assuming a decay energy of 2.82 MeV/decay. Assuming all the decay energy is transformed into heat, the heat generation rate for 1.22 TBq (33 Ci) of Co-60 would be approximately 0.55 Watts. The thermal evaluation for the heat test is described in Section 3.

Assuming the entire decay heat, 0.55 watts, is absorbed by the package, this would result in a worst case package surface temperature of 39.9°C (103.7°F) (Section 3.4.1.2). Accounting for solar heating effects (Section 3.4.1.1), the maximum temperature of the package surface was calculated to be 71°C (160°F). Since each source loaded into the Model 741-OP packages generates no more than 0.55 Watts as shown in Table 2.6.A, it can be assumed that no part of the package will be greater than 71°C (160°F) or be significantly affected by heating effects. In addition, the materials used in these packages will not be significantly affected by 71°C (160°F).

Table 2.6.A: Radionuclide Decay Energy

Radionuclide	Package Activity (Ci)	MeV/Decay	Watts/Package
Cobalt-60	33	2.82	0.55

Resource references:

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

2.6.1.1 Summary of Pressures and Temperatures

Table 2.6.B: Summary Temperatures Normal Transport

Temperature Condition	Model 741-OP	Comments
Insolation (38°C in full sun)	71°C (160°F)	Section 3.4.1.1.
Decay Heating (38°C in shade)	39.9°C (103.7°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.B.

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.

2.6.1.3 Stress Calculations

Stress calculations for normal transport of this package are contained in Sections 2.5.1 and 2.7.4.3. Results of these calculations demonstrate that the package meets the requirements for Normal Transport.

2.6.1.4 Comparison with Allowable Stresses

The Model 741-OP package was assessed based on testing performed on the 680-OP and determined to pass under Normal Conditions of transport. It is therefore concluded that the Model 741-OP package will satisfy the performance requirements specified by the regulations.

2.6.2 Cold

The carbon steel components of the Model 741-OP transport packages are susceptible to brittle fracture at low temperature. To assess the package performance under the worst case test conditions, the drop and penetration tests described in 10 CFR 71.71(c)(7) and (10) were performed with the package at the coldest temperature referenced in the regulations. This condition was most likely to produce package failure under these test conditions due to the brittle fracture nature of the package components. As demonstrated in Test Plan 82 Report, the transport package successfully met Type B(U)-96 Transport Tests requirements at temperatures below -40°C (-40°F), the minimum specified in the 10 CFR 71.71(c)(2), therefore it is concluded that the Model 741-OP transport packages will withstand the normal transport cold condition.

2.6.3 Reduced External Pressure

The transport package is open to the atmosphere and contains no components which could create a differential pressure relative to atmospheric conditions or components within the package. 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 2919-1999 classification of Class 3 for pressure. This classification is more limiting than the reduced external pressure requirement as it covers 25 kN/m^2 to 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 2919-1999, Radiation Protection – Sealed radioactive sources - General requirements and classification.

2.6.4 Increased External Pressure

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

The authorized contents are special form source capsules that meet a minimum ISO 2919-1999 classification of Class 3 for pressure. This classification is more limiting than the increased external pressure requirement as it covers 25 kN/m^2 to 2 MN/m^2. Therefore, the increased external pressure requirements of 20 psi in 10 CFR 71 will not adversely affect the package containment.

2.6.5 Vibration

The 741 Projectors have been in use and transported for a number of years. In this period, there has been no evidence of vibration-induced failure. The use of the outer container will not adversely affect those results, as the container inserts hold the projector in place.

The outer container is a folded and welded steel construction with a lid retained by a piano hinge (welded in place) which is closed by two padlocks. These components are not susceptible to vibration induced failure. The padlock hasps are secured by U-bolts, the retaining nuts of which are secured with lock washers and thread locking compound to prevent them from vibrating loose.

It is therefore concluded that the Model 741-OP packages will withstand vibration normally incident to transport.

2.6.6 Water Spray

Water spray preconditioning of the package was not performed. The 741 projectors are constructed of waterproof materials throughout. The outer container, while not being air or water tight is constructed of waterproof material and will provide protection from rainfall. The outer container lid to body interface incorporates a land and a lip which prevents rain ingress.

2.6.7 Free Drop

As described in Test Plan 82 Report (Section 2.12.7), compliance of the Model 741-OP is based on testing performed on the Model 680-OP under Test Plan 72 Report (Section 2.12.3). The following describes the testing of the Model 680-OP test units.

Test unit TP72(A) was dropped onto the front top edge of the package above the two padlock latches. The intention was to test the package ability to absorb the energy from an impact on its front edge and maintain the containment of the projector. Such an impact might cause the locks to shear, or the outer steel box to distort, forcing the lid to open. Additionally, the outer steel box may prove inadequate in providing protection for the internal components.

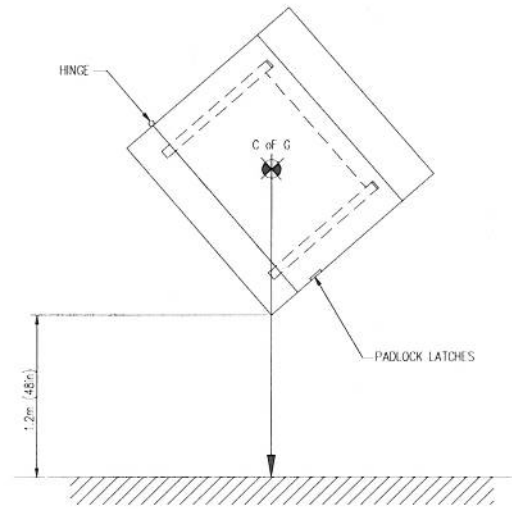


Figure 2.6.A – Specimen TP72(A) Orientation for the 1.2 m Drop Test

The results in the Test Plan Report 72 demonstrate that the Model 741-OP transport package maintains its structural integrity and shielding effectiveness under the Normal Conditions of Transport free drop test. The package was dropped at -40°C onto the front top edge of the outer container nearest the lock assembly.

Damage from the drop was limited to slight deformation of the lid with no damage occurring to the padlocks, hinge, or significant change in radiation dose levels. Test Plan Report 89 assessed the impact of modifying the outer box assembly with the addition of access doors on the 1.2 m drop test results obtained from Test Plan Report 72.

The removal of 0.5 lbs (approximately 22% by weight) of polyurethane foam per box side to accommodate insertion of access ports has essentially no effect on the package's ability to survive the 1.2 m drop. This is demonstrated by the package ability to survive, with minimal damage, the 9 m drop which imparts more than 700% of the unit energy into the foam as would the 1.2 m drop. The removal of 22% of the polyurethane foam increases the unit energy input to the remaining foam less than 140%.

Test unit TP72(A) weighed a total of 598 lbs. The maximum requested package weight for the Model 741-OP is 510 lbs. In the normal condition drop test, the test unit sustained no damage to the inner 680 device and received less physical damage to the overpack than was produced by the hypothetical accident testing (See Section 2.7).

Therefore the test information obtained for TP72(A) under Test Plan Report 72 is considered conservative and remains valid to demonstrate that the Model 741-OP transport package maintains its structural integrity under the Normal Conditions of Transport, 1.2 m drop test.

2.6.8 Corner Drop

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

2.6.9 Compression or Stacking

As described in Test Plan 82 Report (Section 2.12.7), compliance of the Model 741-OP is based on testing performed on the Model 680-OP under Test Plan 72 Report (Section 2.12.3). The following describes the testing of the Model 680-OP test units.

Test Plan Report 72 demonstrated that the test unit maintained its structural integrity and shielding effectiveness under the Normal Conditions of Transport compression test. The actual test specimen for the compression test weighed 598 lbs. The test specimen was subjected to a compressive load of 3,149 lbs (1,431 kg) for a period of 24 hours, which exceeds six times the package weight of 510 lb. This is greater than 2 lb/in^2 (13 kPa) multiplied by the vertically projected surface area of the package.

Following the test, no damage to the unit was observed. There was a 5/16" reduction in overall height but this was due to settling of the lid and occurred immediately after the load was applied.

Based on testing performed on the Model 680-OP and the package similarities with the Model 741-OP it is concluded that the Model 741-OP transport package will maintain its structural integrity under the Normal Conditions of Transport, compression test.

2.6.10 Penetration

As described in Test Plan 82 Report (Section 2.12.7), compliance of the Model 741-OP is based on testing performed on the Model 680-OP under Test Plan 72 Report (Section 2.12.3). The following describes the testing of the Model 680-OP test units.

In Test Plan Report 72, test unit TP72(A) was impacted by the penetration bar on one of the padlock latches with the intention of damaging the latch and padlock assembly. Inspection following the test indicated that no damage occurred. There was no loss of structural integrity or reduction of shielding efficiency resulting from this impact.

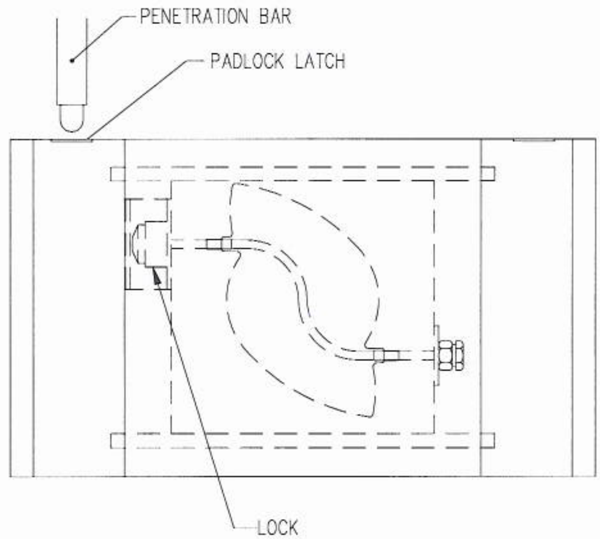


Figure 2.6.B – Specimen TP72(A) Orientation for the Penetration Test

The results in Test Plan Report 72, and comparison of the test unit to the Model 741-OP transport package, demonstrates that the Model 741-OP transport package maintains its structural integrity and shielding effectiveness under the Normal Conditions of Transport penetration test.

2.7 Hypothetical Accident Conditions

Sections 2.7.1 through 2.7.5 summarize evaluations and testing for the hypothetical accident conditions of transport tests. Section 2.7.6 summarizes the results of this testing. The test sequence as specified in 10 CFR 71.73 was determined to be the order which would result in the maximum damage to the package, considering the subsequent application of the fire test, because the inner device is more vulnerable to containment related damage during the puncture test than the device inside the overpack assembly. The intention of the 30 ft drop was to release the inner device and test the device without the overpack for both the puncture and thermal tests which would produce the worst case potential damage to the containment system.

2.7.1 Free Drop

As described in Test Plan 82 Report (Section 2.12.7), compliance of the Model 741-OP is based on testing performed on the Model 680-OP under Test Plan 72 Report (Section 2.12.3). Based on the Model 680-OP testing, the results were evaluated to determine the worst case 9 m drop orientation for physical testing of a Model 741-OP test unit. The following describes the testing of the Model 680-OP and Model 741-OP test units. Justification for all test unit drop orientations are included in Test Plan Reports 72, 82 and 89 (see Appendix 2.12).

2.7.1.1 End Drop

This orientation was used for test sample TP72(E). The test was performed with the impact being on the end face of the steel box nearest the lock system. The intention was to test the polyurethane foam's ability to act as a shock absorber, or whether its rigidity would allow transmission of the impact energy directly onto the projector and lock system. See Test Plan Report 72 (Appendix 2.12).

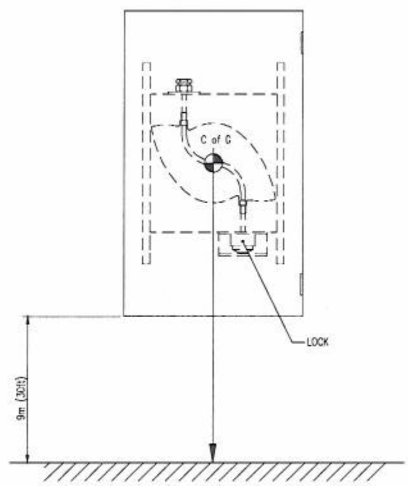


Figure 2.7.A – Specimen TP72(E) Orientation for the 9 m Drop Test

2.7.1.2 Side Drop

This orientation was used for test sample TP72(D). The test was performed to subject the feet of the package to the full force of a 9 m drop to see what degree they crush and therefore absorb impact energy. A consequence of a lack of deformation would be that the heavy internal projector, and in particular the shield, might retain enough momentum to be able to punch through the base of the outer steel box and strike the test plate. This might result in damage to the projector components and even movement of the shield within the polyurethane foam as this is ineffective as a shock absorber in this orientation. See Test Plan

Report 72 (Appendix 2.12).

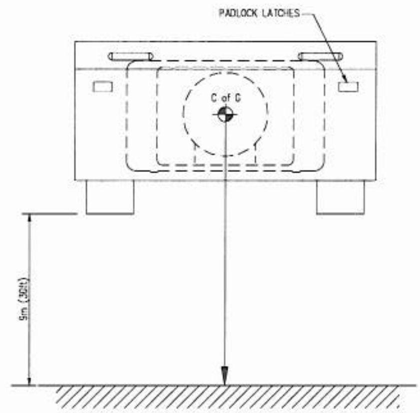


Figure 2.7.B – Specimen TP72(D) Orientation for the 9 m Drop Test

2.7.1.3 Corner Drop

The corner drop was not performed as this orientation was determined to be less damaging than other orientations that were tested. As was seen in TP 72 Report (see Section 2.12.3), TP 82 Report (Section 2.12.7) and TP 89 Report (see Section 2.12.6), some energy was transferred to the inner shield container in the side and edge drops. Results of testing showed that more package deformation occurred in the edge drops than was seen in the side drops. In addition, the deformation in 680-OP style test unit drop orientations caused bending of the side plates inwards towards the main body of the shield container instead of causing a shearing action on the four plate bolts. Had the bolts sheared, this could have exposed the rigid polyurethane foam and depleted uranium shield to degradation during a thermal test.

As was seen in the edge and side drops, a pure corner drop would transfer most of its energy into deformation of the outer package. This would result in a very slow deceleration, thus limiting the energy generated at impact and transmitted to the projector. A corner drop would also transfer less energy in a direction parallel to the side plates. This would further aggravate the tendency of the side plates to wrap inward around the main container body instead of causing the four side plate bolts to fail in shear. Without this type of failure, the depleted uranium shield is not vulnerable to degradation in a thermal test.

In a corner drop, the package could break one of the lock hasps, but due to the localized impact area, it is not likely that sufficient energy would be transferred to both lock hasps causing their break upon impact as was seen with TP82(A). Therefore the shield container would remain inside the overpack prior to the 1 m puncture drop.

If the package was dropped on a corner of the lid hinge and caused the hinge to unzip upon impact, there would be insufficient energy transfer to the lid lock hasps to cause their failure in the same drop. Again, the shield container would remain inside the overpack prior to the puncture test.

Based on results in TP 89 Report, the subsequent 1 m puncture test would be insufficient to cause failure of the secondary lock hasp. However, even if failure of the second lock hasp is assumed and the shield container is thermal tested outside of the overpack, the package would still pass the thermal test requirements. As was seen for the test unit TP72-S1(B) (see TP 72 Report Section 2.12.3), thermal testing of the shield container outside of the overpack where the shield container had bent side frames did not cause failure of the package. From this assessment it is determined that a corner drop of the package would be less damaging than the drop orientations performed for this package, therefore it was not performed.

2.7.1.4 Oblique Drops

This orientation was used for some of the test samples. See Test Plan 72 Report and Test Plan 82 Report (Appendix 2.12). The individual drop orientations are described as follows:

2.7.1.4.1 Test samples TP72(B), TP72-S1(B) and TP82(A) were dropped onto the front top edge of the package above the two padlock latches. The intention was to try and shear the lid off by subjecting it to the full force of a 9 m impact. If the lid were to shear off, then the projector inside would be exposed to direct targeting from the following puncture test.

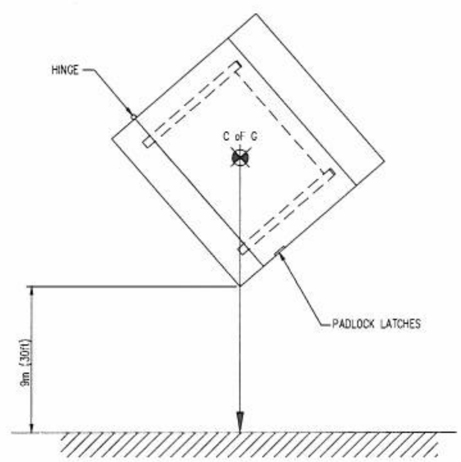


Figure 2.7.C – Specimen TP72(B) and TP72-S1(B) Orientation for the 9 m Drop Test

2.7.1.4.2 Test samples TP72-S1(C) and TP89(B) were dropped to test the ability of one of the package's short edges to crush and absorb the impact energy while retaining the contents and protecting them from damage. The intention was to deform the outer steel box, thereby forcing the lid off. The effectiveness of the polyurethane foam protection and its ability to absorb shock loading was also tested in this drop orientation.

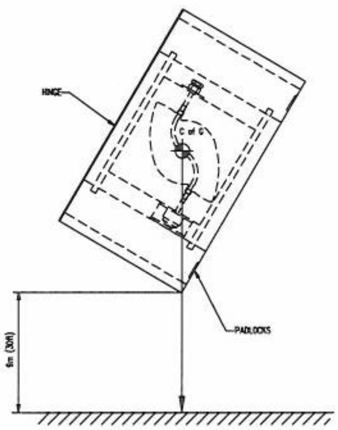


Figure 2.7.D – Specimen TP72-S1(C) and TP89(B) Orientation for the 9 m Drop Test

2.7.1.5 Summary of Results

See Table 2.7.A 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

Justification for all test unit puncture orientations are included in Test Plan Reports 72, 72-S1, 82 and 89 (see Appendix 2.12). The orientations were determined following the 9 meter drop tests and were selected based on an assessment as to which orientation would impart the most damage to each specimen.

All puncture tests were carried out with the projector retained within the steel box with the exception of test specimens TP72-S1(B) and TP82(A). These specimens were subjected to unprotected impacts on the puncture bar. TP72-S1(B) impacted directly on the lock assembly with the center of gravity directly above the shipping cover. This resulted in deformation and cracking of the shipping cover along the lower set of bolt holes with the upper set of bolts holding the cover in place. The deformed shipping cover did not impact the lock assembly and left the locking mechanism undamaged. TP82(A) impacted on the top edge of the projector side plate with the intention of causing additional damage to the side plate and possibly causing the shell to crack. This caused additional bending of the side plate but no damage to the shell.

2.7.4 Thermal

See Section 3.5 for a discussion of the Thermal test performed on the 741-OP package components.

2.7.4.1 Summary of Pressures and Temperatures

These containers are vented to atmosphere. As such, no pressure will build up in the units under Hypothetical Accident conditions. See Tables 3.1.A and 3.1.B for summary tables of temperature and maximum pressure related to the Model 741-OP package.

2.7.4.2 Differential Thermal Expansion

Actual testing on similar packages such as the 650L (USA/9269/B(U)-85) and the 702 (USA/6613/B(U)-85) 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. Design clearances between fitted components in the 741-OP are sufficient to allow for thermal expansion at the maximum temperature of 71°C (160°F). It can be drawn from the actual testing results that thermal expansion will not have a significant effect on the Model 741-OP packages.

2.7.4.3 Stress Calculations

This analysis demonstrates that the pressure inside the source capsule used in conjunction with the model 741-OP container, when subjected to the Hypothetical Accident Conditions of Transport thermal test, does not exceed the pressure which corresponds to the minimum yield strength at the thermal test temperature.

The source capsule is fabricated from stainless steel, either Type 304 or 304L. The maximum inside diameter of the capsule is 0.21 inches (5.3 mm). The source capsule is seal-welded. The minimum weld penetration is 0.012 inches (0.3 mm). Under conditions of internal pressure, the critical location for failure is this weld.

The internal volume of the source capsule contains a second source capsule which is seal welded to enclose the Cobalt 60 metal (as a solid metal), spacers and air. It is assumed at the time of loading, any entrapped air is at standard temperature and pressure, 20°C (68°F) and 14.7 psi (101 kN/m^2), respectively. This is a conservative assumption because, during the welding process, the internal air is heated, causing some of the air mass to escape before the capsule is sealed. When the welded capsule returns to ambient temperature, the internal pressure would be somewhat reduced.

Under the Hypothetical Accident Conditions, it is assumed that the capsule could reach a temperature of 800°C (1,475°F). Using the ideal gas law and requiring the air to occupy a constant volume, the internal gas pressure could reach 54 psi (370 kN/m^2).

The capsule is assumed to be a thin walled cylindrical pressure vessel with the wall thickness equal to the depth of weld penetration.

The maximum longitudinal stress is calculated from:

$$\sigma_L A = PA_p$$

where

σ_L	=	Longitudinal stress
A	=	Stress Area $= \pi d t_p$ = (5 mm^2 or 0.0079 $inches^2$)
t_p	=	minimum weld penetration
P	=	Pressure (54 psi)
A_p	=	Pressure Area $= \pi r^2$ = (22 mm^2 or 0.33 $inches^2$)

From this relationship, the maximum longitudinal stress is calculated to be 238 psi (1.6 MN/m^2).

The hoop stress is calculated from:

$$2\sigma_h t = Pd$$

where

t	=	Thickness of the cylinder (0.3 mm or 0.012 inches)
d	=	Inside diameter (5.3 mm or 0.21 inches)
σ_h	=	Hoop stress

From this relationship, the hoop stress is calculated to be 473 psi (3.3 MN/m^2).

At a temperature of 870°C (1,598°F), the yield strength of type 304 stainless steel is 10,000 psi (69 MN/m^2). Therefore, the stress generated is less than 7% of the yield strength of the material.

2.7.4.4 Comparision of Allowable Stresses

All stresses calculated in Section 2.7.4 are well below strengths for the materials of construction. Further, these packages were tested and/or assessed for compliance to the Normal and Hypothetical Accident Conditions of transport. It is therefore concluded that the Model 741-OP 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

The Model 741-OP Transport Packages are open to the atmosphere and contains no other components that would create a differential pressure under immersion. All materials are impervious to water and would not be affected.

The primary containment system in these packages is a special form source, which minimally meets the ANSI N43.6 and ISO 2919 requirements for Class 3 pressure testing. Therefore the Model 741-OP could withstand the immersion test criteria since the Class 3 pressure test requirements are in excess of the required 150 kPa (21.7 lb ft/in2).

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

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

2.7.8 Summary of Damage

Table 2.7.A summarizes the results of the Normal Conditions of Transport and Hypothetical Accident testing performed on the test specimens used to demonstrate compliance of the Model 741-OP transport packages.

Following assessment of the damage caused by the initial drops, in particular that caused by the drop of TP72(B), the configuration of the wood inserts within the lid of the steel box was changed. In particular, the design of the lining of the box lid was changed to provide additional impact absorption capability. These modifications are shown in the descriptive drawing contained in Appendix 1.3. Three packages incorporating these changes were then subjected to the 9 meter drop test. These units were TP72-S1(B), TP72-S1(C) and TP82(A) described in Section 2.7.1.4.

The modifications to the 741-OP outer container following the initial 9 meter drop tests had the effect of increasing the overall mass of the 741-OP package by 3%, the additional mass being located in the lid. It is reasonable to assume that the impact energy also increased by 3% as a result of the modifications. From TP72-S1(C) unit serial number B201 weighed 624 lbs (468 lbs for the 741 device and 156 lbs for the overpack assembly components). This test unit was re-used in Test Plan 89 as test unit TP89(B). In this 9 m (30 ft) drop test the package passed the testing. It was concluded that the 9 meter drop test for the other tested orientations would not need to be repeated on the modified package for the reasons described above and further supported by the reasons described in 2.7.8.1 through 2.7.8.3:

2.7.8.1 TP72(A) Test Specimen

a. The drop of Test Specimen TP72(A) did not result in any damage to the projector.

b. The additional 3% of impact energy would be absorbed by further deformation of the container feet and body. The post test examination carried out on the sample tested showed that there was further capacity for deformation and therefore energy absorption, see Test plan 72 report.

c. The additional 3% mass added to the lid would apply an increased load to the top of the projector. However, the increase is not significant considering that the Test Plan 72 report observed no damage to the projector after this drop.

As a result, it is concluded that the results for Test Specimen TP72(A) test drop are applicable to the modified packaging.

2.7.8.2 TP72(D) Test Specimen

a. The drop of Test Specimen TP72(D) did not result in any damage to the projector.

b. The additional 3% of impact energy would be absorbed by further deformation of the container feet and body. The post test examination carried out on the sample tested showed that there was further capacity for deformation and therefore energy absorption, see Test plan 72 report.

c. The additional 3% mass added to the lid would apply an increased load to the top of the projector. However, the increase is not significant considering that the Test Plan 72 report observed no damage to the projector after this drop.

As a result, it is concluded that the results for Test Specimen TP72(D) test drop are applicable to the modified packaging.

2.7.8.3 TP72(E) Test Specimen

a. The drop of Test Specimen TP72(E) did not result in any damage to the projector.

b. The impact orientation is such that the additional weight in the edge of the lid is not carried by the projector. Rather the lid impacts directly on the drop pad.

As a result it is considered that the results for test drop TP72(E) are applicable to the modified package.

Table 2.7.A: Summary of Damages During Performance of TP72, TP72-S2, TP82 and TP89

Specimen	Test Performed	Test Results
TP72(A) (680-OP)	Compression test	• After weight applied, specimen height reduced by 5/16" due to lid settling. • No damage to the package.
	1 meter (40 inch) penetration bar on padlock	No damage to the padlock.
	1.2 meter (4 foot) drop on top front edge	• Lid deformed slightly backwards, but did not open. • No damage to projector
	Post-Drop Inspection	• There was no damage to source containment which would allow dispersal of radioactive contents. • No source movement measured. • No significant change in radiation levels from the pre-test profile. • Surface and 1 meter dose rates remained within limit of 200 mR/hr and 10 mR/hr respectively (See Appendix 2.12).
TP72(B) (680-OP)	9 meter (30 foot) drop on top front edge	Lid deformed but did not open.
	1 meter (40 inch) puncture on top front corner	• Packaged dropped twice to achieve impact orientation. • Box deformed but did not open.
	Post-Drop Inspection	• Top Edge of projector side plate bent and shell cracked. • Test unit prompted modification of lid design as described in 2.7.8.

Specimen	Test Performed	Test Results
TP72-S1(B) (680-OP)	9 meter (30 foot) drop on top front edge	• Both lock hasps broke and the hinge unzipped. • Projector came out of the box. • Projector side plate bent slightly.
	1 meter (40 inch) puncture on lock assembly shipping cover	• Shipping cover deformed and cracked along lower set of bolt holes. Upper set of bolt holes retained shipping cover in place. • The shipping cover did not impact the lock assembly.
	Post-Drop Inspection	• There was no damage to source containment which would allow dispersal of radioactive contents. • No source movement measured. • No significant change in radiation levels from the pre-test profile. • 1 meter dose rates remained within limit of 1 R/hr (See Appendix 2.12).
	Thermal Testing (741 sn B198 tested without outer container)	• The shield moved as predicted within the projector. • The radiation levels increased to 330 mR/hr at 1 meter in one small area, with most of the readings being below 20 mR/hr at 1 meter. Radiation level within requirements by a safety factor of 3.
TP72-S1(C) (680-OP)	9 meter (30 foot) drop, on front side edge on lock assembly side	• Edge of box crushed inward from impact and recessed area in the side of the box deformed outward. • Padlock nearest the impact broke but the latch remained closed.
	1 meter (40 inch) puncture test on left top corner	Additional deformation of the steel box at the impact point but the lid did not open.
	Post-Drop Inspection	• One projector side plate was bent slightly on side adjacent to the lock assembly due to impact with the padlock. No damage to the lock assembly or shipping cover. • No source movement measured. • No significant change in radiation levels from the pre-test profile. • 1 meter dose rates remained within limit of 1 R/hr (See Appendix 2.12).
	Thermal Test	Not performed. Test unit performance bounded by thermal tests performed on TP72-S1(B) and TP72(D).
TP72(D) (680-OP)	9 meter (30 foot) drop flat on bottom feet of box	• Right foot of box was crushed more than the left foot. • Bottom of box deformed downward ~2 inches but did not contact drop pad surface. • Locks and lid intact.

Specimen	Test Performed	Test Results
	1 meter (40 inch) puncture on bottom of box	• Witness mark in the bottom of the box. • No additional damage apparent.
	Post-Drop Inspection	• Padlocks operational after test. • Deformation of the steel box and wood packing occurred. • Source position measurement showed movement of 1/16 inch. • No significant change in radiation levels from the pre-test profile. • 1 meter dose rates remained within limit of 1 R/hr (See Appendix 2.12).
	Thermal Test (741 sn B199 in outer container without lid)	• The maximum radiation level at one meter was 2.5 mR/hr. No significant increase from pre-test profile. • 1 meter dose rates remained within limit of 1 R/hr (See Appendix 2.12).
TP72(E) (680-OP)	9 meter (30 foot) drop flat on lock assembly side of box	• Left padlock (nearest impact side) broken. Right lock intact. • Recessed area in box side deformed outward.
	1 meter (40 inch) puncture on unbroken lock	• Lid opened and projector came partially out of the box. • Top corner of the projector side plate near impact area was slightly bent.
	Post-Drop Inspection	• There was no damage to source containment which would allow dispersal of radioactive contents. • No source movement measured. • No significant change in radiation levels from the pre-test profile. • 1 meter dose rates remained within limit of 1 R/hr (See Appendix 2.12).
	Thermal Test	Not performed. Test unit performance bounded by thermal tests performed on TP72-S1(B) and TP72(D).
TP82(A) (741-OP)	9 meter (30 foot) drop on front vertical edge	• Broke both lock hasps but the 741 did not come out of the box
	1 meter (40 inch) puncture on 741 removed from box. Impact on top edge of side plate	• Top edge of the side plate sustained some additional deformation. • No damage was done to the shell.
	Post-Drop Inspection	• Other than the bent side plate, no damage to the projector was observed. • No significant change in radiation levels from the pre-test profile. • 1 meter dose rates remained within limit of 1 R/hr (See Appendix 2.12).

Specimen	Test Performed	Test Results
	Thermal Test	Not performed. Test unit performance bounded by thermal tests performed on TP72-S1(B) and TP72(D).
TP89(B) (680-OP)	9 meter (30 foot) drop on front vertical edge	• Lock hasp closest impact point broken. Other remained attached. • Box did not open. • Aluminum door almost off. Tear in side of box.
	1 meter (40 inch) puncture on box cover on latched side	• Cover and box dented. • Latch stayed secure.
	Post-Drop Inspection	• End of projector side plate bent slightly inward towards lock. Opposite side slightly bent from secondary impact. • No other damage.
	Thermal Test	Not performed. Test unit performance bounded by thermal tests performed on TP72-S1(B) and TP72(D).

Based on these results and assessments for the heavier 680-OP and the 741-OP transport package addressed in Test Plan Reports TP72, TP72-S1, TP82 and TP 89 (see Appendix 2.12), it is concluded that the Model 741-OP maintains structural integrity and shielding effectiveness during Hypothetical Accident Conditions and Normal Conditions of Transport.

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

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

2.9 Accident Conditions for Fissile Material Packages for Air Transport

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

2.10 Special Form

The Model 741-OP transport packages are designed for use with a special form source capsule Model 60011 attached to a flexible source wire assembly (Model A424-18). The source capsule is approved under U.S. Department of Transportation special form certification USA/0377/S-96. A copy of the current USDOT certificate, including the current approved capsule drawing, is included in Section 2.12.9. Details of encapsulation as well as chemical and physical form of the radioactive material will comply with specifications approved under U.S. Department of Transportation special form certifications.

Details of the Model A424-18 source wire assembly can be found under USA SS&D registration MA-1059-S-105-S and CNSC device registrations R-061-2054-3-2016 or R-061-2098-3-2016.

2.11 Fuel Rods

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

2.12 Appendices

2.12.1 Test Plan 72 dated December 1998
2.12.2 Test Plan 72-S1 dated December 1998
2.12.3 Test Plan 72 Report dated 8 January 1999 (minus Appendices A, B and D)
2.12.4 Test Plan 72-S2 dated January 1999
2.12.5 Test Plan 72-S2 Report dated 15 February 1999 (minus Appendices A and C)
2.12.6 Test Plan 89 Report dated September 1999 (minus Appendices B, C-2 and D-2)
2.12.7 Test Plan 82 Report dated February 1999 (minus Appendices A, B, C and E)
2.12.8 Test Plan 82 dated December 1998
2.12.9 USDOT Special Form Certificate USA/0377/S-96 Rev 7

2.12.1 Test Plan 72 dated December 1998.

2.12.2 Test Plan 72-S1 dated December 1998.

2.12.3 Test Plan 72 Report dated 8 January 1999 (minus Appendices A, B and D).

2.12.4 Test Plan 72-S2 dated January 1999.

2.12.5 Test Plan 72-S2 Report dated 15 February 1999 (minus Appendices A and C).

2.12.6 Test Plan 89 Report dated September 1999 (minus Appendices B, C-2 and D-2).

2.12.7 Test Plan 82 Report dated February 1999 (minus Appendices A, B, C and E).

2.12.8 Test Plan 82 dated December 1998.

2.12.9 USDOT Special Form Certificate USA/0377/S-96 Rev 7

Section 3 - THERMAL EVALUATION

3.1 Description of Thermal Design

The Model 741-OP Transport Packages are a completely passive thermal device having no mechanical cooling system or relief valves. All cooling of the transport package is through free convection and radiation. The maximum heat source is 1.22 TBq (33 Ci) of ^{60}Cobalt. The corresponding decay heat generation rate is approximately 0.55 Watts (See Section 2.6.1, "Heat").

3.1.1 Design Features

The Model 741-OP package is described in Section 1. Features uniquely relevant to thermal performance are detailed below.

3.1.1.1 Wood and Foam Container Inserts

During a fire test, the foam and wood will tend to char and eventually ignite. If the outer container is present during the fire test, these materials will initially serve to slow the heat transfer to the inner 741 projector.

3.1.1.2 Thin Walled Steel Container

The thin walls of the outer container exhibits almost no thermal gradient. During a fire test, the entire steel structure will very quickly be at uniform temperature, eliminating stresses induced by thermal differentials within the material. Further, the container will move and flex easily, thus relieving any thermal expansion stress without rupture.

3.1.1.3 741 Projector

The 741 projector is a fully enclosed welded/bolted steel structure. This structure prevents oxidation by severely limiting oxygen from getting to the depleted uranium shield.

3.1.2 Decay Heat of Contents

From Table 2.6.A, a maximum of 0.55 Watts of decay energy is available to be absorbed by the package.

3.1.3 Summary Tables of Temperatures

Table 3.1.A: Summary Table of Temperatures

Surface Temperature Condition	Model 741	Model 741-OP Package	Comments
Insolation (38°C in full sun)	71°C (160°F)	71°C (160°F)	Section 3.4.1.1
Decay Heating (38°C in shade)	39.9°C (103.7°F)	39.9°C (103.7°F)	Section 3.4.1.2
Fire Test During	1,005°C (1,841°F)	1,022°C (1,872°F)	See Test Plan Report TP72-S2 (Appendix 2.12) Results based on 680-OP Testing.
Post-Fire (Maximum Temperature)	1,005°C (1,841°F)	979°C (1,794°F)	Maximum did not exceed temperatures seen immediately before removal from oven. Results based on 680-OP Testing.

3.1.4 Summary Tables of Maximum Pressures

All package components are vented to atmosphere. As such, no pressure will build up in the units under either Normal or Hypothetical Accident conditions. Normal operating conditions will generate negligible pressure differential within the package. The package has the ability to withstand elevated atmospheric pressure because all components except the special form source are open to the atmosphere.

Any pressure generated within the special form source is significantly below that which would be generated during the Hypothetical Accident Conditions thermal test, which is shown in Section 2.7.4.3 to result in no loss of structural integrity or containment

Table 3.1.B: Summary Table of Maximum Pressures

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

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

Table 3.2.A 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 3.2.A: Thermal Properties of Principal Transport Package Materials

Material	Density (lb/in^3)	Melting/Combustion Temperature	Thermal Expansion	Source
Depleted Uranium (U-0.75 Ti)	0.68	1,133°C (2,071°F)	8µin/in°F	Reference #2, p. 20-35
Copper	0.32	1,083°C (1,981°F)	16.5µin/in°F	Reference #1, p. 6-7 and 6-11
Lead (99%)	0.41	327°C (621°F)	16µin/in°F	Reference #2, p.1-46
Low Carbon Steel (nominal)	0.28	1,510°C (2,750°F)	7µin/in°F	Reference #1, p.6-11
Titanium Tube, Ti-3Ai-2.5V	0.16	1,704°C (3,100°F)	5µin/in°F	Reference #4
Stainless Steel-Type 304	0.29	1,427°C (2,600°F)	9.9µin/in°F	Reference #1, p. 6-11
Polyurethane Foam	20 lb/ft^3 8 lb/ft^3	Unknown	120µin/in°F	Reference #1, p. 6-199
Wood (12% moisture)	25 lb/ft^3	399°C (≈750°F)	31µin/in°F	Reference #3, p.260-262

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. Howard E. Boyer and Timothy L. Gall, Editors, *Metals Handbook.* Metals Park, Ohio: American Society for Metals 1985.

3. Lawrence H. Van Vlack, *Materials for Engineering: Concepts and Applicants*. Boston: Addison-Wesley Publishing Company, 1992.

4. Compact Disc: *Material Spec,* Volume 1.1 San Rafael, California: Autodesk Data Publishing, 1985.

3.2.2 Component Specifications

All components are specified and described on the 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 the Test Plans contained in Section 2.12.

3.3.2 Evaluation by Test

Evaluations by direct testing are documented in the Test Plans contained in Section 2.12 or are described in the section they apply to in this Safety Analysis Report.

3.4 Thermal Evaluation Under Normal Conditions of Transport

3.4.1 Heat and Cold

3.4.1.1 Insolation and Decay Heat

This analysis determines the maximum surface temperature produced by solar heating of the Model 741-OP transport package loaded at maximum activity in accordance with 10 CFR 71.71(c)(1) and IAEA TS-R-1. This will be compared to the Normal Transport test conditions temperature range to determine which is the most onerous for thermal stress considerations.

The model consists of taking a steady state heat balance over the surface of the package. In order to assure conservatism, the following assumptions are made:

- The package is assumed to undergo free convective heat transfer and radiative heat transfer from the top and four sides.
- The inside package faces are considered perfectly insulated so there is no conduction into the package. The faces are considered to be sufficiently thin so that no temperature gradients exist in the faces.
- The package is approximated as a rectangular solid, 32" (813mm) long, 19" (483mm) wide and 15 1/2" (394mm) high. (The package height does not include the contribution made by the bottom feet).
- The decay heat load (0.55 Watts) is added to the solar heat input load.
- The steel surface of the package is painted semigloss black and therefore the emissivity coefficient is taken to be 0.9.

Reference: Thermal Analysis using Fundamentals of Heat and Mass Transfer, F.P. Incropera, 4th Edition, 1996.

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 total heat input is the sum of the solar heat input and decay heat.

Where ,

Solar heat input:

The solar heat input is the combined solar heating of the top horizontal surface and four vertical side surfaces multiplied by the absorptive constant (∀) for the material. The insolation data, provided in 10 CFR 71.71(c)(1), is found in Table 3.4.A.

Table 3.4.A: Insolation Data

Surface	Insolation for a 12 hour period ($g\text{-}cal/cm^2$ or W/m^2)
Horizontal base	None
Other horizontal flat surfaces	800
Non-horizontal flat surfaces	200
Curved surfaces	400

Top surface heat input: $Q_{IT} = 800\ W/m^2 \times 0.393 = 314\ W$

Side surface heat input: $Q_{IS} = 200\ W/m^2 \times 1.02 = 204\ W$

Decay heat input: $Q_{DT} = 0.55\ W$

Absorptive constant $\forall = 1.0$ (most conservative)

Total heat input: $Q_{IN} = \forall\ (Q_{IT} + Q_{IS}) + Q_{DT} = 519\ W$

Heat Output:

The total heat output is the sum of the radiation and convection heat transfer (Reference: Heat Transfer, J.P. Holman, 4th Edition, 1976, p.253).

Radiation heat transfer (Q_R):

$$Q_R = B \times E \times A_{TS} \times \{(T_W + 273)^4 - (T_A + 273)^4\}$$

Where: Stefan Boltzmann Constant, $B = 5.669 \times 10^{-8}\ W/m^2\ °K^4$
Emissivity, $E = 0.9$
The top & side surface area of the package, $A_{TS} = 1.41\ m^2$
The maximum surface temperature of the package, T_W °C

The ambient temperature, $T_A = 38°C$

$$Q_R = 7.21 \times 10^{-8} \times \{(T_W + 273)^4 - (T_A + 273)^4\}$$

<u>Top surface convection (Q_T):</u>

$$Q_T = H_T \times A_T \times (T_W - T_A)$$

Where: The top surface area, $A_T = 0.39\ m^2$
The free convection coefficient for a flat horizontal surface is H_T

From ; Engineering Thermodynamics, Work and Heat Transfer. 4th Edition, Rogers and Mayhew, page 585.

For a heated plate facing up,

$$H_T = 1.32\{(\theta/l)/[K/m]\}^{1/4}$$

Where: $\theta = T_W - T_A$
and $l = L_T$
L_T is the average length of the top surface $= (L + W)/2 = 0.65$ m

Therefore:

$$H_T = 1.32 \times \{(1/L_T)^{0.25} \times [(T_W - T_A)^{0.25}]\}$$
$$H_T = 1.32 \times \{(1/0.65)^{0.25} \times [(T_W - T_A)^{0.25}]\}$$
$$H_T = 1.47 \times [(T_W - T_A)^{0.25}]$$

Substituting gives:

$$Q_T = 0.577\ (T_W - T_A)^{1.25}$$

<u>Side surface convection (Q_S):</u>

$$Q_S = H_S \times A_S \times (T_S - T_A)$$

Where: A_S is the total side surface area , ($1.02\ m^2$)
H_S is the free convection coefficient for flat vertical surface

From; Engineering Thermodynamics, Work and Heat Transfer. 4th Edition, Rogers and Mayhew, page 585.

For a vertical plate,

$$H_S = 1.42\{(\theta/l)/[K/m]\}^{1/4}$$

Where: $\theta = T_W - T_A$
and $l = L_S$
L_S is the average side surface length = $(L_T + H)/2 = 0.52$ m

Therefore:

$$H_S = 1.42 \text{ x } \{(1/L_S)^{0.25} \text{ x } [(T_W - T_A)^{0.25}]\}$$

$$H_S = 1.67 \ (T_W - T_A)^{0.25}$$

Substituting gives:

$$Q_S = 1.7 \ (T_W - T_A)^{1.25}$$

Total heat output:

$$Q_{OUT} = Q_R + Q_T + Q_S$$

and

$$Q_{IN} = Q_R + Q_T + Q_S = 519 \text{ W}$$

Substituting for Q_R, Q_T and Q_S results in:

$$519 = 7.21 \text{ x } 10^{-8} \{(T_W + 273)^4 - (T_A + 273)^4\} + 0.577 \ (T_W - T_A)^{1.25} + 1.7 \ (T_W - T_A)^{1.25}$$

Iteration of this relationship yields a maximum wall temperature (T_w) of 71°C (160°F).

This temperature would not adversely affect the package during normal transport since the melting temperatures of all safety critical components are well above this temperature. Additionally the wooden inserts have an exothermic reaction temperature of approximately 273°C (523°F) and charring of the polyurethane foam will not begin to occur at such low temperatures.

3.4.1.2 Still Air (shaded) Decay Heating

This analysis demonstrates that the maximum surface temperature of the Model 741-OP transport package will not exceed 50°C (122°F) with the package in the shade and an ambient temperature of 38°C (100°F).

To assure conservatism, the following assumptions are used:

- The entire decay heat (0.55 watts) is deposited in the exterior surfaces of the package.
- The interior of the package is perfectly insulated and heat transfer occurs only from the exterior surface to the environment.
- For conservatism, it is assumed that 100% of the total heat is deposited in the smallest face.
- The only heat transfer mechanism is free convection.
- The smallest face undergoes one-dimensional convective heat transfer.

Using these assumptions, the maximum wall temperature (T_W) is found from

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

where

q is the heat deposited per unit time on the face, 0.55 watts
h is the free convection heat transfer coefficient for air: 5 watts/m^2
A is the surface area of the smallest face, 0.184 m^2
T_A is the ambient air temperature, 38°C (311 k)

From this relationship, the maximum temperature of the surface is 38.6°C (101.5°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 steel components of the Model 741-OP 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. During the direct testing on the 741-OP (and as assessed based on testing of the similar 680-OP test specimens), the outer steel container absorbed the majority of the energy and the inner steel components of the 741/680 projectors were not damaged during testing.

All materials exhibit some contraction due to lower temperatures. However in this limited temperature range, the Model 741-OP was not adversely effected as all test specimens passed the more onerous Hypothetical Accidental Drop

3.4.2 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. It is therefore concluded that the Model 741-OP transport packages will maintain its structural integrity and shielding effectiveness under the normal transport thermal stress conditions.

3.4.3 Maximum Normal Operating Pressure

The Model 741-OP transport packages are vented to the atmosphere. As such, pressure will not build up in the package during Normal Transport conditions. These containers will exhibit a pressure differential of 0 psi as they are vented to the atmosphere with no means for creating a pressure differential. No other contributing gas sources are present.

3.5 Thermal Evaluation Under Hypothetical Accident Conditions

3.5.1 Initial Conditions

The thermal test, as described in 10CFR71.73(c)(4), was deemed necessary for the reasons given below. In determining the maximum possible damage to the projector as a result of the thermal test, it was decided to test the projector both in and out of the box.

After investigation into the high temperature characteristics of materials used in the projector, scoping assessments of the shield support system, and bearing tests on the pyrolized foam, it was concluded that it would be difficult to develop a purely analytic basis to calculate potential shield movement. In addition, due to the presence of combustible materials (wood and polyurethane foam) in the outer box, the possible additional thermal input the projector could sustain after the 30 minute oven test would be difficult to model conclusively.

As a result, it was decided that the most straight forward way to demonstrate compliance with the requirements of 10CFR71.73(c)(4) was to perform thermal tests on the package. In particular, it was decided that two test specimens should be subjected to thermal testing.

3.5.2 Fire Test Conditions

Thermal tests were performed on two units. The 680 projector s/n B198 outside of the overpack was tested in its worst case orientation. Additionally the 680 projector s/n B199 (test specimen TP72-S1(B)) was tested inside the overpack but with the cover removed.

The 680 and the 741 use basically the same overpack container and the 680 and 741 are of similar construction with the 680 being the larger (heavier) of the two devices. Damage sustained by the 680 and 680-OP packages is assumed to be a conservative estimate of the damage a 741 or 741-OP would sustain if thermal tested.

3.5.2.1 <u>680 Projector without Overpack Thermal Test</u>

The Model 680 Projector S/N B198 (with no overpack) was placed in the test oven in the worst case orientation. The intent of this test was to place a projector in the orientation which had the potential to result in the largest movement.

Based on a review of the projector design, it was determined that the worst case orientation is achieved by rotating the projector 60° up from horizontal (a figure showing this orientation is provided in Appendix B-2, TP72 Test Plan, Supplement 2). A projector in this orientation has the largest potential for shield motion relative to the source. In particular, this angle would allow the shield to slip out and away from the upper rods of the internal support jig. All of the shield weight would then be concentrated on the lower rods of the internal support jig and the source tube. In addition, any shield movement would tend to bend the source tube, limiting the contribution of any columnar rigidity that the tube might have. Further, this orientation would allow the shield to settle into the corner of the shell, as geometrically far away from the secured source as possible. All other projector orientations would result in less movement of the shield relative to the source. Contributing factors are:

- The source tube will "pivot" the shield as it descends and bends the tube. This will begin to force the lower ear of the shield toward the side plate. Once the ear contacts the plate, the shield will try to rotate, and the upper ear will become jammed on the leveling jig. Any increase in angle from horizontal will increase the columnar rigidity of the tube, thus increasing its contribution to shield support.

- The clearance between the top of the shield and the shell is very small. This, along with the hot top in intimate contact with the opposite side of the shell, will force the shield to move linearly through the projector and prevent any rotation that could cause further exposure of the source in the plane parallel to the side plates. Any contact with the shell would add their strength to shield position retention.

- The clearance between the ears and the side plates is also small. This prevents significant rotation through the axis perpendicular to the side plates. When rotation occurs, the ears jam against the side plates and prevent any additional rotation or translation of the shield. Positions toward horizontal would decrease the shield movement needed for the ears to contact the side plates.

- The leveling jig's strength at test temperatures will tend to partially support the lower portion of the shield. Additionally, as the shield ear slips out of the upper portion of the jig, it will force the shield toward the side frame. Increasing angles from horizontal would allow the upper jig rods to support more of the weight of the shield limiting the weight available to deform the lower rods.

The thermal test period of 30 minutes was conservatively not considered to start until the surface of the projector reached 800°C. In addition, air was conservatively allowed to flow into the furnace to support the combustion of the projector within the furnace. In particular, the door of the furnace was held open by 1" thick insulating strips placed on each side of the furnace door. This created a 1" wide by 36" long opening at the top and bottom of the oven door (total 72 square inches). This opening created a "chimney effect" within the oven, drawing air in through the bottom and exhausting it out the top, as was evidenced by the flames emanating from the oven throughout the tests. This natural convection of air into the furnace was sufficient to combust the pyrolization gases from the projector.

The shield moved as predicted within the projector. As described above, any change in orientation would present a less severe test condition. As such, the shield could not have been displaced more than as tested. Additionally, the thermal input to the projector alone far exceeded the test requirements as evidenced by the thermal data and physical condition of the projector itself.

The radiation levels only increased to 330 mR/hr at one meter. This was found only in one small area, with most of the readings being below 20 mR/hr at one meter. The radiation level increase was maintained within regulatory requirements by a safety factor of 3. Therefore, the unit satisfies the thermal test requirements of 10CFR71.73 (c)(4).

3.5.2.2 680 Projector inside Overpack Thermal Test

Model 680 Projector S/N B199 was placed in overpack test specimen TP72-S1(B). The overpack cover was removed to allow for the ready combustion of the overpack wood and foam contents. The overpack was placed in the oven flat, with the bottom of the overpack down. The intent of this test was to verify that the combustion of the wood and foam in the overpack, after the package is removed from the oven, does not result in a more limiting accident scenario.

The thermal test period of 30 minutes was conservatively not considered to start until the surface of the package reached 800°C. In addition, air was conservatively allowed to flow into the furnace to support the combustion of the packages within the furnace. In particular, the door of the furnace was held open by 1" thick insulating strips placed on each side of the furnace door. This created a 1" wide by 36" long opening at the top and bottom of the oven door (total 72 square inches). This opening created a "chimney effect" within the oven, drawing air in through the bottom and exhausting it out the top, as was evidenced by the flames emanating from the oven throughout the tests. This natural convection of air into the furnace was sufficient to combust the pyrolization gases from the projector and the bracing materials of the overpack.

The temperatures on the bottom and front of the overpack took about 30 minutes to reach 800°C which signaled the start of the timed thermal exposure. Upon removal from the oven, the packing materials within the overpack continued to burn until it self-extinguished approximately 245 minutes later.

The maximum radiation level at one meter was 2.5 mR/hr. This is consistent with the pre-test profile readings and showed no significant increase due to the thermal test. Therefore, the unit satisfies the thermal test requirements of 10CFR71.73 (c)(4)

3.5.3 Maximum Temperatures and Pressure

See Sections 3.1.3 and 3.1.4.

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. This assumption was further supported by direct thermal testing of the package. It is therefore concluded that the Model 741-OP transport package will maintain its 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 primary containment system for the package is the welded radioactive source capsule. This source capsule shall be qualified as Special Form radioactive material under 49 CFR 173 and IAEA TS-R-1. The special form source capsule is attached to flexible handling wires and maintained within the shielded configuration of the package by means of lock mechanisms after the source wire assemblies are inserted into the shield tube(s).

For all Model 741 Projectors the source assembly is secured in position inside the source tube within the shield by the locking assembly. The source connector is designed so that the source cannot be exposed unless the source assembly is properly coupled to a drive control assembly. The lock assembly prevents unauthorized access to the coupling. The shipping plug and S-shaped source tube minimize radiation from the exit port when the source is properly stored.

The 741 device is secured inside the 741-OP transport package by the transport container lid which has two padlock latches.

4.1.1 Special Requirements for Damaged Spent Nuclear Fuel

Not applicable. This package is not used for the transport of spent nuclear fuel.

4.2 Containment Under Normal Conditions of Transport

As demonstrated in the Test Plan Reports contained in Section 2.12, after performance of the normal and hypothetical accident condition transport testing there was 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 741-OP transport packages meet the requirements of this section.

4.3 Containment Under Hypothetical Accident Conditions

As demonstrated in the Test Plan Reports contained in Section 2.12, after performance of the hypothetical accident conditions of transport testing radiation level at one meter from the surface of the package did not exceed 1 R/hr. The Model 741-OP transport packages 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 741-OP Transport Packages are the radioactive source capsule. All source capsules authorized for Type B transport in the Model 741-OP are certified as special form radioactive material under 10 CFR Part 71, 49 CFR Part 173 and IAEA TS-R-1. After manufacture and again once every six months thereafter prior to transport, the source capsule is leak tested in accordance with ISO9978:1992(E) (or more recent editions) to ensure that containment of the source does not allow release of more than 0.005 μCi of radioactive material. These fabrication and periodic tests ensure that contamination release from the package does not exceed the regulatory limits.

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

4.5 Appendix

Not Applicable.

Section 5 - SHIELDING EVALUATION

5.1 Description of Shielding Design

5.1.1 Design Features

The principal shielding in the Model 741-OP transport packages is depleted uranium augmented in some cases by lead. Dimensional information for the shield is contained in the drawings included in Section 1.3. Table 3.2.A lists the material densities of the packaging.

5.1.2 Summary Table of Maximum Radiation Levels

Tables 5.1.A and 5.1.B include radiation profile data obtained from the 741 projector that was used in testing under Test Plan 82 (see Appendix 2.12). The results of the 741-OP Hypothetical Accident Condition testing were used to demonstrate compliance for the 741-OP under Normal Conditions of Transport as this is less severe.

Dose rates in Table 5.1.A are from the 741 projector outside of the overpack. The actual dose rates from a Model 741-OP package will be less than the values measured from the inner 741 projector device and the 741-OP will therefore comply with the regulatory requirements

Table 5.1.A: Model 741-OP Summary Table of External Radiation Levels Extrapolated to Capacity of 1.22 TBq (33 Ci) Co-60 (Non-Exclusive Use)

	Package Surface mSv/h (mrem/h)			1 Meter from Package Surface mSv/h (mrem/h)		
Normal Conditions of Transport[2]	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.87 (87)	1.45 (145)	0.44 (44)	0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.87 (87)	1.45 (145)	0.44 (44)	0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
10 CFR 71.47(a) or Paragraphs 530 and 531 of TS-R-1 Limit	2 (200)	2 (200)	2 (200)	0.1 (10)[1]	0.1 (10)[1]	0.1 (10)[1]
Hypothetical Accident Conditions[3]						
Gamma				0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
Neutron				NA	NA	NA
Total				0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
10 CFR 71.51(a)(2) or Paragraph 656(b)(ii)(I) of TS-R-1 Limit				10 (1000)	10 (1000)	10 (1000)

[1] Transport Index may not exceed 10.

[2] The Profile Source for these survey results was a Model A424-18, sn 2697. The source measured 31.3 Ci on 10 Dec 1998 (date of profile survey). Table results are extrapolated to the device capacity and incorporate surface correction factors.

[3] The Profile Source for these survey results was a Model A424-18, sn 2697. The source measured 30.9 Ci on 11 Jan 1999 (date of profile survey). Table results are extrapolated to the device capacity and incorporate surface correction factors.

Table 5.1.B: Model 741-OP Summary Table of External Radiation Levels Extrapolated to Capacity of 1.22 TBq (33 Ci) Co-60 (Exclusive Use)[1]

	Package (or Freight Container) Surface mSv/h (mrem/h)			2 Meters from Outer Vehicle Surface mSv/h (mrem/h)		
Normal Conditions of Transport[4]	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.87 (87)	1.45 (145)	0.44 (44)	0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
Neutron	NA	NA	NA	NA	NA	NA
Total	0.87 (87)	1.45 (145)	0.44 (44)	0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
10 CFR 71.47(b) or Paragraph 572 of TS-R-1 Limit	10 (1000)[2]	10 (1000)[2]	10 (1000)[2]	0.1 (10)	0.1 (10)	0.1 (10)
	Vehicle Surface mSv/h (mrem/h)			**Occupied Position mSv/h (mrem/hr)**		
Gamma	< 0.71 (71)	< 1.44 (144)	< 0.35 (35)	≤ 0.02 (2)[3]		
Neutron	NA	NA	NA	NA		
Total	< 0.71 (71)	< 1.44 (144)	< 0.35 (35)	≤ 0.02 (2)[3]		
10 CFR 71.47(b) or Paragraph 572 of TS-R-1 Limit	2 (200)	2 (200)	2 (200)	0.02 (2)		
Hypothetical Accident Conditions[5]				**1 Meter from Package Surface mSv/h (mrem/hr)**		
Gamma				0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
Neutron				NA	NA	NA
Total				0.010 (1.0)	0.021 (2.1)	0.007 (0.7)
10 CFR 71.51(a)(2) or Paragraph 656(b)(ii)(I) of TS-R-1 Limit				10 (1000)	10 (1000)	10 (1000)

[1]For packages transported by roadway, railway and sea.
[2]For packages in closed vehicles, otherwise, 2 (200).
[3]Confirmed at time of vehicle loading prior to shipment.
[4] The Profile Source for these survey results was a Model A424-18, sn 2697. The source measured 31.3 Ci on 10 Dec 1998 (date of profile survey). Table results are extrapolated to the device capacity and incorporate surface correction factors.
[5]The Profile Source for these survey results was a Model A424-18, sn 2697. The source measured 30.9 Ci on 11 Jan 1999 (date of profile survey). Table results are extrapolated to the device capacity and incorporate surface correction factors.

5.2 Source Specification

5.2.1 Gamma Source

The gamma sources allowed for transport in the Model 741-OP are described in Sections 1.2.2 and 2.10.

5.2.2 Neutron Source

Not Applicable. The Model 741-OP transport packages are not used for the transportation of neutron emitting sources.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

Not Applicable. A shielding model was not used in the justification for these packages. Shielding justification was based on direct measurement.

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 Reports (see Section 2.12) for results of radiation surveys of the 741-OP test specimens.

Since only one 741-OP was used for all testing, radiation profiles were only taken on the TP82(A) specimen. The test specimen was profiled before testing, and after the hypothetical accident testing. In Test Plan Report 82, the Co-60 data was extrapolated to 33 Curies for comparison of relative dose rate changes before and after testing when profiles were performed using sources with less activity. These results are shown in Tables 5.1.A and 5.1.B. All radiation profile data are within regulatory acceptance limits.

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:

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

$$For\,Example,\ if\ A_P = 27\,Ci\ and\ A_C = 33Ci,\ then$$

$$CF_A = \frac{33Ci}{27Ci} = 1.2$$

Therefore all original surface and 1 meter profile measurements would be multiplied by a factor of 1.2 for a package profiled using 27 Ci and a package capacity of 33 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.

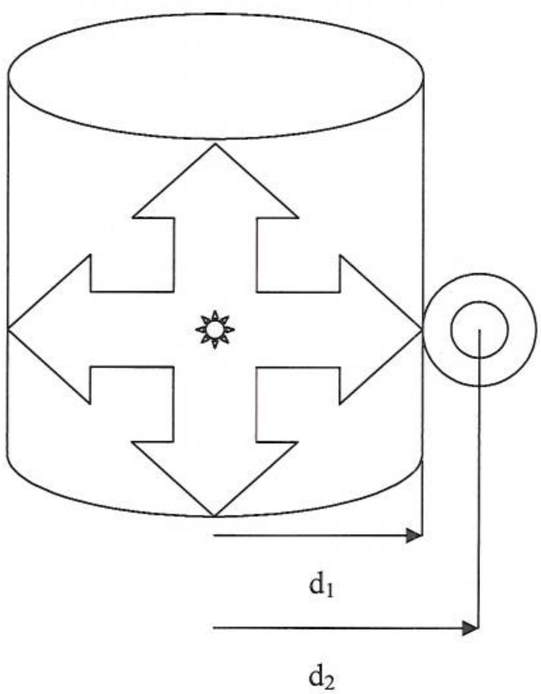
Surface correction factors (SCF) were obtained by using the following relationship:

$$SCF = \frac{d_2}{d_1} \text{ where } d_1 \text{ and } d_2 \text{ are determined as shown in Figure 5.1a.}$$

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

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

Therefore in the example shown, all original surface profile measurements located along the side of the package shown in Figure 5.4.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 5.4.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 741 showed maximum surface and 1 meter radiation levels from the transport packages within regulatory limits. Radiation surveys of 741 and 680 projectors (See Test Plan Reports in Section 2.12) after undergoing normal and accident condition transport testing were also well within the regulatory limits. By inference, dose rates of the 741 projectors inside the 741-OP outer steel container assemblies will also be within the applicable regulatory limits.

5.5 Appendix

Not Applicable.

Section 6 - CRITICALITY EVALUATION

All parts of this section are not applicable. The Model 741-OP Transport Packages are not used for shipment of Type B quantities of fissile material.

Section 7 – Package Operations

Operation of the Model 741-OP Transport Packages must be in accordance with the operating instructions supplied with the transport package, per 10 CFR 71.87 and 71.89. Operation of the 741 style inner device must be in accordance with the operation manual supplied with the package per 10 CFR 71.89. All subsequent paragraph references to IAEA TS-R-1 apply to IAEA Regulations for the Safe Transport of Radioactive Material No. TS-R-1 (ST-1, Revised) 1996 Edition (Revised).

7.1 Package Loading

7.1.1 Preparation for Loading

The Model 741-OP transport packages must be loaded and closed in accordance with procedures that, at a minimum, include the requirements specified in this section. Shipment of Type B quantities of radioactive material are authorized for sources specified in Section 7.1.1.1. Maintenance and inspection of these packages is in accordance with the requirements specified in Section 7.1.1.2.

7.1.1.1 Authorized Package Contents

The Model 741-OP transport packages are designed to transport 1.22 TBq (33 Ci) of Co-60 as special form capsules attached to a source wire assembly.

The Model 741-OP transport packages are designed for use with a special form source capsules as approved under a U.S. Department of Transportation special form certification. Details of encapsulation as well as chemical and physical form of the radioactive material will comply with specifications approved under U.S. Department of Transportation special form certifications.

7.1.1.2 Packaging Maintenance and Inspection Prior to Loading

7.1.1.2.a Instructions for the 741 Projector

1. Inspect the labels for legibility and that they are securely fastened to the projector housing.

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. Assure all bolts and fasteners (hardware) required for assembly of the package and as specified on the drawings referenced on the Type B transport certificate are fit for use. Without removing the hardware by disassembly from the device, examine the visible external surfaces of the bolts/fasteners for any signs of fatigue cracking.

   Note: A visual examination of the bolt/fastener thread condition is performed after removal from the exposure device as part of the Quarterly and Annual Maintenance inspections required for radiography devices under 10 CFR 34.31 or equivalent Agreement State regulations.

   The bolts/fasteners must be replaced if they are no longer fit for use (e.g., threads stripped, unable to fully thread, signs of cracking, etc). Assure the front port is properly secured. Ensure a seal wire is properly installed. Ensure any replacement hardware meets all applicable specifications listed on the drawings referenced on the Type B transport certificate.

4. Check the shipping plug and assure that it threads fully and securely into the shipping plug plate assembly.

5. Ensure the dust cover installs and secures over the lock assembly. Ensure the lock plunger operates from the lock to the open positions using the lock plunger key. Ensure that the cover plate can be secured over the lock assembly using the hardware specified on the Type B transport certificate.

6. If the container fails any of the inspections in steps 7.1.1.2.a.1-5, 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 Overpack and Overpack Inserts

1. Visually inspect the outer container to verify the following:

   a) The inserts are properly installed and secured within the container.

   b) The sides, top and bottom of the foam and wood inserts have no significant damage, and there are no missing pieces.

   c) Replace any missing or significantly damaged pieces.

d) The outer container and lid are in good physical condition with no excessive rust, cracked welds, major dents or holes. DO NOT use the container if it is not in good condition.

e) The latches, including the sliding doors, are not broken and can be properly installed and secured.

f) The two padlocks are in good working order and that the keys fit and work in the locks.

g) The container feet are in good condition

2. Inspect the labels for legibility and that they are securely fastened to the outer container.

If the outer container fails any of the inspections in steps 7.1.1.2.b.1-2, remove the container from use until it can be brought into compliance with the Type B certificate.

7.1.2 Loading of Contents

NOTE: ***These loading operations apply to "dry" loading only. The Model 741-OP packages are NOT approved for wet loading.***

7.1.2.1 **Ensure the contents are authorized for use in the package.**

7.1.2.2 Ensure the package condition has been inspected in accordance with Section 7.1.1.2.

7.1.2.3 Ensure that the sources is 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.

7.1.2.3.a 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.

7.1.2.3.b Model 741 Projector and Overpack

1. Using remote handling techniques, load the source assembly so that it is fully retracted into the device shield and secured by the lock assembly. Once the source is loaded, install the lock cover, ensure the plunger lock is depressed and the key removed.

2. Fully thread the shipping plug into the nut on the shipping plug plate assembly.

3. Secure the shipping plate to the container using the hardware specified on the descriptive assembly drawing (see the drawings referenced on the Type B transport certificate). Tighten the screws so that no gap exists between the screw heads, lid or container.

4. Using mechanical lifting aids, place the projector into the container, re-insert all removable wood inserts and close the lid.

5. Secure the latches of the lid by engaging the padlocks.

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.a Remove the 741 projector from the outer overpack using mechanical lifting aids.

7.2.2.2.b Transfer the 741 to a remote handling cell, or prepare the 741 projector for source transfer/exposure in accordance with the applicable licensing provisions for the user's facility related to radioactive material handling.

7.3 Preparation of Empty Package for Transport

In the following instructions, an *empty* transport package refers to a Model 741-OP transport package without an active source contained within the inner device (e.g., 741 style device). To ship an empty transport package:

7.3.1. Unload the container in accordance with Section 7.2.2.

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 741-OP Transport Packages are empty, prepare the transport package for shipment and survey to determine ensure the external surface radiation level does not exceed 5 μSv/h (0.5 mR/hr).

7.3.5 Ship the container according to the procedure for transporting radioactive material as established in 10 CFR 71.5.

7.4 Other Operations

7.4.1 Package Transportation By Consignor

Persons transporting the Model 741-OP 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 (0.005 μCi).

7.4.1.2 If contamination above 4 Bq/cm^2 (0.0001 μCi/cm^2) based on wiping an area of 300 cm^2 is detected on any part of a conveyance or equipment used regularly for radioactive material transport, or if a radiation level exceeding 5 μSv/h (0.5 mR/hr) is detected on any conveyance or equipment surface, then remove the affected item from use until decontaminated or decayed to meets these limits.

7.4.1.3 Ensure the package is properly blocked and braced prior to transport to prevent movement within the conveyance during transport.

7.4.2 Emergency Response

In the event of a transport emergency or accident involving this package, follow the guidance contained in "2008 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident", or equivalent guidance documentation.

7.5 Appendix

7.5.1 Reference: "2008 Emergency Response Guidebook: A Guidebook for First Responders During the Initial Phase of a Dangerous Goods/Hazardous Materials Incident"

Section 8 - ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Test

8.1.1 Visual Inspections and Measurements

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

8.1.1.1 The transport package was assembled properly to the applicable drawings referenced on the Type B transport certificate.

8.1.1.2 Evaluate the 741 shield container for shielding integrity to ensure the transport dose rate requirements are met when the container is loaded to capacity.

8.1.1.3 All fasteners as required by the applicable drawings referenced on the Type B transport certificate are properly installed and secured.

8.1.1.4 The relevant labels are attached, contain the required information, and are marked in accordance with 10 CFR 20.1904, 10 CFR 40.13(c)(6)(i), 10 CFR 34, and 10 CFR 71 or equivalent Agreement State regulations.

8.1.1.5 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 Model 741-OP Transport Package, container structural conformance will be evaluated in accordance with the applicable drawings requirements and in accordance with QSA Global, Inc.'s USNRC approved Quality Assurance Program No. 0040. The containment system is not designed to require increased or decreased operating pressures to maintain containment during transport, therefore pressure tests of package components prior to first use are 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 185 Bq (0.005 μCi). 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.

The lock assembly of the device is tested to assure that the security of the radioactive source will be maintained. Failure of this test prevents use of the device until the lock assembly is corrected and re-tested.

8.1.6 Shielding Tests

The radiation levels at the surface of the Model 741 inner device and at 40 inches (1 m) from the surface were measured prior to first transport at the time of manufacture (Note: The Model 741 inner devices are no longer manufactured. Only the overpack box assembly and other inserts continues to be manufactured at this time). This survey, was 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 device. This survey was used to identify any significant void volumes or shield porosity which could prevent the finished device from complying with the dose limits in 10 CFR 71.47.

The radiation profile survey was made with the radiation detector housing in contact with the surface of the container and then also at one meter from the surface of the container. These radiation levels, when extrapolated to the rated capacity of the transport package, could not exceed 200 mR/hr at the surface, nor 10 mR/hr at 1 meter from the surface of the 741 device. Failure of this test prevented use of the device. As the use of the overpack will further reduce the measured radiation levels, a separate radiation profile is not taken of the package upon initial manufacture, it is measured prior to every shipment. If the reading exceeds 200 mR/hr at the surface or 10 mR/hr at one meter, the package is not shipped

Failure of the radiation profile tests for any Model 741 inner container indicated the potential of significant shielding porosity and caused the rejection of the affected Model 741 device. Rejected packages which do not comply with the construction requirements on the applicable drawings referenced on the Type B certificate, or that do not comply with the radiation profile requirements will not be distributed as approved Type B(U) packages.

8.1.7 Thermal Tests

Not applicable. The source content of the Model 741-OP 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

Upon initial manufacture of the source assembly and prior to first shipment of the source assembly, subject the swage coupling between the source capsule and cable to a static tensile test with a load of 100 lbs (445 N). Failure of this test will prevent use of the source in the Type B(U) transport package.

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 Model 741-OP packaging system is not designed to require increased or decreased operating pressures to maintain containment during transport, therefore pressure tests of package components prior to individual shipment is not required.

8.2.2 Leakage Tests

As described in Section 8.1.4, "Leakage Tests," the radioactive source assembly is leak-tested at manufacture. In addition, the sources are leak tested in accordance with that Section at least once every six months thereafter if being transported to ensure that removable contamination is less than 185 Bq (0.005 μCi).

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. Further the lock assembly of the device is tested to assure that the security of the radioactive source will be maintained. Failure of this test prevents use of the device until the lock assembly is corrected and re-tested.

8.2.4 Thermal Tests

Not applicable. The source content of the Model 741-OP 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.