71-9148

QSA GLOBAL

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

14 March 2007

Ms. Jessica Glenny, Project Engineer
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.: 71-9148 & TAC No. L24020

Subject: Additional Supportive Information for the Model 770 Type B Container

Dear Ms. Glenny:

The following is provided in response to your request for additional information. After review of this information if any of these issues remain unclear or you feel additional discussion is advisable to resolve these open issues please contact me and we will arrange to discuss this submission with your staff at your Headquarter offices:

1-1 The supplemental lead shielding is initially attached to the exterior of the depleted uranium shield by use of adhesive tape (e.g., filament tape, glass tape, duct tape, etc.). (See the pictures 1 and 2 below which show typical lead attachment method for this shield style.) The tape is used for initial positioning only, as the lead is permanently secured in place against the shield by the 65 lbs/ft^3 rigid polyurethane (RP) potting material which fills the void space outside the shield and inside the inner container weldment. Confirmation of proper lead placement against the shield is obtained by the radiation profile of the package after the RP is installed and hardened.

Picture 1 – 770 Style Shield in Process Showing Lead Attachment using Duct Tape (View 1)

Picture 2 – 770 Style Shield in Process Showing Lead Attachment using Duct Tape (View 2)

NMSS01

Once the RP has cured, movement of the lead cannot occur without destruction or intentional removal of the RP from the shield. This would require a breach of the inner containment weldment to allow access for removal of the RP. (This has been demonstrated during disassembly of one of the test units from Test Plan 114 related to the extraction of that test units shield. During the disassembly process, the potting material had to be chipped away from the shield surface and surrounding steel structure in order to reach the inner shield for extraction.)

As further demonstrated under Test Plan 114, after hypothetical accident testing of the unit, the RP in the inner weldment remained fully intact without experiencing any degradation in its integrity. The RP and surrounding steel structure of the inner weldment prevented movement of the lead attached to the shield. As demonstrated by the test units under Test Plan 114 and as seen by other Type B packages which incorporate the use of supplemental lead attachment to the shield (e.g., 741-OP – USA/9027/B(U); 680-OP – USA/9035/B(U); 660-OP - USA/9283/B(U)-96, etc.) after fabrication, movement of the lead relative to its original placement against the depleted uranium shield surface will not occur.

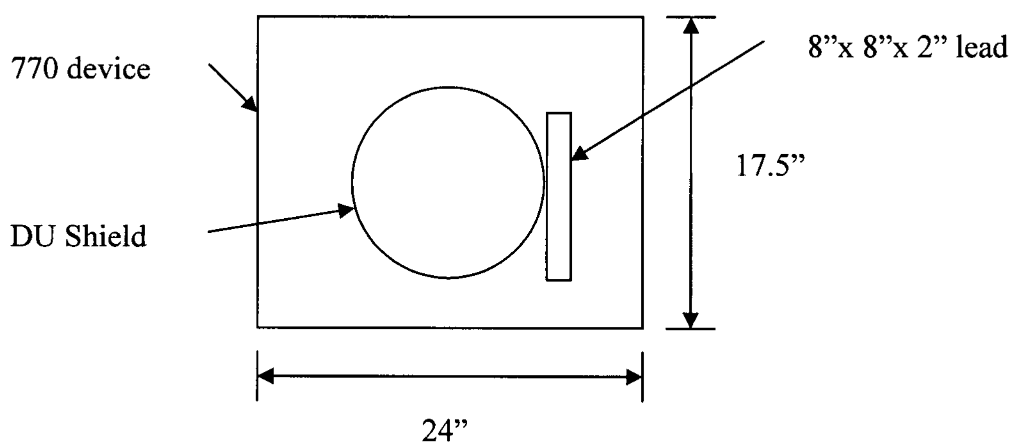
The addition of supplemental lead for the Model 770 and 770B under drawing R77090 Rev F is specified in the same manner as currently appears for the Models 660, 741 and 680 referenced above (e.g., maximum lead thickness at any single location and maximum total quantity of lead allowed for addition to a single package). As this method of description has been acceptable to your office in the recent past, we trust the current format of description on the drawing along with this discussion of the lead attachment meets your requirements for compliance to 10 CFR 71.33, 7.147 and 71.51.

1-2 The method of the lead attachment to the shield is described in response to item 1-1 of this letter. As noted, the lead becomes permanently attached to the shield surface by the RP. Due to the construction of the inner steel assembly and RP, the lead will be unable to move from its original placement during the normal and hypothetical accident test conditions of 10 CFR 71.

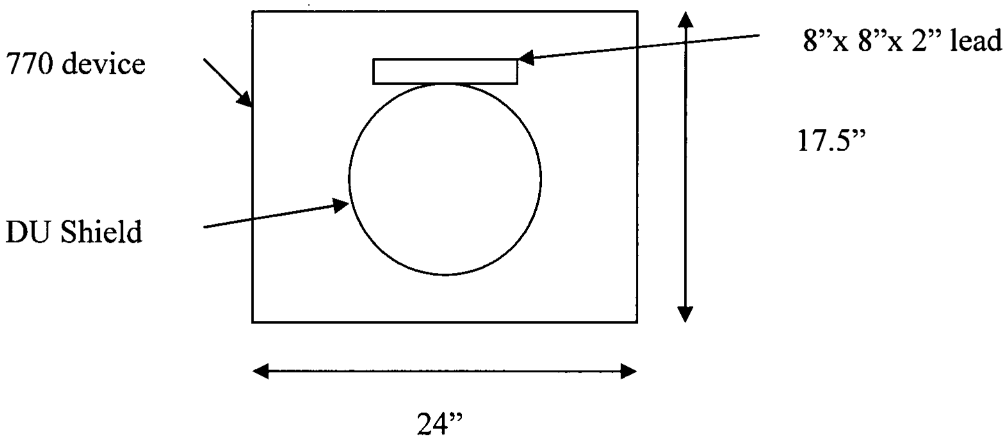
The lead distribution on the shield surface, when necessary, would be based on preliminary radiation shielding evaluations performed on the shield prior to full assembly within the inner container steel weldment. As exact locations requiring additional lead may vary from shield to shield, no one location is specified on the drawings. The lead addition is controlled by limiting the maximum thickness of lead which can be used at any one point on the shield and to also limiting the maximum total mass of lead that can be applied to any one shield.

The method for documenting the addition of supplemental lead shielding for the Model 770 and 770B packages is addressed in the same manner on the drawing R77090 Rev F as has previously been submitted and accepted by the USNRC for the Models 680, 741 and 660 devices which are parts of Type B package approvals USA/9035/B(U)-96, USA/9027/B(U)-96 and USA/9283/B(U)-96 respectively. The exact location of shield variability which may occur during the depleted uranium pouring operations can vary due to a number of factors. In order to assure the container will comply with the normal and hypothetical accident transport conditions, the maximum thickness of lead at any one point surrounding the depleted uranium shield as well as the cumulative mass of lead adhered to the surface of the shield is limited by maximum values which are factored into the assessments performed in Technical Report 92.

The worst case scenario for addition of lead to a package shield would be placement as a single piece of lead over one large segment of the shield. Taking the maximum lead thickness of 2 inches, placement of a 8 inch square piece of lead would localize the 55 lbs of lead to one area of the shield/package. The depleted uranium shield is centered in the package and has an approximate diameter of 11 inches. Since the lead is attached directly to the shield, the two extreme cases are as follows:



This would shift the center of gravity 0.3" to the right.



This would shift the center of gravity 0.35" in the upward direction.

In either case, the change of the center of gravity on the package will not adversely impact the package performance during the drop testing. The Model 770 was impacted in separate 30 ft drops on a side, an edge and on a corner. Since the package is effectively a cube any slight rotation that might be caused by the localization of the lead in a single spot (worst case placement) on the shield would be bounded by the test results previously seen for this package under Test Plan 114 Report (SAR 2.12.2). As such the additional lead will contribute slightly more damage to the package upon impact (see evaluation in Section 2-4 of this letter) based on a linear extrapolation of force, however its specific location of attachment to the shield, assuming the thickness constraint of 2 inches is complied with, will have no adverse impact on the structural ability of the package to meet the performance requirements of 10 CFR 71. The lead placements shielding effectiveness will be confirmed by direct radiation measurements prior to final acceptance of the package after manufacture and after introduction of the RP this placement location cannot change short of distruction/disassembly or fire damage through the breach of two weldments surrounding the shield.

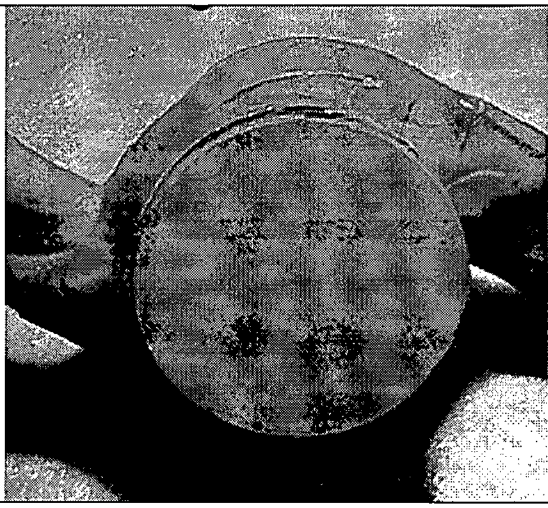
2-1 Depleted uranium shields are obtained from suppliers to design specifications provided by QSA Global and incorporated into shield molds used by the suppliers. We believe the process, described as follows, adequately controls shield production to obtain shields fit for purpose and structurally sound.

Upon receipt of shields from the supplier, QSA Global performs acceptance inspections based on external dimensional requirements and 100% radiation shielding transmission measurement inspections for each package fabricated. This radiation profile evaluation is currently identified and described in Section 8.1.6. and further reinforced in Section 5.4.1. of the SAR. Section 2.3.2 currently references Section 8 regarding the acceptance testing requirements for the package. As noted on drawing R77090 sheet 5 and indicated in Section 8.1.6 and 5.4.1, acceptance of the shield is based on the finished device demonstrating compliance with the radiation profile limits specified in Section 8.1.6. Any package which is unable to comply with the radiation dose limit criteria of Section 8.1.6 is rejected for use as a Type B container.

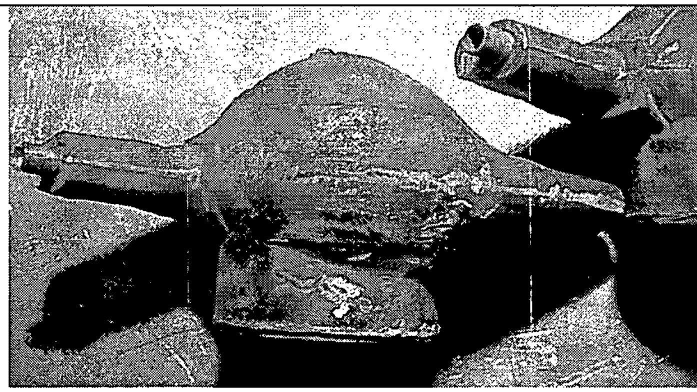
For the purposes of simplification, we have historically used the term "porosity" to address any shield variations which may occur during the shield pouring process to describe minor variations in the manufacture of the shields which can produce shields with localized shielding deficiencies. Technically, calling all potential contributing factors to shield variability "porosity", was an over-simplification on our part of the potential causes for shield variability. Based on your response to our amendment request, this appears to have implied that the "porosity" in shields used for this device may contain larger, sponge-like void cavities which could affect the structural integrity of the metallic shield. This is erroneous as any actual void cavities which may be produced in the depleted uranium shield pours are of insufficient size and/or quantity to affect the structural strength of the depleted uranium shield under the normal or accident transport conditions.

Actual causes for shield effectiveness variability, previously addressed by us collectively as "porosity", can be affected by:

- Variations in shield cooling rates (this can impact the relative density of the finished product in localized areas);
- Slight flexing and/or shifting of the s-tube in the shield mold during the pour process (this can slightly off-set the tube location to points external to the shield surface which though small in physical distance acts to remove effective depleted uranium thickness at the point nearest the source when contained in the package)
- Minor voids in the depleted uranium, which are a natural result of out gassing during the depleted uranium metal pour process, may be more noticeable at thinner points along the shield mold (e.g. ears) or in the hot top cut off area (this can allow greater transmission in localized areas);
- Tolerance variations in the outer diameter of the s-tube (for s-tubes on the high side of the tolerance this will reduce the amount of depleted uranium located nearest to the source location within the shield and reduce the effective shielding capability of the finished shield).
- Surface imperfections caused during removal of the shields from the molds (see Pictures 3 through 6)

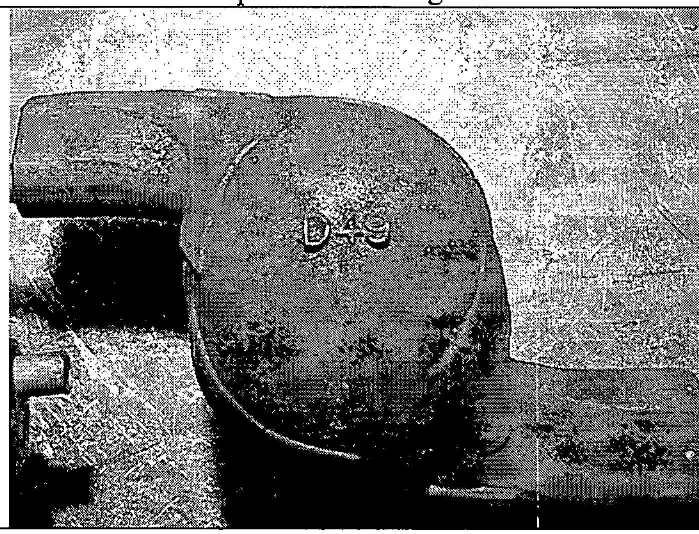


Picture 3 – 880 Style Shield After Mold Removal Showing Hot Top



Picture 4 – 880 Style Shield in Showing Mold Separation Parting Line

Picture 5 – 880 Style Shield After Mold Removal but Before Cleaning & Painting Variations



Picture 6 – 880 Style Shield in After Cleaning, Ready For Painting

The potential variations noted are part of the normal fabrication process for production of any depleted uranium shield and are controlled (where possible and financially feasible) within acceptable limits such that the final device radiation profile, after lead augmentation, will meet the criteria for normal and accident condition transport.

Though not all package designs incorporate the use of lead for supplemental shielding purposes, due to the extensive labor associated with fabrication of the Model 770 and 770B packages, as well as the large costs for depleted uranium shields of this size, it is desirable to incorporate the use of supplemental lead shielding if necessary to ensure the ability to utilize shields which may contain some variability but which are otherwise fully acceptable for fabrication in the package. Due to the costs associated with fabrication of these packages, the lead time required to obtain shields for these packages, and the total fabrication time associated with their construction due to the detailed inner weldment configuration, fabrication of the Model 770 style packages are a low volume production.

Unlike other Type B(U) packaging where the production volume is large and it is financially feasible to incorporate shield mold modifications which can be evaluated to fine-tune or minimize variability effects in the final shield production (e.g., Model 880 Series packages – USA/9296/B(U)-96), the Model 770/770B package production will not be sufficiently large in numbers to justify modification of the shield molds such that supplemental lead shielding can be completely eliminated. Financially it is not feasible to run a series of shield mold modifications until an optimized shield can be produced 100% of the time during the shield pour process. Here, as with other packages noted previously (e.g., 680, 741), it is more economical and realistic to deal with any shield variances by the incorporation of additional, localized lead shielding.

Currently we have a single Model 770 package which meets the criteria specified for the current Type B package and has demonstrated it shielding capacity (without the use of supplemental lead) to allow the maximum transport of 800 Ci of Co-60. The shield used in the current transport package was manufactured prior to 1981. The mold used in that shield's fabrication, as well as the supplier of the shield, no longer exist to provide new shields for these packages. Subsequently the shield mold was re-designed in Jan 2006 and though the design remains compliant with the requirements under the Type B(U) certificate it has not produced a shield with the same shielding effectiveness as the current Model 770 package in active service.

The addition of lead to the current shield design, was considered necessary to compensate for the mold design and supplier fabrication changes and to allow use of the shields with minor imperfections produced by the new shield mold design. At the time of application the maximum thickness of lead requested was estimated based on a worst case, reverse extrapolation of the acceptable dose rate under accidental transport conditions (e.g., 1 R/hr at 1 meter from the package) and the initial acceptance criteria of 10 mR/hr at 1 meter from the package for normal transport conditions of the package. This produced a potential additional lead thickness to the shield which exceeded anything we would realististically add to the package for a production unit. This also may have implied a degradation in shield quality that does not actually exist in product used to produce this package. We have revised the descriptive drawing (see enclosure) to more accurately reflect the maximum thickness of lead we would anticipate adding to a package without rejection of the shield. Drawing R77090 Rev G, sheet 5 of 6 references a maximum lead thickness of ½ inch with a total mass not to exceed 55 lbs. We trust this clarification addresses any remaining concerns regarding the solidity and integrity of the depleted uranium shields.

2-2 See response to question 2-1.

2-3 Regarding the pressure questions, 25 kPa is about 3.6 psi absolute. Since the package is not airtight, any increased/decreased pressure will not adversely affect the package as currently stated in Sections 2.6.3 and 2.6.4 of the SAR. However, an increase/decrease in pressure will affect the source as this is a welded, sealed containment. The ISO 2919-1999 pressure test requirement referenced for the source are higher than required to meet the pressure differential requirements under these sections.

Regarding the attachment referenced in your letter and the ISO 2919-1999 criteria for a Class 3 pressure classification, there remained an unresolved error in the units listed for this reference. The Class 3 criteria should appear in the SAR as 25 kN/m^2 to 2 MN/m^2. This has been corrected in Sections 2.6.3 and 2.6.4 of SAR Revision 7.

2-4 A linear extrapolation in the structural response was used as it is the most conservative method to evaluate the only damage that was observed to the test units under the testing referenced in Section 2.12 of the SAR. If a non-linear model is used, any additional force would need to be absorbed in the package. Based on the evidential damage occurring to the test units, a linear model was assumed. Also, given the minimal nature and scope of the test unit damage after the 30 ft drop test, it is reasonable to assume that the structural response would be linear in the 1.2 m drop conditions give an additional 55 lbs of weight.

2-5 As noted in response to question 1-2, the non-uniform addition of lead to the shield will have minimal impact on the center of gravity for the package. Since we are now requesting a reduction in the maximum thickness of the additional lead from 2 inches down to ½ inch, the impact evaluated in question 1-2 will have an even smaller impact on the package center of gravity.

As further demonstrated in response to question 1-1, addition of the lead is performed in a manner that fully secures and incorporates the lead into the package without allowance for movement after fabrication. There was no damage to the depleted uranium material component of the inner shield of test unit serial number 10 after extraction from the test unit. Due to the solidarity of the surrounding steel and RP structure around the shield and since the only significant damage to the test unit was assessed on the outside of the package, it is reasonable to assume that any additional damage induced in impact of a package weighing 55 lbs more than the current package mass would be translated into additional damage to the outside of the package. This implies that the mass differential should be assessed against the total package mass and not the sub-component shield mass. Therefore use of a 6-7% ratio is appropriate for use in the scaling factor.

2-6 See response to question 2-1.

5-1 Section 5 has been revised to address your concerns regarding the referencing of package compliance to the regulatory limits. Separate tables have been added to address package compliance with Normal and Hypothetical Accident transport conditions for the various radionuclides and package configurations. Additional information and in most cases table entries have been added to address the Model 770B package and the impact of lead use in this design when applicable. Regulatory acceptance criteria references for each table are also updated to reflect the associated regulatory reference.

5-2 The reference to the maximum transport index measurement of 0.8 which appeared at the bottom of page 5-1 was a remnant from a previous submission and is in error. That note has been revised to remove the first sentence.

5-3 Section 5 has been revised to address separate shielding evaluations for the Model 770 and the Model 770B. The issues related to shifting or movement of the lead in a finished package have been described in our response to items 1-1 and 1-2 of this letter and movement is not possible. A statement regarding the securement of supplemental lead shielding to the depleted uranium shield has been added to Section 5.1.1 of SAR Rev 7.

5-4 The omission of the Microshield calculations as well as their reference under Section 5.5.1 has been corrected in Revision 7 of the SAR provided.

5-5 The table references noted in your letter have been corrected in Revision 7 of the SAR provided.

5-6 All table unit references are not identical to the units referenced in NUREG 1609 throughout Section 5.

5-7 The tables for Sc-46 have been revised to reflect the correct capacity of 800 Ci. Reference to 1,000 Ci in the tables has been removed.

5-8 Section 5.4.2. has been clarified to remove the reference to more than one method for calculating the surface correction factor and to correct the figure reference in this section to call out Figure 5.4a.

7-1 Section 7.1.1.2 has been clarified to note preparation of the container for loading after performance of functional checks in this section. As described in Revision 7 of the SAR, cover plates, cover plate screws and shipping covers are noted to be removed prior to initiation of loading the container.

7-2 Section 7.1.2.1.d has been added to address installation of the cover plates prior to shipment.

7-3 Section 7.2.1.2.c has been revised to reference the criteria specified under 10 CFR 20.1906(d)(2) (i.e., the limits in 10 CFR 71.47).

7-4 The text of Section 7 of the SAR has been revised to reference both the 770 and 770B throughout this section.

7-5 Section 7.3.1.5 was actually a continuation of Section 7.3.1.4. Revision 7 of the SAR has eliminated the separate Section 7.3.1.5. This criteria has been incorporated into Section 7.3.1.4 and now includes further instruction after removal of the gauge.

7-6 Though technically covered by the requirement for compliance to 49 CFR 171-178 (section 7.1.3.4 in SAR Revision 6), Section 7.1.3.4 has been revised to provide the specific regulatory requirement reference for activity compliance when transporting multiple radionuclides in a single transport package. The old requirement from Revision 6 of the SAR is now listed in Revision 7 of the SAR as Section 7.1.3.5.

8-1 See response to question 2-1.

8-2 Section 8.1.1.1.a from Revision 6 of the SAR has been removed and Section 8.1.1.1 re-sequenced.

8-3 Reference to inspections in Section 8.1.1.1 refer to the drawings referenced on the Type B certificate in Revision 7 of the SAR.

8-4 As noted in Section 1.2.2. the source capsule will be attached to a flexible steel wire but the attachment is not limited to a 'swaged' connection as alternate methods may be used by ourselves and other manufacturers to ensure that the connection is secure. A statement has been added to Section 8.1.3 which states that for sources transported in these containers and manufactured by QSA Global, then QSA Global will perform source assembly integrity inspections to ensure that the source capsule is securely attached to the flexible steel wire prior to transport.

It should be noted that these containers are compatible for the transport of special form source wire assemblies which are not manufactured by QSA Global. In either case, should the connection of the source capsule to the flexible steel wire fail during transport, the presence of the flexible steel wire will prevent displacement of the source capsule from the fully shielded position.

Loss of connection during transport will have no adverse effect on the container integrity and is only of operational concern for users of the container wishing to extract the source assembly from the device after completion of transportation. Should this unlikely event ever occur after transport, the operational instructions provided to users of this container as a radioactive source changing device will identify the issue based on radiation surveys and informs the users to contact QSA Global Inc. for assistance in such situations.

8-5 As noted in your letter the lock assembly test has been re-inserted to Section 8.1.5. of Revision 7 of the SAR.

One additional correction was made with this submission. Drawing R77090 Rev G also contains one correction of a typographical error noticed during review of this package. On Sheet 2 of 6, the dimension "2 ¼ 2x" has been revised to read "1 1/8 ± 1/8 2x". This corrects the tolerance stack up created by the 3/8"spacer plates from sheet 4 of 6.

The revised pages from Revision 7 to the Model 770 and 770B SAR are submitted as they are the only pages that change from Revision 6 of the SAR. Changes to the text of Revision 7 of the SAR addressing items discussed in this letter are indicated by vertical lines in the right hand margin. Should you have any additional questions or wish to discuss this submission, please contact me.

Sincerely,

Lori Podolak

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

C. Ronfelt | 16 Mar 07
RA/QA Approval | Date

Daniel | 13 Mar-07
Engineering Approval | Date

Enclosures:

A List of Affected Pages
B Revised Pages of SAR Revision 7
C Drawing R77090 Revision G

List of Affected Pages	
Revision 1, 21 December 2001	Revision in entirety. This revision supercedes previously submitted SAR's for the 770.
Revision 2, 13 September 2002	Revisions to Sections 2.7.6, 5.4, 7 and Appendix C for clarification and additional detail.
Revision 3, 7 November 2002	Revisions to Sections 1.2.2, 2.4.2, and Table 2-1 for clarification and additional detail. Revision to descriptive assembly drawings in Appendix A.
Revision 4, 10 April 2006	Reformatting of the SAR to cover compliance to IAEA TS-R-1 and NRC guidance format. Revisions to descriptive drawings.
Revision 5, 30 August 2006	Changes incorporating addition of Model 770B, increase of package maximum weight and option of using supplemental lead to compensate for shield porosity. Change detail is contained in "Revision Description for the Model 770 SAR from Revision 4 to Revision 5"
Revision 6, 31 October 2006	Changes incorporating modifications to address generic SAR details as specified in letter dated 31 Oct 06. Revisions to pages 1-1, 2-1, 2-6, 2-9, 2-11, 2-14, 7-1, 7-3 and 7-4.
Revision 7, 15 February 2007	Changes incorporating modifications to address SAR details in response to NRC RAI letter faxed 22 Jan 07 . Revisions to indices and pages 1-3, 2-7, 2-14, 5-1 through 5-8, 5-11 through 5-13, and Section 1.4 (Drawing R77090 Rev G)

Safety Analysis Report

QSA Global Inc.

Model 770 and 770B
Type B(U) - 96
Transport Packages

15 February 2007

Revision 7

Contents

List of Tables

List of Figures

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

1.2.1.1 External container weldment: The exterior weldment is fabricated from ¼ inch (6.35 mm) thick stainless steel and encloses an internal stainless steel framework. The void spaces between the exterior of the internal weldment and the interior of the exterior weldment are filled with polyurethane foam with a nominal density of 20 lb/ft^3.

1.2.1.2 Internal container weldment: The internal weldment incorporates an exo-skeleton comprised of stainless steel tubing. This tubing acts as a shock absorber and impact limiter for the device as well as adding significant structural integrity. The internal weldment surrounds the depleted uranium shield and incorporates the lock assemblies (two oriented at 180 degrees from each other). The void spaces between the exterior of the depleted uranium shield and the interior of the internal weldment are filled with polyurethane foam with a nominal density of 65 lb/ft^3.

1.2.1.3 Depleted Uranium Shield: The depleted uranium shield provides the primary radiation protection for the packages. There is a crimp and stop plug installed at the center of the source tube prior to casting which prevents the sources from exiting the opposite side of the container during loading into the fully stored position. A maximum of two (2) source assemblies can be loaded into the Model 770 or 770B for shipment, one in each side of the source tube of the device. In some cases, to compensate for depleted uranium porosity associated with the casting process, supplemental lead may be added where necessary to ensure surface dose rate requirements of the final package are met. Additional lead shielding will not exceed a maximum of 1/2 inch thick at any one location on the depleted uranium and and will not exceed a total weight of 55 lb. for any one device. The lead will be located on the exterior surface of the depleted uranium shield using adhesive tape prior to the addition of the polyurethane foam to the package assembly. The lead is permanently secured in place next to the shield surface by the rigid polyurethane foam during device manufacture.

The depleted uranium shield for both the 770 and the 770B are essentially identical. The 770B designation will be used for shielding where porosity in the depleted uranium shield, even after compensation of additional lead, is unable to achieve a Co-60 shielding capacity of 800 Ci. In these cases the unit will be designated a 770B and its Co-60 and Sc-46 activity capacities will be lower as noted in Table 1.2a.

1.2.1.4 Source Locking Assemblies: The device lock assemblies are key operated to prevent unauthorized personnel from actuating the mechanisms. The lock assemblies are recessed into the package exterior weldment. The lock assemblies secure over the source wire which is part of the source positioning assembly. Once the lock is engaged and the source cap installed, source movement within the container is prevented, keeping the sources in the shielded storage positions.

5 4 3 2 1

D

C

Security-Related Information Figure Withhheld Under 10 CFR 2.390

B

A

QSA GLOBAL

DESCRIPTIVE DRAWING

ERF#	APPROVALS	DATE	TITLE MODEL 770 & 770B SOURCE CHANGER DESCRIPTIVE ASSEMBLY		
1635	[signature]	13Mar07	SIZE A	DWG. NO. R77090	REV G
	S. Gregoire	12Mar07		SCALE: 4/1	SHEET 1 OF 6
	[signature]	12Mar07			

5 4 3 2 1

5 4 3 2 1

D

C

B

A

Security-Related Information Figure
Withhheld Under 10 CFR 2.390

QSA GLOBAL		DESCRIPTIVE DRAWING	
TITLE MODEL 770 & 770B SOURCE CHANGER DESCRIPTIVE ASSEMBLY			
SIZE A	DWG. NO. R77090		REV G
	SCALE: 4/1	SHEET 2 OF 6	

5 4 3 2 1

Security-Related Information Figure
Withhheld Under 10 CFR 2.390

QSA GLOBAL		DESCRIPTIVE DRAWING	
TITLE MODEL 770 & 770B SOURCE CHANGER DESCRIPTIVE ASSEMBLY			
SIZE A	DWG. NO. R77090		REV G
	SCALE: 4/1	SHEET 3 OF 6	

Security-Related Information Figure
Withhheld Under 10 CFR 2.390

QSA GLOBAL	DESCRIPTIVE DRAWING		
TITLE	MODEL 770 & 770B SOURCE CHANGER DESCRIPTIVE ASSEMBLY		
SIZE A	DWG. NO. R77090		REV G
	SCALE: 4/1	SHEET 4 OF 6	

Security-Related Information Figure
Withhheld Under 10 CFR 2.390

QSA GLOBAL

DESCRIPTIVE DRAWING

TITLE MODEL 770 & 770B SOURCE CHANGER DESCRIPTIVE ASSEMBLY			
SIZE A	DWG. NO. R77090		REV G
	SCALE: 4/1	SHEET 5 OF 6	

Security-Related Information Figure
Withhheld Under 10 CFR 2.390

QSA GLOBAL		DESCRIPTIVE DRAWING	
TITLE MODEL 770 & 770B SOURCE CHANGER DESCRIPTIVE ASSEMBLY			
SIZE A	DWG. NO. R77090		REV G
	SCALE: 2/1	SHEET 6 OF 6	

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, 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

(Reference:
- *USNRC, 10 CFR 71.71(c)(4))*

See 2.6.3. No differential pressures can build up by the same argument. None of the solid components are detrimentally affected by this magnitude of pressure. As such, the entire package will always equalize to ambient pressures and will not be affected by pressure reductions.

Again, 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

(Reference:
- *USNRC, 10 CFR 71.71(c)(5)*
- *IAEA TS-R-1, paragraph 612)*

In the 19 years that the old Model 770 package had been in use, no transport package had failed due to vibration. In addition, being a fully welded structure, these packages are not affected by normal incident vibration. The lock assembly attachment screws are safety wired in pairs to prevent unintentional release even after repeated use. Further, each cover plate has two (2) of the eight (8) attachment screws seal wired during transport. It is therefore concluded that these packages will withstand vibration normally incident to transport.

2.6.6 Water Spray

(Reference:
- *USNRC, 10 CFR 71.71(c)(6)*
- *IAEA TS-R-1, paragraph 719, 720 and 721)*

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

2.6.7 Free Drop

(Reference:
- *USNRC, 10 CFR 71.71(c)(7)*
- *IAEA TS-R-1, paragraph 722(a))*

See Table 2.7.c for additional test unit results summary. A more detailed summary is given in Test Plan Report 114 (Section 2.12.2) and Technical Report 92 (Section 2.12.5). In all cases, radiation profiles performed at the conclusion of the puncture testing showed no significant increase in radiation levels for the test units and demonstrated that the package complies with the requirements of this section.

2.7.4 Thermal

(Reference:

- *USNRC, 10 CFR 71.73(c)(4)*
- *IAEA TS-R-1, paragraph 651 through 655, and 728)*

An assessment was performed to determine the ability of the package to pass the fire test based on previous satisfactory thermal tests performed on the Model 680 (CoC 9035) and 650L (CoC 9269) containers. (Reference Test Plan TP72-S2 Report Section 2.12.3 and Test Plan 80 Report Section 2.12.4). These reports detail thermal tests performed on the 680 projector with and without the overpack and on a cracked 650L respectively.

The Model 770 and 770B packages are less susceptible to the thermal test than either the 680-OP or the 650L due to the package designs double shell construction which acts as a thermal insulator in the thermal test. Also the Model 770 and 770B packages are substantially more robust than either of the other two containers limiting movement/displacement of the shield should the polyurethane foam burn away and/or any of the additional lead shielding melt away during the thermal test.

Since the addition of lead is limited to a maximum thickness of ½ inch (1 half-value layers for Co-60), the complete loss of lead would result in a worst case maximum dose rate at 1 meter of 3 mR/hr (assuming the maximum allowable 10 mR/hr at 1 m prior to the test). Although Ir-192 has a higher activity capacity, Technical Report 92 (Section 2.12.5) and Section 5 demonstrates that the depleted uranium shielding efficiency for 1,000 Ci of Ir-192 (minus consideration of the supplemental lead) would produce a maximum reading at 1 m from the package that is less than 0.002 mR/hr As a result, the evaluation of the lead removal in the thermal test when based on consideration of Co-60 will bound the other radionuclides transported within the packages. See Technical Report 92 (Section 2.12.5) and Section 5 for further details of this assessment.

Since the weldments were not breached during the 9 m (30 ft) and puncture bar drop tests, there is an insufficient pathway for air to enter the interior of the device and therefore shield oxidation will not occur. Since there was minimal deformation of the outer shell and not shield displacement on the test units, it is assessed that these packages would have passed the thermal test if it had been performed, therefore the containers are compliant with the requirements of 10 CFR 71.73(c)(4) and IAEA TS-R-1.

Section 5 - SHIELDING EVALUATION

5.1 Description of Shielding Design

(Reference:

- *USNRC, 10 CFR 71.31*
- *IAEA TS-R-1, paragraph 701 and 702)*

5.1.1 Design Features

The principal shielding in the packages are the depleted uranium shield assembly. In some cases additional supplemental lead shielding is added to the shield assembly as described in the drawings included in Section 1.4. Due to the design of the package construction, when used supplemental lead shielding is immobilized with regard to its placement on the depleted uranium shield by the solidification of the rigid polyurethane foam and the dual steel weldment which surrounds the shield assembly.

5.1.2 Summary Table of Maximum Radiation Levels

Radiation profiling, with Co-60, of the test specimen following Type B testing showed effectively no increase in the radiation levels measured prior to testing and therefore the dose remained within regulatory limits. The tables in this Section include radiation profile data obtained from the 770 packages that were tested to the Hypothetical Accident Conditions of Transport under Test Plan Report 114 (see Section 2.12.2).

Performance of the Model 770 and 770B under Normal Conditions of Transport will be bounded by the results obtained after performance of the Hypothetical Accident Conditions of transport (see Table 5.1a(1)). The values shown in Table 5.1a(2) demonstrate that the packages, when subjected to the Normal Condition of Transport testing, will comply with the dose rate requirements for a non-exclusive use package.

Performance of the Model 770B under Hypothetical Accident Conditions will be bounded by the results obtained for the test unit (Table 5.1a(1)) and assessment regarding the worst case impact from loss of the maximum thickness of lead shielding that might be necessary to obtain acceptable pre-test dose rate limits for the package.

Assuming the Model 770 or 770B requires the maximum amount of supplemental lead to achieve a dose rate of 10 mR/hr at one meter from the surface of the package prior to testing, then the maximum increase in radiation reading after thermal testing (assuming elimination of all the lead shielding) can be assessed. For both the Model 770 and 770B this increase in the dose rate will be by a factor of 1.73 or 17.3 mR/hr. (See Section 5.5.2 for Microshield calculations for 660 Ci and 800 Ci of Co-60 through ½ inch of air and through ½ inch of lead. The ratio of these values in both cases produces an increased dose factor of 1.73 for an unshielded source term.)

The following notes apply to all tables in this section:

Note 1: Transport Index may not exceed 10. The Transport Index is equivalent to the 1 meter reading in mRem per hour (i.e., 5 mRem per hour at 1 meter = a Transport Index of 5.0).

Note 2: All packages accepted and released for shipment under these package designations will have a Transport Index less than or equal to 10.

Table 5.1a(1): Model 770 Test Unit serial number 10 After Hypothetical Accident Transport Testing Summary Table of External Radiation Levels Extrapolated to Capacity of 800 Ci Co-60 (Non-Exclusive Use)

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.017 (1.7)	0.052 (5.2)	0.022 (2.2)[1]
Neutron	NA	NA	NA
Total	0.017 (1.7)	0.052 (5.2)	0.022 (2.2)[1]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1a(2): Model 770 Test Unit serial number 10 After Hypothetical Accident Transport Testing and Evaluated for Compliance with the Normal Transport External Radiation Levels Extrapolated to Capacity of 800 Ci Co-60 (Non-Exclusive Use)

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.46 (46)	1.49 (149)	0.52 (52)	0.017 (1.7)	0.052 (5.2)	0.022 (2.2)[1]
Neutron	NA	NA	NA	NA	NA	NA
Total	0.46 (46)	1.49 (149)	0.52 (52)	0.017 (1.7)	0.052 (5.2)	0.022 (2.2)[1]
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)

[1]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Based on the profile results for Co-60 after the hypothetical accident condition testing, the device shielding capacities for the other radionuclides can be assessed. Table 5.1b shows general information for each nuclide as well as a calculated shielding transmission, at capacity, for each nuclide through the depleted uranium shield and titanium source tube in the Model 770. Although the Model 770B has lower maximum capacities for Co-60 and Sc-46, the assessments made for the Model 770 with the higher capacities will remain applicable to the Model 770B as the magnitude of the transmission ratio to Co-60 for the other nuclides is essentially the same.

Table 5.1b: Transmission Shielding Assessment for the Model 770

Nuclide	770 (770B) Capacity (Ci)	Γ (R m²/hr Ci)	Transmission (mR/hr)	Transmission Ratio Relative to Co-60	Transmission Factor for ½ inch of Lead
Co-60	800 (660)	1.3	279	1	1.73
Ir-192	1,000 (1,000)	0.48	1.1E-4	3.94E-7	12.33
Cs-137	1,000 (1,000)	0.32	5E-5	1.79E-7	3.24
Sc-46	800 (660)	1.17	24.6	0.088	1.96

Transmission exposure rates were determined using Microshield V5 (See Section 5.5.1). Transmission was calculated through the shortest portion of the depleted uranium shield and included attenuation through the titanium source tube wall. These calculations did not take into account shielding reductions due to the presence of the optional lead. The source was assumed to be a point source located at the center of the shield. (Note that the effective shielding between a source located at the center of the shield and one off-set slightly due to tube positioning in these package shields is the same due to the curved shield shape in this area.) Benefits from shielding/dose reduction of the steel in these packages and the additional distance to the surface of the device were not taken into account in the assessments. Therefore, the source transmission/dose rate values stated in Table 5.1b are conservative.

Shielding material thicknesses and densities used in the Microshield calculations are shown in Table 5.1c. Dimensions were based on the configuration shown in Figure 5.1a

Table 5.1c: Shielding Transmission Parameters

Material	Density (g/cm³)	Shielding Thickness (cm)
Depleted Uranium	18.75	12.1
Titanium	4.5	0.1

Figure 5.1a: Shielding Assessment Configuration

Security-Related Information
Figure Withhheld Under 10 CFR
2.390

Based on the Microshield transmission calculations and the physical radiation profiles performed using Co-60, the dose rates for the other three nuclides transported in the Model 770 can be conservatively assessed by taking the Co-60 results and multiplying those values by the respective transmission ratio from Table 5.1b. These transmission values will also apply for Normal Transport Conditions for the Models 770 and 770B which incorporate supplemental lead shielding as the supplemental lead shielding will be used to compensate for variability of the depleted uranium shield to the same maximum surface and 1 meter dose rates as shields where no supplemental lead is required. In the case of Hypothetical Accident conditions of transport for the Models 770 and 770B, the transmission factors will be further increased by the equivalent transmission factor for ½ inch of lead for each of the radionuclides.

In the case of Ir-192 and Cs-137, the shield attenuation essentially prevents photon transmission. In these cases, the dose reported for Normal and Hypothetical Accident conditions are based on the radiation transmitted by the depleted uranium shield itself. The worst case estimated values are shown in the following tables.

Table 5.1d(1): Model 770 or 770B without Supplemental Lead Shielding - Hypothetical Accident Transport Dose Rate for Ir-192 Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci (Non-Exclusive Use) [1]

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
Neutron	NA	NA	NA
Total	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Due to Ir-192 attenuation to background levels, surface values are based on depleted uranium transmission from an empty device. One meter readings are based on the background levels and meter sensitivity.

[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1d(2): Model 770 or 770B with the Maximum Supplemental Lead Shielding - Hypothetical Accident Transport Dose Rate for Ir-192 Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci (Non-Exclusive Use) [1]

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.0012 (0.12)	0.0012 (0.12)	0.0012 (0.12)[2]
Neutron	NA	NA	NA
Total	0.0012 (0.12)	0.0012 (0.12)	0.0012 (0.12)[2]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Due to Ir-192 attenuation to background levels, one meter values are based on depleted uranium transmission from an empty device (see Table 5.1d(1)), meter sensitivity and incorporation of an increased transmission factor of 12.33 assuming the loss of ½ inch of supplemental lead shielding from the shield.
[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1d(3): Model 770 and 770B Normal Transport Dose Rate for Ir-192 Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci (Non-Exclusive Use) [1]

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.004 (0.4)	0.002 (0.2)	0.003 (0.3)	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
Neutron	NA	NA	NA	NA	NA	NA
Total	0.004 (0.4)	0.002 (0.2)	0.003 (0.3)	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)

[1]Due to Ir-192 attenuation to background levels, surface values are based on depleted uranium transmission from an empty device. One meter readings are based on the background levels and meter sensitivity.
[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1e(1): Model 770 or 770B without Supplemental Lead Shielding - Hypothetical Accident Transport Dose Rate for Cs-137 Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci (Non-Exclusive Use) [1]

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
Neutron	NA	NA	NA
Total	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Due to Cs-137 attenuation to background levels, surface values are based on depleted uranium transmission from an empty device. One meter readings are based on the background levels and meter sensitivity.
[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1e(2): Model 770 or 770B with the Maximum Supplemental Lead Shielding - Hypothetical Accident Transport Dose Rate for Cs-137 Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci (Non-Exclusive Use) [1]

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.0003 (0.03)	0.0003 (0.03)	0.0003 (0.03)[2]
Neutron	NA	NA	NA
Total	0.0003 (0.03)	0.0003 (0.03)	0.0003 (0.03)[2]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Due to Cs-137 attenuation to background levels, 1 meter values are based on depleted uranium transmission from an empty device (see Table 5.1e(1)), meter sensitivity and incorporation of an increased transmission factor of 3.24 assuming the loss of ½ inch of supplemental lead shielding from the shield.

[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1e(3): Model 770 and 770B Normal Transport Dose Rate for Cs-137 Summary Table of External Radiation Levels Extrapolated to Capacity of 1,000 Ci (Non-Exclusive Use) [1]

Normal Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.004 (0.4)	0.002 (0.2)	0.003 (0.3)	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
Neutron	NA	NA	NA	NA	NA	NA
Total	0.004 (0.4)	0.002 (0.2)	0.003 (0.3)	<0.0001 (<0.01)	<0.0001 (<0.01)	<0.0001 (<0.01)[2]
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)

[1]Due to Cs-137 attenuation to background levels, surface values are based on depleted uranium transmission from an empty device. One meter readings are based on the background levels and meter sensitivity.

[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1f(1): Model 770 or 770B without Supplemental Lead Shielding - Hypothetical Accident Transport Dose Rate for Sc-46 Summary Table of External Radiation Levels Extrapolated to Maximum Capacity (800 for the Model 770 or 660 Ci for the Model 770B) (Non-Exclusive Use) [1]

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.002 (0.2)	0.005 (0.5)	0.002 (0.2)[2]
Neutron	NA	NA	NA
Total	0.002 (0.2)	0.005 (0.5)	0.002 (0.2)[2]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Due to Sc-46 attenuation in the shield, 1 meter values are based on the Model 770 sn 10 transmission results corrected by an increased transmission factor of 0.088 for Sc-46 relative to Co-60 (see Table 5.1b).
[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1f(2): Model 770 or 770B with the Maximum Supplemental Lead Shielding - Hypothetical Accident Transport Dose Rate for Sc-46 Summary Table of External Radiation Levels Extrapolated to Maximum Capacity (800 Ci for the Model 770 or 660 Ci for the Model 770B) (Non-Exclusive Use) [1]

Hypothetical Accident Conditions	1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom
Gamma	0.0039 (0.39)	0.0098 (0.98)	0.0039 (0.39)[2]
Neutron	NA	NA	NA
Total	0.0039 (0.39)	0.0098 (0.98)	0.0039 (0.39)[2]
10 CFR 71.51(a) Limit	10 (1,000)	10 (1,000)	10 (1,000)

[1]Due to Sc-46 attenuation, 1 meter values are based on the levels from Table 5.1f(1), meter sensitivity and incorporation of an increased transmission factor of 1.96 assuming the loss of ½ inch of supplemental lead shielding from the shield.
[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

Table 5.1f(3): Model 770 and 770B Normal Transport Dose Rate for Sc-46 Summary Table of External Radiation Levels Extrapolated to Maximum Capacity of (800 Ci for the Model 770 and 660 Ci for the Model 770B) (Non-Exclusive Use)[1]

Hypothetical Accident Conditions of Transport	Package Surface mSv per hour (mrem per hour)			1 Meter from Package Surface mSv per hour (mrem per hour)		
Radiation	Top	Side	Bottom	Top	Side	Bottom
Gamma	0.041 (4.1)	0.131 (13.1)	0.046 (4.6)	0.002 (0.2)	0.005 (0.5)	0.002 (0.2)[2]
Neutron	NA	NA	NA	NA	NA	NA
Total	0.041 (4.1)	0.131 (13.1)	0.046 (4.6)	0.002 (0.2)	0.005 (0.5)	0.002 (0.2)[2]
10 CFR 71.47(a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)

[1]Due to Sc-46 attenuation in the shield, surface and 1 meter values are based on the Model 770 sn 10 transmission results corrected by an increased transmission factor of 0.088 for Sc-46 relative to Co-60 (see Table 5.1b).
[2]Dose rate at one meter from the bottom extrapolated based on other profile readings due to difficulty involved with obtaining a 1 meter reading from the bottom of the 970 lb device.

From the physical measurements with Co-60 and assessments for the other nuclides, it is shown that the Model 770 and 770B packages can effectively shield the nuclides at the capacities requested. The device was measured with the most penetrating radionuclide (Co-60). Based on the assessments for the other nuclides, any two different radionuclides can be transported as two separate sources (one on either side). The device would meet the dose rate requirements so long as the sum of the fractional source activities to unit capacities is less than or equal to one (see example below):

$$For\ 300\ Ci\ Co-60\ and\ 500\ Ci\ Ir-192$$

$$\left(\frac{300Ci}{800Ci}+\frac{500Ci}{1{,}000Ci}\right)=(0.375+0.5)=0.875\ which\ is\ less\ than\ 1$$

Additionally there is a significant amount of steel, as well as distance, between the shielded sources and the external surface of these packages. Since the measured dose rates were from the test unit which had undergone the hypothetical transport testing, values provided for Co-60 are worst case. The assessed dose rates were based on values calculated at the surface and one meter from the surface of the shield. Since the damage incurred by the Model 770 during the testing did not alter the available depleted uranium shielding, the values provided for the other nuclides are conservative estimates.

From these measurements and assessments it is concluded that the Model 770 and 770B, when transporting any of the listed nuclides, will not produce dose rates on the surface which exceed 200 mR/hr or 10 mR/hr at 1 meter from the surface in normal or hypothetical accident conditions of transport.

5.2 Source Specification

5.2.1 Gamma Source

(Reference:

- *USNRC, 10 CFR 71.33(b)(1) & (3))*
- *IAEA TS-R-1, Section IV & paragraph 807(a))*

The gamma sources allowed for transport in these packages are specified in Sections 1.2.3 and 2.10.

5.2.2 Neutron Source

Not Applicable. The packages are not used for the transportation of neutron emitting sources.

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

The shielding model used to justify acceptance of some of the nuclides transported in this package was Microshield V5. Shielding justifications are described in Section 5.1.

5.3.2 Material Properties

Shielding justifications are described in Section 5.1.

5.4 Shielding Evaluation

5.4.1 Methods

Shielding justification was based on direct measurement and assessment as described in Section 5.1 All packages are profiled prior to final acceptance and shipment. This profile takes into account the maximum capacity of the package. Any package not meeting the required dose rates is rejected.

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

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

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

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

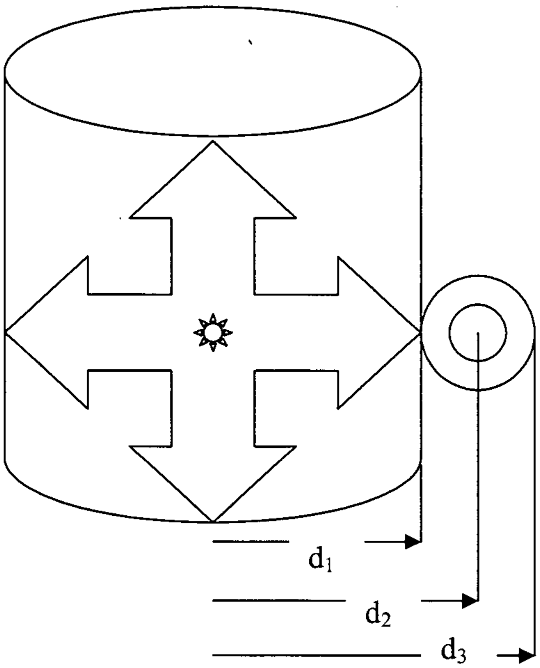
Therefore all original surface and 1 meter profile measurements would be multiplied by a factor of 1.2 for a package profiled using 834 Ci and a package capacity of 1,000 Ci.

Radiation measurements at the surface of the container were also adjusted to compensate for the off-set of the survey meter probe from the true surface of the package. Surface correction factors (SCF) were obtained by using the following relationship:

$$SCF = \sqrt{\frac{d_2^2}{d_1^2}} \text{ where } d_1 \text{ and } d_2 \text{ are determined as shown in Figure 5.4a.}$$

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

$$SCF = \sqrt{\frac{(9.5\,inches)^2}{(9\,inches)^2}} = 1.06$$



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.
d_3 =	distance from activity center to back of the probe.

FIGURE 5.4a. SAMPLE SURFACE CORRECTION FACTOR DISTANCE CRITERIA

Therefore in the example shown, all original surface profile measurements located along the side of the device shown in Figure 5.4a. would also be multiplied by a factor to account for surface correction of the detector to the device. 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.

The radiation profile data showed no increase in radiation dose after testing beyond normal measurement variations. The test specimen 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 the Model 770 test unit after undergoing accident condition transport testing showed maximum surface and 1 meter radiation levels from the transport packages within regulatory limits.

5.5 Appendix

5.5.1 Microshield Calculations for Depleted Uranium Transmission

5.5.2 Microshield Calculations for Transmission of 660 Ci Co-60 through Air and Lead

Section 5.5.1 Appendix: Microshield Calculations for Depleted Uranium Transmission

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770CO2.MS5
Run Date: January 29, 2007
Run Time: 1:58:25 PM
Duration: 00:00:00

File Ref: ___________
Date: ___________
By: ___________
Checked: ___________

Case Title: 770 Shield
Description: Co-60 Transmission 800 Ci
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	12.2 cm	0 cm	0 cm
	4.8 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	.1 cm	titanium	4.5
Shield 2	12.1 cm	Uranium	18.75
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	8.0000e+002	2.9600e+013

Buildup
The material reference is : Shield 2

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	4.828e+09	7.832e-06	2.318e-05	1.512e-08	4.476e-08
1.1732	2.960e+13	6.934e+03	2.662e+04	1.239e+01	4.758e+01
1.3325	2.960e+13	3.312e+04	1.333e+05	5.745e+01	2.313e+02
TOTALS:	5.920e+13	4.005e+04	1.599e+05	6.985e+01	2.789e+02

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770IR2.MS5
Run Date: January 29, 2007
Run Time: 1:59:36 PM
Duration: 00:00:00

File Ref: ____
Date: ____
By: ____
Checked: ____

Case Title: 770 Shield
Description: Ir-192 Transmission 1,000 Ci
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	12.2 cm	0 cm	0 cm
	4.8 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	.1 cm	titanium	4.5
Shield 2	12.1 cm	Uranium	18.75
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels
Ir-192	1.0000e+003	3.7000e+013

Buildup
The material reference is : Shield 2

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.056e+12	0.000e+00	1.444e-19	0.000e+00	1.238e-20
0.06	3.790e+12	0.000e+00	1.165e-18	0.000e+00	2.313e-21
0.08	1.039e+12	2.328e-294	4.558e-19	3.683e-297	7.214e-22
0.15	6.683e+10	4.351e-238	2.991e-08	7.165e-241	4.925e-11
0.2	1.389e+12	9.009e-114	2.447e-18	1.590e-116	4.319e-21
0.3	5.247e+13	7.785e-39	1.220e-16	1.477e-41	2.315e-19
0.4	5.441e+11	1.260e-19	2.155e-18	2.454e-22	4.199e-21
0.5	1.910e+13	2.659e-09	6.726e-09	5.218e-12	1.320e-11
0.6	6.701e+12	3.119e-05	8.502e-05	6.087e-08	1.659e-07
0.8	1.481e+11	1.857e-02	5.964e-02	3.532e-05	1.134e-04
TOTALS:	8.730e+13	1.860e-02	5.973e-02	3.538e-05	1.136e-04

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page	: 1	File Ref:	
DOS File:	770CS2.MS5	Date:	
Run Date:	January 29, 2007	By:	
Run Time:	2:02:49 PM	Checked:	
Duration:	00:00:00		

Case Title: 770 Shield
Description: Cs-137 Transmission 1,000 Ci
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	12.2 cm	0 cm	0 cm
	4.8 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	.1 cm	titanium	4.5
Shield 2	12.1 cm	Uranium	18.75
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	9.4600e+002	3.5002e+013
Cs-137	1.0000e+003	3.7000e+013

Buildup
The material reference is : Shield 2

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0045	3.634e+11	0.000e+00	7.604e-21	0.000e+00	5.212e-21
0.0318	7.246e+11	0.000e+00	1.091e-19	0.000e+00	9.085e-22
0.0322	1.337e+12	0.000e+00	2.038e-19	0.000e+00	1.640e-21
0.0364	4.865e+11	0.000e+00	8.460e-20	0.000e+00	4.807e-22
0.6616	3.149e+13	9.074e-03	2.610e-02	1.759e-05	5.059e-05
TOTALS:	3.441e+13	9.074e-03	2.610e-02	1.759e-05	5.059e-05

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770SC2.MS5
Run Date: January 29, 2007
Run Time: 2:00:53 PM
Duration: 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: 770 Shield
Description: Sc-46 Transmission 800 Ci
Geometry: 1 - Point

Dose Points

	X	Y	Z
# 1	12.2 cm	0 cm	0 cm
	4.8 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	.1 cm	titanium	4.5
Shield 2	12.1 cm	Uranium	18.75
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Sc-46	8.0000e+002	2.9600e+013

Buildup
The material reference is : Shield 2

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.8892	2.960e+13	4.965e+01	1.678e+02	9.319e-02	3.149e-01
1.1205	2.960e+13	3.572e+03	1.345e+04	6.444e+00	2.426e+01
2.0098	3.552e+06	7.283e-02	3.257e-01	1.125e-04	5.029e-04
TOTALS:	5.919e+13	3.621e+03	1.361e+04	6.538e+00	2.458e+01

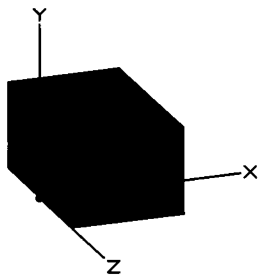
Section 5.5.2 Appendix: Microshield Calculations for Transmission of 660 Ci Co-60 through Air and Lead

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770COP.MS5
Run Date: March 12, 2007
Run Time: 2:52:57 PM
Duration: 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Pb Transmission Co
Description: 1/2 inch Pb Shielding 800 Ci Co-60
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.27 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	8.0000e+002	2.9600e+013

Buildup
The material reference is : Shield 1

Results

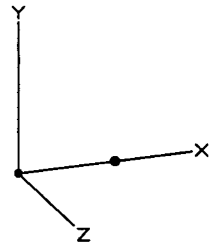
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	4.828e+09	3.980e+07	5.613e+07	7.685e+04	1.084e+05
1.1732	2.960e+13	7.224e+11	9.636e+11	1.291e+09	1.722e+09
1.3325	2.960e+13	8.843e+11	1.152e+12	1.534e+09	1.999e+09
TOTALS:	5.920e+13	1.607e+12	2.116e+12	2.825e+09	3.721e+09

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770COA.MS5
Run Date: March 12, 2007
Run Time: 2:55:17 PM
Duration: 00:00:00

File Ref: ______
Date: ______
By: ______
Checked: ______

Case Title: Air Transmission Co
Description: 1/2 inch Air Shielding 800 Ci Co-60
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	8.0000e+002	2.9600e+013

Buildup
The material reference is : Air Gap

Results

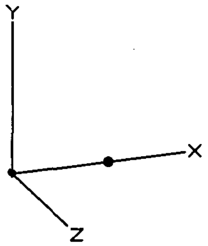
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	4.828e+09	1.653e+08	1.653e+08	3.191e+05	3.191e+05
1.1732	2.960e+13	1.713e+12	1.713e+12	3.062e+09	3.062e+09
1.3325	2.960e+13	1.946e+12	1.946e+12	3.376e+09	3.376e+09
TOTALS:	5.920e+13	3.659e+12	3.659e+12	6.438e+09	6.438e+09

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770BCOA.MS5
Run Date: March 12, 2007
Run Time: 2:56:00 PM
Duration: 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Air Transmission Co
Description: 1/2 inch Air Shielding 660 Ci Co-60
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	6.6000e+002	2.4420e+013

Buildup
The material reference is : Air Gap

Results

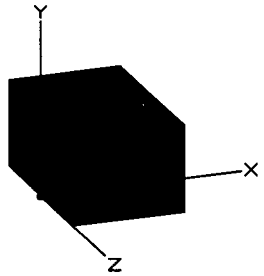
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	3.983e+09	1.363e+08	1.364e+08	2.632e+05	2.633e+05
1.1732	2.442e+13	1.413e+12	1.413e+12	2.526e+09	2.526e+09
1.3325	2.442e+13	1.605e+12	1.605e+12	2.785e+09	2.785e+09
TOTALS:	4.884e+13	3.019e+12	3.019e+12	5.311e+09	5.311e+09

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770BCOP.MS5
Run Date: March 12, 2007
Run Time: 2:54:08 PM
Duration: 00:00:00

File Ref: ________
Date: ________
By: ________
Checked: ________

Case Title: Pb Transmission Co
Description: 1/2 inch Pb Shielding 660 Ci Co-60
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.27 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Co-60	6.6000e+002	2.4420e+013

Buildup
The material reference is : Shield 1

Results

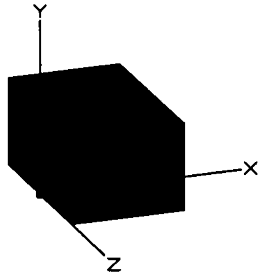
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.6938	3.983e+09	3.284e+07	4.631e+07	6.340e+04	8.941e+04
1.1732	2.442e+13	5.960e+11	7.949e+11	1.065e+09	1.421e+09
1.3325	2.442e+13	7.296e+11	9.503e+11	1.266e+09	1.649e+09
TOTALS:	4.884e+13	1.326e+12	1.745e+12	2.331e+09	3.069e+09

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770BIRP.MS5
Run Date: March 12, 2007
Run Time: 2:57:03 PM
Duration: 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Pb Transmission Ir
Description: 1/2 inch Pb Shielding 1,000 Ci Ir-192
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.27 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ir-192	1.0000e+003	3.7000e+013

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0615	4.190e+11	2.241e-18	1.280e-17	4.320e-21	2.468e-20
0.063	7.235e+11	1.808e-16	2.090e-16	3.389e-19	3.920e-19
0.0651	9.749e+11	3.091e-14	3.590e-14	5.600e-17	6.505e-17
0.0668	1.672e+12	1.766e-12	2.059e-12	3.124e-15	3.642e-15
0.0714	3.108e+11	9.330e-10	1.100e-09	1.567e-12	1.848e-12
0.0757	7.280e+11	8.983e-07	1.076e-06	1.457e-09	1.745e-09
0.1363	6.683e+10	2.404e-07	5.392e-04	3.865e-10	8.668e-07
0.2013	1.729e+11	2.677e+03	3.669e+03	4.731e+00	6.484e+00
0.2058	1.216e+12	3.837e+04	5.195e+04	6.814e+01	9.226e+01
0.2833	9.675e+10	2.940e+06	3.900e+06	5.533e+03	7.341e+03
0.296	1.074e+13	5.866e+08	7.844e+08	1.111e+06	1.485e+06
0.3085	1.098e+13	9.893e+08	1.332e+09	1.883e+06	2.535e+06
0.3165	3.066e+13	3.682e+09	4.978e+09	7.031e+06	9.505e+06
0.3745	2.688e+11	1.469e+08	2.033e+08	2.850e+05	3.944e+05
0.4165	2.459e+11	2.731e+08	3.824e+08	5.334e+05	7.468e+05
0.4231	2.949e+10	3.593e+07	5.038e+07	7.023e+04	9.847e+04
0.4681	1.778e+13	3.685e+10	5.201e+10	7.228e+07	1.020e+08
0.4846	1.170e+12	2.846e+09	4.023e+09	5.586e+06	7.895e+06
0.4891	1.474e+11	3.735e+08	5.280e+08	7.332e+05	1.036e+06
0.5886	1.692e+12	8.634e+09	1.220e+10	1.687e+07	2.385e+07
0.6044	3.035e+12	1.685e+10	2.382e+10	3.288e+07	4.647e+07
0.6125	1.974e+12	1.142e+10	1.614e+10	2.227e+07	3.146e+07
0.8717	3.648e+10	5.122e+08	7.144e+08	9.638e+05	1.344e+06
0.8845	1.116e+11	1.615e+09	2.250e+09	3.033e+06	4.225e+06

Page : 2
DOS File: 770BIRP.MS5
Run Date: March 12, 2007
Run Time: 2:57:03 PM
Duration: 00:00:00

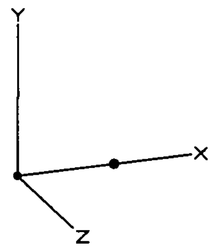
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
TOTALS:	8.524e+13	8.483e+10	1.194e+11	1.655e+08	2.331e+08

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770BIRA.MS5
Run Date: March 12, 2007
Run Time: 2:57:52 PM
Duration: 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Air Transmission Ir
Description: 1/2 inch Air Shielding 1,000 Ci Ir-192
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ir-192	1.0000e+003	3.7000e+013

Buildup
The material reference is : Air Gap

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0615	4.190e+11	1.271e+09	1.271e+09	2.449e+06	2.450e+06
0.063	7.235e+11	2.248e+09	2.250e+09	4.216e+06	4.218e+06
0.0651	9.749e+11	3.132e+09	3.133e+09	5.674e+06	5.677e+06
0.0668	1.672e+12	5.513e+09	5.515e+09	9.750e+06	9.755e+06
0.0714	3.108e+11	1.094e+09	1.095e+09	1.838e+06	1.839e+06
0.0757	7.280e+11	2.718e+09	2.720e+09	4.408e+06	4.410e+06
0.1363	6.683e+10	4.495e+08	4.496e+08	7.226e+05	7.228e+05
0.2013	1.729e+11	1.717e+09	1.718e+09	3.035e+06	3.036e+06
0.2058	1.216e+12	1.235e+10	1.235e+10	2.193e+07	2.193e+07
0.2833	9.675e+10	1.352e+09	1.352e+09	2.544e+06	2.545e+06
0.296	1.074e+13	1.567e+11	1.568e+11	2.968e+08	2.968e+08
0.3085	1.098e+13	1.671e+11	1.671e+11	3.181e+08	3.181e+08
0.3165	3.066e+13	4.786e+11	4.787e+11	9.139e+08	9.140e+08
0.3745	2.688e+11	4.965e+09	4.966e+09	9.630e+06	9.632e+06
0.4165	2.459e+11	5.051e+09	5.052e+09	9.864e+06	9.866e+06
0.4231	2.949e+10	6.154e+08	6.155e+08	1.203e+06	1.203e+06
0.4681	1.778e+13	4.106e+11	4.106e+11	8.053e+08	8.054e+08
0.4846	1.170e+12	2.797e+10	2.798e+10	5.490e+07	5.491e+07
0.4891	1.474e+11	3.557e+09	3.557e+09	6.981e+06	6.982e+06
0.5886	1.692e+12	4.913e+10	4.914e+10	9.601e+07	9.602e+07
0.6044	3.035e+12	9.049e+10	9.050e+10	1.766e+08	1.766e+08
0.6125	1.974e+12	5.965e+10	5.966e+10	1.163e+08	1.163e+08
0.8717	3.648e+10	1.569e+09	1.569e+09	2.952e+06	2.952e+06
0.8845	1.116e+11	4.869e+09	4.869e+09	9.145e+06	9.145e+06

Page : 2
DOS File: 770BIRA.MS5
Run Date: March 12, 2007
Run Time: 2:57:52 PM
Duration: 00:00:00

Energy MeV	Activity photons/sec	Fluence Rate $MeV/cm^2/sec$ No Buildup	Fluence Rate $MeV/cm^2/sec$ With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
TOTALS:	8.524e+13	1.493e+12	1.493e+12	2.874e+09	2.875e+09

MicroShield v5.05 (5.05-00161)
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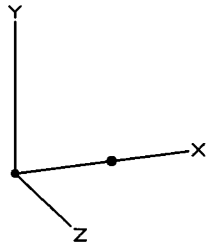
Page : 1
DOS File: 770BCSA.MS5
Run Date: March 12, 2007
Run Time: 2:58:59 PM
Duration: 00:00:00

File Ref: ______
Date: ______
By: ______
Checked: ______

Case Title: Air Transmission Cs
Description: 1/2 inch Air Shielding 1,000 Ci Cs-137
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	9.4600e+002	3.5002e+013
Cs-137	1.0000e+003	3.7000e+013

Buildup
The material reference is : Air Gap

Results

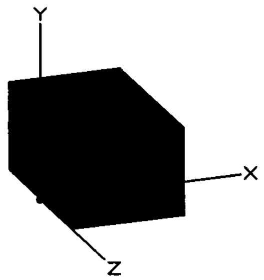
Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	7.246e+11	1.137e+09	1.138e+09	9.471e+06	9.476e+06
0.0322	1.337e+12	2.123e+09	2.124e+09	1.708e+07	1.709e+07
0.0364	4.865e+11	8.734e+08	8.739e+08	4.962e+06	4.965e+06
0.6616	3.149e+13	1.028e+12	1.028e+12	1.993e+09	1.993e+09
TOTALS:	3.404e+13	1.032e+12	1.032e+12	2.024e+09	2.025e+09

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page : 1
DOS File: 770BCSP.MS5
Run Date: March 12, 2007
Run Time: 2:59:47 PM
Duration: 00:00:00

File Ref: ____________
Date: ____________
By: ____________
Checked: ____________

Case Title: Pb Transmission Cs
Description: 1/2 inch Pb Shielding 1,000 Ci Cs-137
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.27 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Ba-137m	9.4600e+002	3.5002e+013
Cs-137	1.0000e+003	3.7000e+013

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0318	7.246e+11	7.884e-147	1.030e-17	6.567e-149	8.576e-20
0.0322	1.337e+12	8.878e-142	1.924e-17	7.145e-144	1.549e-19
0.0364	4.865e+11	2.859e-100	8.010e-18	1.624e-102	4.551e-20
0.6616	3.149e+13	2.284e+11	3.224e+11	4.428e+08	6.250e+08
TOTALS:	3.404e+13	2.284e+11	3.224e+11	4.428e+08	6.250e+08

MicroShield v5.05 (5.05-00161)
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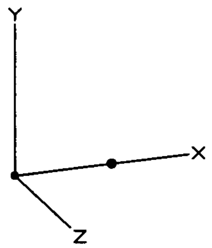
Page : 1
DOS File: 770BSCA.MS5
Run Date: March 12, 2007
Run Time: 3:00:29 PM
Duration: 00:00:00

File Ref: ___________
Date: ___________
By: ___________
Checked: ___________

Case Title: Air Transmission Sc
Description: 1/2 inch Air Shielding 660 Ci Sc-46
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Material	Density
Air Gap	Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Sc-46	6.6000e+002	2.4420e+013

Buildup
The material reference is : Air Gap

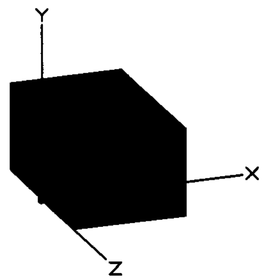
Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.8892	2.442e+13	1.071e+12	1.071e+12	2.010e+09	2.010e+09
1.1205	2.442e+13	1.350e+12	1.350e+12	2.435e+09	2.436e+09
2.0098	2.930e+06	2.906e+05	2.906e+05	4.486e+02	4.486e+02
TOTALS:	4.883e+13	2.421e+12	2.421e+12	4.446e+09	4.446e+09

MicroShield v5.05 (5.05-00161)
AEA Technology QSA, Inc.

Page	: 1	File Ref:	
DOS File:	770BSCP.MS5	Date:	
Run Date:	March 12, 2007	By:	
Run Time:	3:01:13 PM	Checked:	
Duration:	00:00:00		

Case Title: Pb Transmission Sc
Description: 1/2 inch Pb Shielding 660 Ci Sc-46
Geometry: 1 - Point



Dose Points

	X	Y	Z
# 1	1.27 cm	0 cm	0 cm
	0.5 in	0.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Shield 1	1.27 cm	Lead	11.34
Air Gap		Air	0.00122

Source Input
Grouping Method : Actual Photon Energies

Nuclide	curies	becquerels
Sc-46	6.6000e+002	2.4420e+013

Buildup
The material reference is : Shield 1

Results

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.8892	2.442e+13	3.572e+11	4.974e+11	6.704e+08	9.335e+08
1.1205	2.442e+13	5.513e+11	7.420e+11	9.948e+08	1.339e+09
2.0098	2.930e+06	1.513e+05	1.922e+05	2.337e+02	2.968e+02
TOTALS:	4.883e+13	9.086e+11	1.239e+12	1.665e+09	2.272e+09