# SAFETY EVALUATION REPORT

**Docket No. 71-9360**
**Model No. Ten Hole Source Changer**
**Certificate of Compliance No. 9360**
**Revision No. 0**

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## SUMMARY

By application dated October 2, 2018, as supplemented on March18, 2019, Industrial Nuclear Company, Inc. (INC) requested that the Nuclear Regulatory Commission approve the Model No. Ten Hole Source Changer (THSC) package as a Type B(U) package for the transport of radioisotopes as sealed source capsules. NRC staff reviewed the application using the guidance in NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material.” Based on the statements and representations in the application, as supplemented, and the conditions listed in the certificate of compliance (CoC), the staff concludes that the package meets the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71.

## 1.0 GENERAL INFORMATION

### 1.1 Packaging

INC designated the Model No. THSC package as a Type B(U)-96 package. The package, which had a maximum gross weight of 340 pounds, consisted of ten titanium source tubes welded to a titanium hub. INC encased the titanium tubes and hub in an enamel-coated depleted uranium (DU) gamma shield assembly. A welded, 12-inch Schedule 10S stainless steel (SS) pipe with overall dimensions of 12.75-inch diameter x 14.5-inch in height enclosed the DU gamma shield assembly. INC welded a 0.25-inch thick SS plate to the bottom of the pipe and a 0.25-inch thick SS mounting plate to the inner surface of the pipe. INC welded eight short SS channel sections to the inner wall of the pipe to provide lateral support for the DU gamma shield assembly. INC also welded a 4-inch diameter Schedule 40S SS pipe and a 1-inch diameter SS bar to the inner surface of the bottom plate to vertically support the DU gamma shield assembly. INC utilized copper shim stock between the DU-SS interfaces to preclude a galvanic reaction between the two metals. A rigid polyurethane foam, which provides moisture protection for the DU gamma shield assembly, filled the void space between the DU gamma shield assembly and the pipe shell. Ten lock box assemblies, which are located on top of the mounting plate, secured the special form capsules within the DU gamma shield assembly. The THSC design also utilized a 0.375-inch closure lid which is bolted to the package by eight 0.375-inch diameter bolts. To support the package during transport, INC welded three SS channels, which are positioned at 120 degrees intervals, to the bottom plate exterior surface.

### 1.2 Drawings

INC provided Engineering Drawing No: THSC-SAR-TA, Sheets 1-7, Revision 1. The staff reviewed the drawings and determined that they comply with NUREG/CR-5502.

### 1.3 Contents

INC designed the THSC to transport up to a maximum of ten (10) 150 Curie (Ci) Iridium-192 (Ir-192) or Selenium-75 (Se-75) special form capsules for a maximum radioactive content of 1,500 Ci per package. A pigtail assembly attached to the special form capsule, along with a lock box and a lockball, secured each capsule against or near a titanium hub in the DU gamma shield.

## 1.4 Evaluation Findings

Based on a review of the statements and representations in the application, the staff concludes that the package has been adequately described to meet the requirements of 10 CFR Part 71.

## 2.0 STRUCTURAL

The objective of the structural evaluation is to verify that the structural performance of the package meets the regulatory requirements of 10 CFR Part 71.

## 2.1 Description of Structural Design

### 2.1.1 Discussion

INC designated the Model No. THSC package as a Type B(U)-96 package with a maximum gross weight of 340 pounds. The package design consisted of ten titanium source tubes welded to a titanium hub encased in an enamel-coated depleted uranium (DU) casting. A 12-inch Schedule 10S SS pipe, with overall dimensions of 12.75-inch diameter x 14.5-inch in height, which had a 0.25-inch thick SS plate welded to the bottom of the pipe and a 0.25-inch thick SS mounting plate is welded to the inner surface of the pipe enclosed the DU gamma shield assembly. Eight short SS channel sections, which are welded to the inner wall of the pipe, laterally supported the DU gamma shield assembly. A 4-inch diameter Schedule 40S SS pipe and a 1-inch diameter SS bar, which are welded to the inner surface of the bottom plate vertically supported the DU gamma shield assembly. INC installed copper shim stock between the DU-SS interfaces to preclude a galvanic reaction between the two metals. To provide moisture protection for the DU gamma shield assembly, INC filled the void space between the DU gamma shield assembly and the pipe shell with approximately ten pounds of rigid polyurethane foam. Ten lock box assemblies, which are located on top of the mounting plate, secured the special form capsules within the DU gamma shield. INC utilized eight 0.375-inch diameter bolts to secure a 0.375-inch closure lid to the package, and welded three SS channels, which are positioned at 120 degrees intervals, to the bottom plate exterior surface for package support during transport.

INC provided the general assembly drawings of the THSC package in safety analysis report (SAR) Appendix 1.3.1 – *General Arrangement Drawings*. The staff reviewed the drawings for completeness and accuracy, and finds that the geometry, dimensions, material, components, notes and fabrication details were adequately incorporated into the drawings.

### 2.1.2 Design Criteria

INC designed the THSC package to meet the regulatory requirements of 10 CFR 71 and demonstrated the adequacy of its design via full-scale model tests to satisfy the requirements of 10 CFR 71.71 and 71.73. For an evaluation of lifting attachments, INC applied the design criteria that the structural lifting features do not exceed the material yield strength when subjected to the requirements of 10 CFR 71.45(a).

### 2.1.3 Buckling

INC stated that there is no buckling concern for the DU gamma shield based on the results of the normal conditions of transport (NCT) and hypothetical accident conditions (HAC) full-scale model tests. The staff reviewed the results of the free and puncture drop tests provided in SAR Section 2.7.1 and confirmed that the DU gamma shield did not buckle due to free or puncture drops. Therefore, buckling of the DU gamma shield is not a concern for NCT and HAC.

### 2.1.4 Weights and Centers of Gravity

INC stated that the maximum gross weight of the THSC package is 340 pounds and that the center of gravity of the assembled package is approximately 7.3 inches above the bottom of the package along the vertical centerline axis.

## 2.2 Materials

### 2.2.1 Materials Selection

For packaging components that are Important to Safety, Quality Category A or B items, an appropriate material standard is required to be specified for the component (e.g., ASTM). For the components that are classified as Quality Category C or Not Important to Safety, a national standard is not required for the item. In response to a request for additional information (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19080A089), INC revised the general arrangement drawings to include the Quality Category levels in accordance with the guidance from NRC Regulatory Guide 7.1, Rev. 3. The staff finds that the material specifications required for ITS Categories acceptable.

INC fabricated the THSC package using austenitic SS, DU, and carbon steel. INC stated in SAR Section 2.1.2.2.1 that each material had previously survived drop and puncture tests at temperatures between -49˚F and -23˚F for the INC package OP-100 (Docket No. 71-9185). INC also stated in SAR Section 2.6.2 that these structural materials showed no negative effects after undergoing cold tests at temperatures less than -40˚F (-40˚C) for several hours. The staff reviewed the properties for these materials and determined that they do not undergo a ductile-to-brittle transition in the temperature range of interest [i.e., down to -40°F (-40°C)]. Therefore, the staff finds the basis for low temperature structural performance acceptable.

INC primarily evaluated the THSC package by testing. However, for evaluations performed by analysis, INC obtained temperature dependent material properties primarily from Section II, Part D, of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code. Since INC used both Type 304 and Type 316 SS in fabricating the package, INC used the Type 304 SS properties in their analyses because Type 316 SS has both a greater yield strength and a greater ultimate strength. Staff finds the use of these material properties appropriate. In fabricating the THSC, INC utilized conventional metal forming and joining techniques. INC also procured materials in accordance with the standards delineated on the drawings in SAR Appendix 1.3.1, *General Arrangement Drawings.* INC qualified all welding procedures and welding personnel in accordance with Section IX of the ASME Boiler B&PV Code. The staff finds the use of standard ASME data acceptable.

Since the structural integrity of the package is established by testing, the melting temperatures for the package components, which are primarily of SS pipes and plates welded into an assembly surrounding a DU gamma shield assembly, established the pertinent temperature limits for the fire-based HAC. INC stated in SAR Section 3.4.2 that the DU and SS melting temperatures, 2,071°F (1,133°C) and 2,800°F (1,538°C) respectively, are higher than the 1472°F (800°C) HAC fire temperature. The staff finds the temperature limits imposed acceptable.

### 2.2.2 Chemical and Galvanic Reactions

Because there was no rupture of the welded body structure from the free drop and puncture tests, INC stated that the thermal test was not necessary. Therefore, INC neither performed the HAC fire test described in 10 CFR 71.73(c)(4) nor performed a HAC thermal analysis of the package. Consequently, staff requested information demonstrating that the DU shield assembly does not oxidize. In their response, INC stated that four conditions are required for oxidation of DU to occur: (1) melting of polyethylene pipe plugs; (2) damage to the polyurethane foam; (3) availability of oxygen to oxidize the DU shield; and (4) a DU metal temperature above the DU oxidation temperature. INC analyzed the impact of these four conditions on the THSC package using thermal test results for the IR-100 package. INC tested the IR-100 in accordance with the HAC requirements of 10 CFR 71.73(c)(4) (ADAMS Accession No. ML15230A241). The IR-100 thermal test demonstrated that charred polyurethane foam remained in the package around the DU shield. The test results also showed no significant DU oxidation of the package. Therefore, INC asserted that the THSC DU shield would not oxidize under HAC. INC implied that the presence of the charred polyurethane foam inhibits oxidation of the DU gamma shield by restricting the flow of oxygen to the DU gamma shield (ADAMS Accession No. ML19080A089). However, to support their assertion, INC provided neither test data for the polyurethane foam nor an assessment of oxygen transport kinetics.

To verify INC's conclusion, the staff reviewed References 1, 2 and 3 in SER Section 2.13. Based upon its review of these references, staff used a maximum DU oxidation rate of approximately 1.9 mm/hr at 800°C as reported in Reference 2. The staff assumed the DU shield assembly remained at a temperature of 800°C for approximately 2.5 hours. The staff explained why this time frame is bounding in SER Section 3.4.3. Using the 1.9 mm/hr oxidation rate and the 2.5 hour time period, the staff approximated the total material loss for the DU shield to be 4.75 mm. In determining this value, the staff identified a number of conservatisms in applying the laboratory test data to the THSC package. First, since oxidation rates generally follow the Arrhenius equation EXP(-Q/[RT]) where Q is activation energy, R is gas constant, and T is absolute temperature, the oxidation rate will decrease as the temperature decreases. Using any of the reference data in the Arrhenius equation, staff noted that the oxidation rate decreases by a factor of approximately three between 800°C and 400°C. Second, the DU samples discussed in the references had high surface area to volume ratios compared to the THSC DU gamma shield. Since oxidation occurs on the surface, the oxidation rate will decrease as the surface area to volume ratio decreases. Staff scaled the test results to mimic a hemispherical mass to approximate the THSC DU gamma shield and noted that the surface area to volume ratio for the THSC decreases by a factor of approximately three from the laboratory test data.

In addition to evaluating the potential oxidation of the DU gamma shield assembly, the staff reviewed the chemical properties of the materials used to fabricate the THSC and determined that no chemical, galvanic, or other reactions are expected from either the passive SS or the enamel paint. The staff also agreed with INC's statement in SAR Section 2.2.2. that the use of copper shims prevents a eutectic reaction from occurring at the DU and SS interfaces. In addition, based on the dose rate estimated by INC, the staff determined that any gas generation by the radiolysis of water (e.g., atmospheric moisture) will not pose a safety issue.

## 2.3 Fabrication and Examination

### 2.3.1 Fabrication

INC stated that the THSC package will be fabricated using conventional metal forming and joining techniques. In addition, INC stated that all welding procedures and welding personnel will be qualified in accordance with ASME B&PV Section IX. The staff reviewed SAR Appendix 1.3.1 – *General Arrangement Drawings* and finds that the fabrication methods of the THSC package using the ASME B&PV Code are acceptable.

### 2.3.2 Examination

INC provided acceptance tests and maintenance programs in SAR Section 8 that included requirements for visual examinations and measurements of the THSC package. INC stated that the primary safety function of the THSC package is to provide gamma shielding of the special form radioactive material; therefore, INC committed to examining each DU gamma shield by performing both a shielding test and an ultrasonic test, as discussed in the SAR Section 8.1.6 - Shielding Tests and SAR Section 8.1.8 - Miscellaneous Tests, respectively, prior to being used in the fabrication of a THSC package. In addition, as identified in SAR Appendix 1.3.1 – *General Arrangement Drawings*, INC stated that all welds are visually inspected in accordance with AWS D1.6. The staff reviewed the testing and maintenance programs outlined in the SAR as well as the SAR drawings. Staff finds the examination requirements provided by INC reasonable.

## 2.4 General Requirements for all Packages

### 2.4.1 Minimum Packaging Size

INC stated that the smallest dimension of the THSC package is approximately 12.5 inches which is greater than the minimum dimension of 4 inches in 10 CFR 71.43(a). Staff reviewed the drawings in Appendix 1.3.1, *General Arrangement Drawings* and confirmed the minimum THSC package dimension is 12.5 inches. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.43(a).

### 2.4.2 Tamper-Indicating Features

INC incorporated a tamper-indicating seal into the THSC package that is attached to the closure lid bolts to ensure that tampering with the package by unauthorized individuals can be detected. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.43(b).

### 2.4.3 Positive Closures

INC provided positive closure of the THSC package by a bolted closure lid. INC also utilized lock box assemblies, which conform to the requirements of 10 CFR 34.22, to access the special form contents. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.43(c).

### 2.4.4 Valves

INC stated that the THSC package does not contain any valves. Therefore, the staff finds that the application satisfies the regulatory requirements of 10 CFR 71.43(e).

### 2.4.5 Venting

INC stated that the THSC package does not include any features which allow continuous venting during transport. Therefore, the staff finds that the application satisfies the regulatory requirements of 10 CFR 71.43(h).

## 2.5 Lifting and Tie-Down Standards for All Packages

### 2.5.1 Lifting Devices

INC designed the THSC package to be lifted by attaching either a standard lift ring or other standard lifting component to two 8-32 UNC threaded holes in the closure lid. INC calculated a maximum induced shear stress for the internal threads due to lifting using both the NCT hot bounding temperature of 197ºF and the yield strength (25,000 psi) of Type 304 steel in the calculation. In addition, INC applied both a reduction factor of 0.6 for the shear failure mode and a minimum required factor of safety (FS) of 3.0. The results of the calculation indicated the THSC package has a margin of safety of 1.72 which is equivalent to a FS of 4.72. Based on the review of the analysis and results, the staff finds the lifting device of the THSC package acceptable. Therefore, staff finds that the application satisfies the regulatory requirements of 10 CFR 71.45(a).

### 2.5.2 Tie-Down Devices

INC stated that the THSC package does not require an evaluation for the tie–down devices because the package has no integral tie–down devices in the package. The staff confirmed the statement. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.45(b).

## 2.6 Normal Conditions of Transport

Structural members of the THSC package shall meet the regulatory requirements of 10 CFR 71.71. INC performed a series of full-scale model tests to demonstrate the compliance with the 10 CFR 71.71 NCT regulatory requirements. The details of the full-scale model tests are provided in SAR Appendix 2.12 - Certification Tests.

### 2.6.1 Heat

INC calculated the maximum peak ambient temperature for any THSC package component to be 100°F. To maximize deformation, INC exposed the THSC package to a temperature greater than 150°F for several hours in an environmental chamber in order to raise the test unit temperature above 100°F prior to the certification drop tests. After performing the free and puncture drop tests at package temperatures higher than 100°F, the test units suffered neither significant damage nor loss in operational capability. Therefore, staff finds that the THSC package is unaffected by an ambient temperature of 100°F, and that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(1).

2.6.2. Cold

INC stated that the THSC package was exposed to temperatures less than -20°F for several hours in an environmental chamber prior to the certification drop tests without negative effects. Performance of the free and puncture drop tests at package temperatures less than -20°F demonstrated that the THSC shielding integrity was maintained. It also demonstrated that the SS and DU packaging components are not susceptible to brittle fracture. In addition, INC pointed out that a similar package (i.e., INC's OP-100 package), which the NRC staff previously reviewed and accepted, had been exposed to ambient temperatures less than -40°F for several hours in an enclosure without any negative effects. Based on these physical observations, INC concluded that the THSC package is unaffected by an ambient temperature of -40°F. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(2).

2.6.3 Reduced External Pressure

INC stated that the THSC package does not have a pressure boundary. Therefore, the effect of reduced external pressure is not applicable. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(3).

2.6.4 Increased External Pressure

INC stated that the THSC package does not have a pressure boundary. Therefore, the effect of increased external pressure is not applicable. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(4).

2.6.5 Vibration

INC stated that the THSC package will not experience any damage or detrimental effects due to vibration because:

(i) the THSC package is a welded SS package with a closure lid, which is secured to the package body by hex head cap screws, and the lock boxes are secured to the SS mounting plate with SS socket head cap screws;
(ii) the bolted lock box assemblies, which are utilized on other INC licensed packages, have been subjected to both the NCT tests as well as rugged field use since 1982 without incident; and
(iii) the welded package is extremely stiff as evidenced by the certification drop testing.

Based on this field experience and the certification testing, INC concluded that the THSC package will not experience any damage or detrimental effects due to vibration. The staff reviewed INC's evaluation and finds it acceptable. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(5).

2.6.6 Water Spray

INC stated that the water spray test will have a negligible effect on the package due to the SS materials utilized in constructing the package. Since the water spray test is primarily intended for packaging relying on material that either absorb water or material bonded by water soluble glue, staff agrees the water spray test is not applicable because the THSC package external surfaces are fabricated entirely of SS material. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(6).

2.6.7 Free Drop

INC performed a full-scale model drop test for the THSC package to demonstrate compliance with the 10 CFR 71.71 requirements. INC performed an NCT, 4 ft. free drop test on a THSC certification test unit (CTU) with impact on the package bottom and provided the test results in SAR Appendix 2.12.1 - Certification Tests. INC stated that there was no visible deformation observed to the CTU after the drop test. In addition, INC stated that radiation surveys following all certification testing demonstrated the ability of the THSC packaging to maintain its shielding integrity. The staff reviewed the results of the test provided in Appendix 2.12.1 and confirmed INC's findings. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(7).

2.6.8 Corner Drop

INC stated that the corner drop test is not applicable to the THSC package because the THSC package is not composed of fiberboard or wood materials. The staff agrees that a corner drop test is not applicable to the THSC package. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(8).

2.6.9 Compression

For packages weighing 11,000 lbs or less, 10 CFR Part 71.71(c)(9) requires that the package be subjected to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported for a 24-hour period. Since the gross weight of the THSC package is less than 11,000 lbs, INC applied a 1,652-pound compressive force, which is equal to five times the gross package weight, to the THSC package while sitting in its normal vertical position for a period of 24 hours. INC stated that there was neither visible deformation nor damage observed to the THSC test unit after the compression test. SAR Figure 2.6-4 showed a view of the THSC compression test. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(9).

2.6.10 Penetration

INC puncture tested the THSC package as discussed in SER Section 2.7.3 below. INC stated that there was no visible damage observed to the THSC test unit due to the puncture drop test. Because the puncture drop test produced no visible damage, INC asserted that performance of the 10 CFR Part 71.71(c)(10) penetration test, which requires that the hemispherical end of a vertical steel cylinder of 1.25 inch diameter and 13-pound mass be dropped from a height of 40 inches onto the exposed surface of the package that is expected to be most vulnerable to puncture, was unnecessary. The staff reviewed the results of the test provided in Appendix 2.12.1 and confirmed INC's findings. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.71(c)(10).

## 2.7 Hypothetical Accident Conditions

INC evaluated the THSC package for HAC of free drop, crush, puncture, fire and water immersion as required by 10 CFR 71.73. The package was evaluated by performing a series of full-scale model drop tests. INC performed a total of seven NCT and HAC model tests. Table

2.7 below summarizes the THSC CTU tests and results. INC provided more details of the model tests in SAR Appendix 2.12.1 - Certification Tests.

Table 2.7- Summary of THSC Certification Test Unit (CTU) Tests and Results

| **Test No.** | **Test Description (Certification Test Unit No.)** | **Test Unit Angular Orientation (Longitudinal Axis, 0° = upright)** | **Test Unit Angular Orientation (Circumferential Axis, 0° = as marked)** | **Test Results** |
|---|---|---|---|---|
| 1 | 4 foot, bottom down (CTU-1) | 0° | N/A | No visible deformation of channels on bottom |
| 2 | 30 foot, bottom down (CTU-1) | 0° | N/A | Bottom channels deformed into inner cavity about ¼ inch |
| 3 | 30 foot, top down, CG-over comer (CTU-1) | 121.7° | N/A | Impacted top edge, deformed about 2 inches, outer shell deformed outward about 9/16 inch, two (2) lid bolts failed |
| 4 | 30 foot, top down (CTU-2) | 180° | N/A | Center of lid deformed about ¼ inch, lift ring damaged ,outer shell deformed about 0.03 inch |
| 5 | 30 foot, side drop (CTU-2) | 90° | N/A | Body deformed about 0.2 inch deep and 3 ¾ inch wide flat |
| 6 | Puncture drop, top down, CG-over-comer (CTU-1) | 120° | 0° | Bar struck previous free drop damage, no additional damage noted |
| 7 | Puncture drop, side (CTU-2) | 90° | N/A | Bar struck inner mounting plate/shell joint, no additional damage noted |

2.7.1 Free Drop

INC dropped multiple CTUs in multiple impact orientations to comply with 10 CFR 71.73(c)(1) which requires that structural adequacy of a package be demonstrated by a free drop through a distance of 30 ft onto a flat, unyielding, horizontal surface in a position for which maximum damage is expected. See Test No 2 thru No. 5 in Table 2.7 above.

INC carefully examined the package after each drop test. INC stated that the HAC free drop testing of the CTUs were successful and that the test results, shown in Table 2.7, indicate the THSC package is adequately designed to withstand the HAC 30 ft free drop event in the worst-case orientation. INC summarized the significant results of the free drop testing as follows:

(i) there was no significant damage to the welded package structure from the free drop impacts;
(ii) there was no evidence of distortion or damage to the lock boxes; and
(iii) there was no rupture of the SS body.

The staff confirmed INC's findings after reviewing the model test results in SAR Section 2.7.1 and Appendix 12.1. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(1).

2.7.2 Crush

Per 10 CFR Part 71.73(c)(2), a crush test is required only when the specimen has a mass not greater than 1,100 lbs, an overall density not greater than $62.4 lb_m/ft^3$ based on external dimensions, and radioactive contents greater than 1000 $A_2$ not as special form radioactive material. Since the density of the THSC is greater than $62.4 lb_m/ft^3$ and its payload is special form, the dynamic crush test for the THSC package is not applicable. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(2).

2.7.3 Puncture

INC dropped multiple CTUs in multiple impact orientations to comply with 10 CFR 71.73(c)(3) which requires that structural adequacy of a package be demonstrated by a free drop, in a position for which maximum damage is expected, through a distance of 40 inches onto a solid, cylindrical, mild steel bar with the following characteristics:

1) the bar must be six inches in diameter with a minimum length of eight inches,
2) the length of the bar will cause maximum damage to the package,
3) the top of the bar must be horizontal with its edge rounded to a radius of not more than 0.25 inch, and
4) the long axis of the bar must be mounted perpendicularly to an essentially unyielding, horizontal surface.

INC carefully examined the package after each drop test. See Test No. 6 and No. 7 in Table 2.7 above. INC stated that the HAC puncture drop testing of the CTUs was successful and the test results indicated that the THSC package is adequately designed to withstand the HAC puncture drop event. INC summarized the results of the puncture drop testing as follows:

(i) there was no evidence of any damage to the THSC body due from impact with the puncture bar;
(ii) there was no evidence of distortion or damage to the lock boxes; and
(iii) there was no rupturing of the SS body.

The staff confirmed INC's findings after reviewing the test results in SAR Section 2.7.3 and Appendix 12.1. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(3).

2.7.4 Thermal

Although 10 CFR 71.73(c)(4) requires that the structural adequacy of a package be demonstrated by a thermal (fire) test, in which a package is exposed to a hydrocarbon fuel and air fire with an average temperature of 1475°F for 30 minutes, INC justified not performing a thermal (fire) test as follows:

(i) the free drop and puncture tests presented in SAR Sections 2.7.1 and 2.7.3 indicate that there was no rupturing of the THSC body that would have directly exposed the DU gamma shield to the fire environment;
(ii) the structural and shielding materials have melting temperatures of 2,800°F and 2,071°F, respectively, which are significantly above the specified fire temperature of 1,475°F; and
(iii) combustion of the closure lid gasket and the non-structural polyurethane foam which fills the cavity around the DU gamma shield for moisture protection (i.e., the only combustible materials in the THSC package) has no effect on the structural performance of the THSC.

Although staff agreed with INC's findings, the staff requested additional information regarding oxidation of the DU gamma shield assembly. After reviewing INC's response to this information request, the staff performed confirmatory oxidation and shielding calculations. Based on the staff's safety evaluations provided in SER Sections 2.2, 3.4.3 and 5.4, the staff determined that the THSC DU shield assembly is not negatively impacted by oxidation. Therefore, the staff finds that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(4).

2.7.5 Immersion - Fissile Material

Because the THSC package does not transport any fissile material subject to the requirements of 10 CFR 71.55, INC stated that HAC immersion test for fissile materials is not applicable. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(5).

2.7.6 Immersion - All Packages

INC stated that the THSC package does not have a pressure boundary. Therefore, the effect of external pressure due to immersion per 10 CFR 71.73(c)(6) is not applicable. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.73(c)(6).

2.7.7 Deep Water Immersion Test

INC stated that the deep water immersion test, which requires that a Type B package containing more than $10^5$ $A_2$ must be designed so that its undamaged containment system can withstand an external water pressure of 290 psi for a period of not less than 1 hour without collapse, buckling, or in-leakage of water per 10 CFR 71.61, is not applicable because the THSC package does not contain more than $10^5$ $A_2$ quantities of radioactive material. Staff reviewed the THSC contents and agrees that the THSC does not contain more than a $10^5$ $A_2$ quantity of radioactive material. The staff finds that the application satisfies the regulatory requirements of 10 CFR 71.61.

2.7.8 Summary of Damage

INC stated that the results of its evaluations, as reported in SAR Sections 2.7.1 through 2.7.7, indicated that damage to the THSC package during the full-scale model 30 ft free drop and 40 inch pin puncture tests are minimal, and do not diminish the package's shielding ability. The shielding remains intact to satisfy the accident shielding criteria. Based on an assessment of the damages above, the staff agrees with INC's conclusion that the THSC package can safely withstand the HAC free drops and punctures. The staff finds that the application meets the regulatory requirements of 10 CFR 71.73.

## 2.8 Accident Conditions for Air Transport of Plutonium

INC stated that the 10 CFR 71.74 regulatory requirements associated with the accident conditions for air transport of plutonium are not applicable because the THSC does not transport plutonium. The staff agrees with INC's assessment and finds that the application satisfies the regulatory requirements of 10 CFR 71.74.

## 2.9 Accident Conditions for Fissile Material Packages for Air Transport

INC stated that the 10 CFR 71.55(f) regulatory requirements associated with the air transport of fissile material are not applicable because the THSC does not transport fissile material in the THSC package. The staff agrees with INC's assessment and finds that the application satisfies the regulatory requirements of 10 CFR 71.55(f).

## 2.10 Special Form

INC stated that the contents of the THSC package are either special form Ir-192 or Se-75 source capsules. INC provided the special form certifications, which demonstrate compliance with the in 10 CFR 71.75 test requirements for qualification as special form material, for the Ir-192 or Se-75 capsules that would be transported in the THSC package in SAR Section 2.10. The staff determines that the application satisfies the 10 CFR 71.75 regulatory requirements for special form.

## 2.11 Fuel Rods

The THSC package does not transport of fuel rods. Thus, INC did not need to consider the effects of the fuel rods for the accident scenarios.

## 2.12 Evaluation Findings

On the basis of the review of the statements and representations in the application, the staff concludes that the THSC package is adequately described and evaluated to demonstrate that its structural capabilities meet the regulatory requirements of 10 CFR Part 71.

## 2.13 DU Oxidation References


1. J.C. Elder and M.C. Tinkle, Oxidation of Depleted Uranium Penetrators and Aerosol Dispersal at High Temperatures, LA-8610-MS, Los Alamos Scientific Laboratory, 1980.

2. R.K. Hillard, Oxidation of Uranium in Air at High Temperatures, HW-58022, General Electric, 1958.

3. J. Mishima, M.A. Parkhurst, R.I. Scherpelz and D.E. Hadlock, Potential Behavior of Depleted Uranium Penetrators under Shipping and Bulk Storage Accident Conditions, PNL-5415, Pacific Northwest Laboratory, 1985.

## 3.0 THERMAL

The objective of this review is to verify that the thermal performance of the package design has been adequately evaluated for the thermal tests specified under NCT and HAC, and that the package design meets the thermal performance requirements of 10 CFR Part 71. This application was also reviewed with consideration of the thermal acceptance criteria listed in Section 3.4 of NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

### 3.1 Description of Thermal Design

Design Features

In the application, Industrial Nuclear Company, Inc. (INC) stated that the THSC is a Type B transportation package designed to transport up to ten special form Ir-192 or Se-75 source capsules. The package consists of a welded circular shell, a bolted closure lid, a welded mounting plate with ten lock box assemblies, a DU gamma shield, and interior polyurethane foam. INC explained that the primary purpose of the polyurethane foam is to provide moisture protection for the DU gamma shield and that it does not act as thermal insulation. The lock boxes maintain the contents within the package DU shield. Since the payload is designated as special form, the THSC design provides no containment for the contents. Staff finds that the THSC thermal design description is acceptable and applicable for the thermal evaluation.

Contents Decay Heat

INC stated, in SAR Section 3.1.2, that the THSC package may contain up to 1,500 Ci of Ir-192 or Se-75, which have decay heats of 7.03 x $10^{-3}$ W/Ci and 2.41x$10^{-3}$ W/Ci respectively, in special form. For the maximum package content of 1,500 Ci, Ir-192 produced a maximum decay heat of 10.55W which INC used throughout the analysis. Staff reviewed SAR Section 3.1.2 and finds the description of the decay heat is acceptable because the decay heat of Ir-192 bounds that of Se-75 by 2.92 times, and because the 10.55W decay heat is the maximum heat load for the package.

### 3.2 Material Properties and Component Specifications

Material Properties
As discussed in SAR Chapter 2 and evaluated in Section 2 of this SER, INC established the package structural integrity by testing. INC identified that the main structural and shielding materials of the package are SS and the DU gamma shield. INC reported the melting temperatures of these materials as 2,800°F and 2,071°F, respectively, in SAR Chapter 2.7.4. Staff confirmed the melting points of SS and DU gamma shield. Staff also investigated the DU properties and determined the DU gamma shield has an oxidation temperature of approximately 752°F (400°C).

Component Specifications
Per SAR Section 2.1.2.2.1, both structural and shielding materials (SS and the DU gamma shield) have been tested to temperatures below -20 °F with no loss of structural or shielding

capabilities, as evaluated in Sections 2 and 6 of this SER. Staff finds the description in SAR Section 2.1.2.2.1 acceptable.

## 3.3 Thermal Evaluation under Normal Conditions of Transport

Heat and Cold

INC stated, in SAR Section 3.3.1, that a very detailed NCT thermal analysis of the package and internals is unnecessary due to this low decay heat. INC also asserted that the internal temperatures will closely match those on the surface of the package. INC created a 3D quarter-symmetry model to determine the maximum package temperatures with and without insolation.

SAR Sections 2.5 and 3.3.1 identified that the maximum peak surface temperature of any THSC component in an ambient environment of 100°F (38°C) and full insolation is between 190 and 197°F (88 and 92°C) and that it occurred on the closure lid. INC calculated the package surface temperature, when loaded with the maximum content decay heat in still air and shade, to be 112°F (45°C). This peak surface temperature does not exceed the 122°F (50°C) nonexclusive use temperature limit. Therefore, the requirements of 10 CFR 71.43(g) are satisfied.

Staff reviewed SAR Section 3.3 and Figures 3.3-1 and 3.3-2 and finds that the maximum component temperatures described in SAR Section 3.3.1 for NCT do not surpass the NCT component temperature limits.

Per 10 CFR 71.71(c)(2), INC evaluated the effect of an ambient temperature of -40°F (-40°C) in still air and the shade on the package. For the cold condition, INC stated the package surface temperature will equal the low temperature ambient condition of -20°F and -40°F (-40°C). As discussed in SAR Chapter 2.6.4, INC exposed the THSC to temperatures less than -20 °F (-29 °C) for several hours in an environmental chamber without negative effects.

Staff finds that the THSC package contains a DU gamma shield and SS housing, which can sustain temperatures as low as -40°C (-40°F). Therefore, the THSC is unaffected by an ambient temperature of -40°F (-40°C).

Maximum Normal Operating Pressure (MNOP)

INC stated, in SAR Section 3.1.4, that the THSC does not contain any pressure boundaries because containment of the radioactive material is provided by the special form payload and gas can freely move from the internal cavity to the environment during all phases of operation.

Staff reviewed the NCT analyses and confirmed that the NCT do not result in a pressure that can diminish packaging structural and/or shielding effectiveness and that there are no internal pressures to be determined for MNOP.

## 3.4 Thermal Evaluation under Hypothetical Accident Conditions

Subpart F of 10 CFR 71 requires performing a thermal test in accordance with the requirements of 10 CFR 71.73(c)(4), which requires a package to be exposed to a hydrocarbon fuel/air fire with an average temperature of 1,475°F (800°C) for 30 minutes.

### 3.4.1 Maximum Temperatures and Pressure

INC stated in SAR Section 3.4 that (a) the only combustible materials in the THSC packaging (i.e., the polyurethane foam and the neoprene rubber lid gasket) are not structural or shielding materials, (b) the structural and shielding materials (i.e., the SS and DU shield) have, as described above, melting temperatures of 2800°F (1538°C) and 2071°F (1133°C) respectively, and (c) the maximum package temperature under HAC is more than 500°F below the lowest melting point of the SS and DU gamma shield components. Thus, INC concluded that the package continues to perform as required for safety when exposed to the HAC fire environment of 1,475°F (800°C) for 30 minutes.

INC stated in SAR Section 3.4.3 that the package containment is provided by the special form payload, and gas can freely move from the internal cavity to the environment during all phases of operation, therefore determination of internal pressure is not required.

Staff recognizes that the melting temperatures of SS and DU shield are significantly above the specified fire temperature of 1,475°F (800°C). Therefore, staff agrees that there is no melting of the THSC structural materials (i.e., the SS and DU). Staff also agrees that combustion of the foam and the neoprene rubber lid gasket, which are not structural or shielding materials, will have no effect on the THSC structural and shielding functions.

### 3.4.2 Maximum Thermal Stress

INC stated, in SAR Section 3.4.4, that the effects of thermal stresses on the THSC package, due to the HAC fire exposure, are minimal for the following reasons:

(a) the THSC package is a welded, austenitic SS package, which will thermally expand uniformly, resulting in no significant thermal stresses, and

(b) the DU gamma shield is not rigidly restrained in the THSC SS structure

INC designed the DU gamma shield to be supported within the welded body of the package by SS components. At each support point in the package, INC installed a copper shim between the DU and the SS. SAR section 3.4.4 states that the copper shims have a Rockwell F hardness of 43-57 while the Type 304 SS has a Rockwell B hardness of 92 and the DU metal has a Rockwell B hardness value of 90.7. Since the copper shim material is softer than either the DU gamma shield or the SS, INC concluded that the formation of excessive thermal stresses in the THSC package from the HAC fire event will be precluded because the copper shims will plastically deform if any differential thermal expansion were to occur between the SS and the DU gamma shield.

Staff finds that based on the material hardness data provided, the presence of the softer copper shims at each SS and DU gamma shield interfaces and the fact that no external restriction exists to prevent SS expansion, the maximum fire temperature for the welded package would not result in any detrimental thermal stress conditions that affect either the shielding or the structural safety functions of the package.

### 3.4.3 DU Gamma Shield Oxidation

INC stated in SAR Section 2.7.4 that the potential oxidation of the DU shield could reduce shielding effectiveness. Under the HAC fire exposure, four conditions would be required for oxidation of the DU metal surface to occur: (1) the polyethylene pipe plugs in the body of the package must melt; (2) the polyurethane foam must be consumed; (3) oxygen must be able to reach the DU gamma shield surface; and (4) the DU shield temperature must exceed the oxidation temperature for an extended period of time.

INC evaluated the potential for the occurrence of all four conditions during the thermal HAC exposure of the THSC package based on previous experience with the IR-100 Exposure Device [1] which was physically tested in accordance with the HAC thermal test of 10 CFR 71.73(c)(4) prior to receiving a Certificate of Compliance from the NRC. The test results revealed that for the IR-100 Exposure Device, the charred foam remained in-place around the DU gamma shield and no significant oxidation of the DU gamma shield had occurred. The DU gamma shield did not experience any deterioration of the shielding effectiveness from the thermal test.

INC noted, in their RAI response, that compared to the IR-100, the THSC has (a) five times the polyurethane foam mass, (b) more than six times the DU gamma shield mass, and (c) the minimum distance from the THSC outer package surface to the DU gamma shield surface is 0.845 inches versus the zero inches of clearance between the IR-100 outer package surface and the DU gamma shield surface (i.e., the DU shield directly contacts the sides of the metallic package body)

Based upon this comparison, INC asserted that the peak temperature from the 30-minute thermal test for the THSC DU shield is bounded by the peak temperature experienced by the DU gamma shield in the IR-100 Exposure Device, which did not experience any deterioration in shielding effectiveness, during the thermal test. INC also asserted that the charred foam would provide an insulating benefit to the DU gamma shield and that the foam char would restrict oxygen flow to the DU gamma shield surface to some degree. Therefore, based upon the information provided in their RAI response and the fact that the certification drop tests did not expose the polyurethane foam or THSC DU gamma shield for oxidation (see SAR Section 2.7.4), INC concluded that the THSC satisfies the requirements of 10 CFR 71.73(c)(4).

The staff reviewed both the polyurethane foam and the DU gamma shield mass comparisons, as well as the distances from the outer package surface to the DU gamma shield surface, between the smaller, lighter IR-100 Exposure Device and the larger, heavier THSC package. Considering the comparison, the staff accepts that the peak temperature from the 30-minute thermal test for the THSC DU shield would be bounded by the peak temperature experienced by the DU gamma shield in the IR-100 Exposure Device, which did not experience any deterioration of the shielding effectiveness, from the HAC thermal test.

Based on (a) temperature bounding correlation between THSC package and IR-100 package, (b) post-fire-test examination which showed IR-100 DU shield was not appreciably oxidized, and (c) post-fire-test radiation survey which indicated little, if any, degradation of the IR-100 DU shield, the staff confirmed that a THSC DU shield temperature of 800°C for approximately 2.5 hours used in the confirmatory material analysis, as described in SER Section 2.2.2, is conservative for a hypothetical THSC DU shield oxidation. The THSC DU shield would neither remain at a temperature of 800°C nor stay at between a temperature range of 400°C and 800°C for 2.5 hours. Therefore, the material loss of 4.75 mm of the THSC DU shield, predicted from the material confirmatory analysis, is acceptable because the amount of time used in the analysis is conservative.

The results from the staff's confirmatory analyses show that there is no significant loss in weight of the DU gamma shield and that the shielding assembly maintains external radiation dose rates below the limit defined in 10 CFR 71.51(a)(2) and the special form source capsules satisfy the intent of 10 CFR 71.75(a)(3) and 71.75(b)(4), under a postulated HAC fire in which the DU gamma shield was assumed to oxidize. Details of the material and shielding confirmatory analyses are presented in SER sections 2.2.2 and 5.4 respectively.

3.4.4 Accident Conditions for Fissile Material Packages for Air Transport

INC stated in SAR Section 3.4.5 that this section does not apply because the THSC does not contain fissile material. Staff reviewed SAR sections 3.1.2 and 3.4.5 and confirmed that the THSC package does not contain fissile material.

## 3.5 Evaluation Findings

Based on the statements and representations in the THSC package application, the staff concludes that the thermal design has been adequately described and evaluated, that the THSC package satisfies the NCT thermal requirements in 10 CFR 71.71 and the HAC thermal requirements of 10 CFR 71.73(c)(4) and that the special form qualification of the payload capsules demonstrate the contents can withstand the HAC fire without degradation, in compliance with 10 CFR 71.75(b)(4), and that, in general, the thermal performance of the THSC package meets the thermal requirements of 10 CFR Part 71.

## 3.6 References

1. *IR-100 Safety Analysis Report, IR-100 Exposure Device*, Revision 4, Industrial Nuclear Company, Inc., NRC Docket No. 71-9157.

## 4.0 CONTAINMENT

INC stated that containment of the radioactive material is provided by the sealed source capsule construction of the contents. INC provided the source capsule special form certifications in SAR Section 4.0. INC also demonstrated by physical tests that the source remains within the sealed capsule under both NCT and HAC.

Based on a review of the statements and representations in the application, the staff concludes that the containment design has been adequately described and evaluated, and that the performance of the package meets the containment requirements of 10 CFR Part 71.

## 5.0 SHIELDING

The purpose of this evaluation is to verify that the shielding design of the THSC transportation package containing Type B quantities of Ir-192 or Se-75 special form sources meets the dose rate limits set forth in 10 CFR Part 71.47 and 71.51 under NCT and HAC.

## 5.1 Description of the Shielding Design

5.1.1 Packaging Design Features

The INC THSC design utilized a cast, enamel-coated DU shield surrounded by polyurethane foam. A cylindrical SS shell, 14.5 inches high with an external diameter of 12.75 inches, completely encased and supported both the DU and the polyurethane foam. INC evenly distributed ten tubes, which are welded to a titanium hub, within the DU shield and loaded the sources in these tubes. INC designed the THSC to transport a maximum of ten special form capsules containing either 150 Ci of Ir-192 or Se-75. INC secured each special form capsule within the DU shield using a pigtail assembly, which is attached to a lock box bolted to a mounting plate. INC welded the mounting plate to the inner surface of the cylindrical SS shell. INC secured a closure lid to the SS shell using eight bolts. INC also installed three polyethene pipe plugs on the side of the package to allow gases generated when the polyurethane foam burns during the HAC fire to escape the package. Licensing drawings THSC-SAR-TA sheets 1 to 7 showed the structural arrangement and the dimensions of the THSC package design. INC designed the package for non-exclusive use shipments and to have a maximum weight of 340 lbs.

5.1.2 Summary Table of Maximum Radiation Levels

INC demonstrated that the package design meets the regulatory dose rate requirements of 71.47 and 71.51 by physical testing. INC-built two CTUs to evaluate the package against the 10 CFR 71.71 and 71.73 requirements. INC performed direct radiation measurements before and after the free drop and the puncture drop tests of CTU-1 and CTU-2 using Ir-192 to demonstrate compliance with the NCT and HAC dose rate limits prescribed in 10 CFR 71.47 and 71.51 respectively. Staff determined the use of Ir-192 in evaluating the package to be conservative because Ir-192 has a higher source strength, both in number of particles emitted per disintegration and in the particle energy, in comparison with Se-75. INC provided the maximum radiation levels in SAR Table 5.1-1 for non-exclusive use. Staff finds these values comply with the NCT and HAC regulatory requirements in 10 CFR 71.47 and 71.51.

## 5.2 Radiation Source

INC designed the THSC package to transport ten special form Ir-192 or Se-75 sources in titanium tubes welded to a titanium hub.

## 5.3 Shielding Evaluation

5.1.2 Methods

INC based the shielding evaluation on direct measurements using a radiation source which was less than 1500 Ci. INC then adjusted the measured dose rates using the ratio of the maximum activity allowed in the package to the activity used for the direct measurements as described in SAR Sections 2.12.1.7.2.5 and 2.12.1.7.1.6. The dose rates calculated from the direct measurements using these correction factors remained below 200-mrem/hr after the NCT tests and below 1-rem/hr at 1 meter (40 inches) from the package external surface after the HAC tests.

The staff reviewed this approach and finds it acceptable because testing is the most reliable method for demonstrating compliance with the regulations. Also, the staff finds using a smaller source and scaling up to the maximum allowable source acceptable because gamma dose rates are linearly proportional to the source strength for a given shielding material.

5.1.2 External Radiation Levels

INC provided the maximum adjusted THSC package dose rates, which were 180 mrem/hr at the package surface and close to zero mrem/hr at one meter from the package surface, in SAR Table 5.1.1. Staff determined that these values comply with the 10 CFR 71.47(a) requirements for non-exclusive use transport. Since the maximum measured dose rate for the package at one meter was close to zero, staff also determined that these values meet the requirements of 10 CFR 71.51(a)(2).

### 5.4 DU Oxidation

INC stated that, because there was no rupture of the welded body structure from the accumulated free drop and puncture tests, the thermal test was not necessary. Therefore, INC neither performed the HAC fire test described in 10 CFR 71.73(c)(4) nor performed a HAC thermal evaluation of the package. Nevertheless, INC asserted that the DU shield would not oxidize under HAC. To verify INC's conclusion, the staff evaluated the potential oxidation of the DU shield in SER Section 2.2.2. Staff's evaluation concluded that oxidation would remove approximately 4.75 mm from the DU shield assembly. The staff performed confirmatory shielding analyses using the MicroShield software to determine if this amount of DU shield degradation would negatively impact the shielding capabilities of the THSC. The results of the MicroShield calculations show that the THSC package dose rates remain below the 10 CFR 71.51(a)(2) regulatory limits even with the loss of 20 mm of DU shielding.

The results from the staff's analyses demonstrate that there is no significant loss in weight of the DU gamma shield and that its shielding performance is maintained such that no external radiation dose rate exceeds the limit defined by 10 CFR 71.51(a)(2). In addition, the special form source capsules satisfy the intent of 10 CFR 71.75(a)(3) and 71.75(b)(4), under a postulated HAC fire in which the DU gamma shield is assumed to oxidize. See SER Sections 2.2.2 for materials confirmatory analysis.

### 5.5 Evaluation Findings

The staff reviewed the application and performed confirmatory analyses of the package shielding design. Based on its review of the statements and representations provided in the application, as well as staff's confirmatory analyses, the staff determined that there is a reasonable assurance that the THSC package containing the maximum allowable sources as meets the regulatory requirements 10 CFR 71.47 and 71.51.

## 6.0 CRITICALITY

INC stated that the THSC does not transport fissile material, and that this section does not apply. After reviewing the application, staff agrees that the THSC does not transport fissile material regulated under 10 CFR 71.55 and 10 CFR 71.59; therefore, this section does not apply.

## 7.0 PACKAGE OPERATIONS

The objective of this review is to verify that the operating controls and procedures meet the requirements of 10 CFR Part 71 and are adequate to assure that the package will be operated in a manner consistent with its evaluation for approval.

### 7.1 Package Loading

INC provided loading instructions which directed the package user to remove the bolted lid, inspect package components for damage and to replace any damaged package components as well as to functionally test the lock boxes to ensure the lock boxes operated properly.

Subsequently, the loading instructions explained how to load the special form capsules and directed the package user to survey the package to ensure the special form capsules were properly positioned within the package. Next, the loading instructions directed the package user to reattach the bolted lid, install a tamper indicating device and secure the package to the conveyance. Finally, the loading instructions directed the package user to measure radiation levels to ensure the transport radiation limits were not exceeded and to install labels and placards in accordance with 10 CFR Part 49 requirements. Staff reviewed the package loading instructions and determined that they were appropriate.

### 7.2 Package Unloading

INC provided loading instructions which directed the package user to monitor radiation levels to detect damaged packages and outlined how to remove the package from the conveyance. Next, the loading instructions directed the package user to remove the tamper indicating seal and the closure lid. Subsequently, the instructions explained how to remove a special form source from the THSC into either a source changer or camera. Staff reviewed the package unloading instructions and determined that they were appropriate.

### 7.3 Empty Package Preparation for Transport

INC provided loading instructions which directed the package user to prepare and transport empty THSC packages in accordance with the requirements of 49 CFR 173.426, Subpart I. Staff reviewed the package instructions for preparing empty packages for transport and determined that they were appropriate.

### 7.4 Evaluation Findings

Based on its review of the statements and representations in the application, the staff has reasonable assurance that the operating procedures meet the requirements of 10 CFR Part 71 and that these procedures are adequate to assure the package will be operated in a manner consistent with its evaluation for approval

## 8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

SAR Section 8 provided information regarding acceptance testing to verify that each packaging is consistent with the package evaluation in Sections 2 through 6, and a maintenance program to assure that the package maintains its ability to meet the regulatory requirements throughout its service life.

### 8.1 Acceptance Tests

In SAR Section 8.1, INC identified that both visual examinations and measurements of materials of construction, as well as weld examinations during construction, are performed in accordance with the drawings in SAR Appendix 1.3.1 – *General Arrangement Drawings*. INC performed an ultrasonic test of each DU shield assembly prior to developing a radiation profile for each DU shield assembly using Ir-192. INC rejected any DU shield assembly for which ultrasonic testing identified significant voids or defects or which had a radiation profile exceeding exceeds the requirements of 49 CFR §173.441. The staff finds these tests and their acceptance criteria to be acceptable since they are tied to the package design specifications and are supported by the package evaluations.

### 8.2 Maintenance Program

In SAR Section 8.2, INC specified all threaded fasteners are inspected quarterly and the lock boxes are checked prior to each use. In addition, INC radiation surveys performed prior to each shipment ensured that the DU gamma shield maintains its shielding function. The staff finds that these maintenance activities provide adequate assurance that the package will continue to meet the regulatory requirements over the course of its service life in a manner that is consistent with the package evaluations.

### 8.3 Evaluation Findings

Based on its review of the statements and representations in the application, the staff has reasonable assurance that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71, and that the maintenance program is adequate to assure packaging performance during its service life.

## CONDITIONS

In addition to the drawings listed in Section 1.2 and the authorized contents listed in Section 1.3 of this SER, the CoC includes the following conditions of approval:

Condition No. 8: In addition to the requirements of Subpart G of 10 CFR Part 71:

(a) The package shall be prepared for shipment and operated in accordance with the Package Operations in Section 7.0 of the application, as supplemented.

(b) The package must meet the Acceptance Tests and Maintenance Program in Section 8.0 of the application, as supplemented.

Condition No. 9: The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

Condition No. 10: Expiration date: August 31, 2024.

## CONCLUSIONS

Based on the statements and representations contained in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated, and the Model No. THSC package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9360, Revision No. 0.