June 6, 2005

Ms. Lori Podolak, Product Licensing Specialist
Regulatory Affairs Department
AEA Technology/QSA Inc.
40 North Avenue
Burlington, MA 01803

SUBJECT: MODEL NO. 976 SERIES PACKAGES

Dear Ms. Podolak:

As requested by your application dated March 9, 2004, as supplemented January 26, April 18, and May 5, 2005, enclosed is Certificate of Compliance No. 9314, Revision No. 0, for the Model No. 976 Series packages. The staff's Safety Evaluation Report is also enclosed.

AEA Technology/QSA Inc., has been registered as a user of the package under the general license provisions of 10 CFR 71.17. The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact me or Julia M. Barto of my staff at (301) 415-8500.

Sincerely,

/RA/

Robert J. Lewis, Chief
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9314
TAC No. L23719

Enclosures: 1. Safety Evaluation Report
2. CoC. No. 9314, Rev. 0

cc w/encl: R. Boyle, Department of Transportation
James M. Shuler, Department of Energy
RAMCERTS

June 6, 2005

Ms. Lori Podolak, Product Licensing Specialist
Regulatory Affairs Department
AEA Technology/QSA Inc.
40 North Avenue
Burlington, MA 01803

SUBJECT: MODEL NO. 976 SERIES PACKAGES

Dear Ms. Podolak:

As requested by your application dated March 9, 2004, as supplemented January 26, April 18, and May 5, 2005, enclosed is Certificate of Compliance No. 9314, Revision No. 0, for the Model No. 976 Series packages. The staff's Safety Evaluation Report is also enclosed.

AEA Technology/QSA Inc., has been registered as a user of the package under the general license provisions of 10 CFR 71.17. The approval constitutes authority to use the package for shipment of radioactive material and for the package to be shipped in accordance with the provisions of 49 CFR 173.471.

If you have any questions regarding this certificate, please contact me or Julia M. Barto of my staff at (301) 415-8500.

Sincerely,
/RA/
Robert J. Lewis, Chief
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-9314
TAC No. L23719

Enclosures: 1. Safety Evaluation Report
2. CoC. No. 9314, Rev. 0

cc w/encl: R. Boyle, Department of Transportation
James M. Shuler, Department of Energy
RAMCERTS

DISTRIBUTION:
S. Baggett R. Bellamy, I D. Collins, II J. Madera, III B. Spitzberg, IV N. Osgood S. Williams
J. Umana J. Cuadrado M. Rahimi
(closes TAC L23719)
E:\Filenet\ML051570261.wpd Package **ML051570246**
G:\SFPO\JBarto\Aea976\71-9314-r0.wpd *see previous concurrence

OFC	SFPO	E	SFPO	E	SFPO	E	SFPO	E	SFPO	E
NAME	*JBarto		*MDeBose		JChuang		SHelton		AHansen	
DATE	5/24/05		5/25/05		5/26/05		5/26/05		5/26/05	

OFC	**SFPO**	E	SFPO	E	SFPO	E	SFPO	E		
NAME	CBrown		GBjorkman		LCampbell		RLewis			
DATE	5/26/05		5/26/05		5/31/05		6/03/05			

C = COVER E = COVER & ENCLOSURE N = NO COPY OFFICIAL RECORD COPY

SAFETY EVALUATION REPORT
Docket No. 71-9314
Model No. 976 Series Packages
Certificate of Compliance No. 9314
Revision No. 0

TABLE OF CONTENTS

SUMMARY

By application dated March 9, 2004, as supplemented, AEA Technology/QSA Inc., requested approval of the Model No. 976 Series transportation packages as Type B(U)-96. Based on the statements and representations in the application, as supplemented, and the conditions listed below, the NRC has concluded that the package meets the requirements of 10 CFR Part 71.

REFERENCES

AEA Technology/QSA Inc., application dated March 9, 2004.

Supplements dated January 26, April 18, and May 5, 2005.

1.0 GENERAL INFORMATION

1.1 Packaging

The Model No. 976 Series packages are designed for use as transport packages for Type B quantities of special form radioactive material. The general design of the packages consist of a steel jacketed lead and/or depleted uranium shield container housed within a cork lined, stainless steel drum.

Shield Container

The Model No. 976 Series packages house six different inner shield containers. The shield containers are comprised of lead, tungsten, depleted uranium or a combination of these materials. The applicant designates the packages as follows:

Model No.	Shield Container
976A	855
976B	3015
976C	3056
976D	3018
976E	3078
976F	1911

The Model No. 976A version of the package houses the 855 shield container. The 855 shield container consists of an outer carbon steel shell, rigid polyurethane potting material, uranium shield, eight titanium "J" tubes, source stop, top and bottom support plates and a gasketed lid which is secured with eight 3/8" - 16 UNC x 5/8" long stainless steel hex head bolts.

The Model No. 976B version of the package houses the 3015 shield container. The 3015 is a lead shield container surrounded on the sides and partially on the top by an outer stainless steel jacket. The steel jacket incorporates two stainless steel lifting handles. The container includes a lower depleted uranium shielding insert encased in stainless steel, a tungsten capsule holder, an upper lead insert, a lead top shield plug with a stainless steel extension, and a gasketed shield lid which secures to the shield container body by two M10 stainless steel screws and washers.

The Model No. 976C version of the package houses the 3056 shield container. The 3056 is a lead shield container which incorporates stainless steel strapping, handle bosses and lifting handles along with a combination lower depleted uranium insert and upper lead insert with ten stainless steel "J" tubes. The lead insert is partially enclosed by stainless steel. The "J" tubes are covered with tube caps and the tube caps are further covered by a stainless steel "top hat" or lid secured to the container by an M12 steel rod and retaining nut.

The Model No. 976D version of the package houses the 3018 shield container. The 3018 is a lead shield container surrounded on the sides and partially on the top by an outer stainless steel jacket. The steel jacket incorporates two stainless steel lifting handles. The container includes a lower depleted uranium shielding insert encased in stainless steel and upper lead insert with four stainless steel "J" tubes. The "J" tubes are covered with tube caps. The shield inserts are secured to the shield body by means of a stainless steel bracket and two M10 stainless steel bolts and washers. The metal bracket also incorporates a stainless steel disk above the "J" tubes which further protects the tube caps during shipment.

The Model No. 976E version of the package houses the 3078 shield container. The 3078 is a stainless steel encased, depleted uranium shield container which includes two stainless steel lifting handles. The shield container incorporates a stainless steel encased depleted uranium upper shield plug that is inserted into the shield body over an optional stainless steel or aluminum source holder can. The upper shield insert is secured to the shield body by a stainless steel cover bolted above the shield insert by four M8 stainless steel screws.

The Model No. 976F version of the package houses the 1911 shield container. The 1911 is a stainless steel encased, lead shield container which includes a bolted shield lid and an M10 stainless steel lifting eyebolt. The shield lid is secured to the shield container body by four stainless steel M8 bolts and washers. The inner shield cavity incorporates either a depleted uranium upper and lower shield insert, a tungsten upper and lower shield insert or a lead upper and lower shield insert. Additional handling source stainless steel, aluminum or tungsten capsule holders or cans may be used in the shield insert cavities.

Cork Liners

The cork liners are comprised of a combination bottom/side liner and a top liner which fits into the bottom liner after insertion of the shield container.

Drum

The outer drum is a 20 gallon capacity drum with 16 gauge, 0.06 inches thick stainless steel walls. The drum measures 19 3/4-inches in diameter and is 21 1/4-inches tall when assembled. The drum includes a removable lid which is secured in place using a clamp band assembly and four stainless steel lid bolts. The lid bolts are inserted through four holes spaced equidistantly around the diameter of the drum. The drum lid has four stainless steel blocks welded on all four sides to the underside of the lid.

The approximate weight of the package varies when each shield container is inserted as follows:

Model No.	Maximum Content Weight (grams)	Maximum Package Weight (lbs)
976A	176	300
976B	1.2	180
976C	220	180
976D	88	180
976E	3.3	212
976F	3.3	263

1.2 Drawings

This packaging is constructed in accordance with the following AEA Technology, QSA, Inc. Drawings.:

R97608, Rev. C, Sheet 1	20 gallon drum
RCLM009, Rev. B, Sheets 1-2	Band clamp
R97637, Rev. A, Sheet 1	Top inner cork spacer
97623, Rev. A, Sheet 1	Bottom inner cork insert
R97623A, Rev. A, Sheet 1	Bottom inner cork insert, alt.
R97615, Rev. B, Sheet 1	Top outer cork insert
R97616, Rev. B, Sheet 1	Bottom outer cork insert
R976A, Rev. C, Sheet 1	Model No. 976A with 855 shield container
R85590, Rev. E, Sheets 1-6	855 source changer
R976B, Rev. C, Sheet 1	Model No. 976B with 3015 shield container
R3015, Rev. B, Sheets 1-3	3015 shield container
R976C, Rev. C, Sheet 1	Model No. 976C with 3056 shield container
R3056, Rev. B, Sheets 1-4	3056 shield container

R976D, Rev. C, Sheet 1	Model No. 976D with 3018 shield container
R3018, Rev. B, Sheets 1-4	3018 shield container
R976E, Rev. C, Sheet 1	Model No. 976E with 3078 shield container
R3078, Rev. B, Sheets 1-4	3078 shield container
R976F, Rev. B, Sheet 1	Model No. 976F with 1911 shield container
R1911, Rev. B, Sheets 1-8	1911 shield container

1.3 Contents

1.3.1 Type and Form of Material

Iridium-192 as sealed sources that meet the requirements of special form radioactive material.

1.3.2 Maximum Quantity of Material per Package

The activity capacities of the Model No. 976 series packages are as follows:

Model No.	Maximum Capacity - Output Activity* (Ci)
976A	1,000
976B	350
976C	800
976D	500
976E	1,000
976F	1,000

* Maximum activity for Ir-192 is defined as output curies as required in accordance with American National Standard N432-1980, “Radiological Safety for the Design Construction of Apparatus for Gamma Radiography.”

2.0 STRUCTURAL EVALUATION

2.1 Objective

The structural review verifies that the engineering design submitted by the applicant provides reasonable assurance that the structural performance of the packaging, components, and systems important to safety complies with the requirements of 10 CFR Part 71.

2.2 Areas of Review

2.2.1 Description of Structural Design

The Model No. 976 Series packages are designed to transport six distinct shield containers, within which are Type B(U)-96 special form material capsules containing Iridium-192. The shield containers vary in size, however, they all fit securely within the outer drum. Detailed drum and shield container design specifications are provided in Section 1.2 of the Safety Analysis Report (SAR) and design drawings are included in Section 1.4 of the SAR. Depending on the shielding container enclosed within the transportation package, the package will vary in weight from 180 lbs (82 kg) to 300 lbs (136 kg). The weights of the individual shield containers and centers of gravity are indicated on the design drawings.

Sources are loaded into the shield containers using remote handling techniques. The drums lids are secured to the drums with four bolts and a drum clamp band (see AEA Technology, QSA, Drawing Nos. RCLM009, Rev. B, Sheets 1-2, and R97608, Rev. C, Sheet 1). Specific details of the handling and closure systems are described in Section 7 of the SAR.

The applicant evaluated the packaging design by a combination of analyses and a series of tests to demonstrate that the package retains its structural integrity under normal conditions of transport and hypothetical accident conditions. The applicant's package performance acceptance criteria required that test and analysis results must support the assumptions used in the safety evaluations. Miscellaneous structural failure modes including brittle fracture, fatigue, and buckling were also considered.

Personnel qualifications, welding and examination procedures are specified in the drawings in accordance with the requirements of the AWS, ASME, and British Standard welding codes.

The staff reviewed the applicant's evaluation of the structural design and found adequate acceptance with the requirements of 10 CFR 71.31(c), 71.33(a)(2), 71.33(a)(5), 71.33(b)(5), 71.33(b)(6), 71.43(a), 71.43(b), and 71.43(c).

2.2.2 Materials

The applicant provided a general description of the materials of construction in Sections 1.2.1, 1.4 (engineering drawings), and 2.2 of the SAR. The staff reviewed the information contained in these sections and the information presented in the drawings to determine whether the Model No. 976 Series (drum and shield containers) meet the requirements of 10 CFR Part 71. In particular, the following aspects were reviewed: materials properties, applicable codes and standards, drum weld seams, chemical and galvanic reactions, specification, long-term package performance issues, and the suitability of cork liner inserts.

Structural Materials

The outer container for this package is a 20 gallon capacity drum with 16 gauge, 0.06 inch thick austenitic stainless steel shell wall. The properties of this type of steel include high strength, ductility, resistance to corrosion, and metallurgical stability. Because there is no ductile-to-brittle transition temperature in the range of temperatures expected to be encountered prior to or during transport, the susceptibility of this type of steel to brittle fracture is negligible.

There are several shield containers for this package. They can be fabricated from depleted uranium, carbon steel, tungsten, lead, copper, polyurethane foam, and cork. In some shield container designs, copper separators will be used between steel/uranium interfaces to reduce the possibility of a phase transformation.

Based on the material properties presented in the SAR for this package design, the staff concludes that these materials are acceptable for use in the package, and the requirements of 10 CFR Part 71 are satisfied.

Mechanical Properties

Staff reviewed and verified the mechanical properties for the materials of construction contained in Table 2.2a using ASTM Standards and other reference documents. In particular, the staff cross referenced the mechanical properties for steel with the exact type and grade of steel based on the mechanical properties presented in Table 2.2a of the SAR. The applicant did not specify the exact type and grade of austenitic and carbon steel that will be used to fabricate the package in the application. Therefore, the staff has conditioned the certificate of compliance to state that the tensile and yield strength for the materials of construction must comply with the values presented in Table 2.2a of the SAR.

Chemical and Galvanic Reactions

In Section 2.2.2 of the SAR, the applicant evaluated whether chemical, galvanic, or other reactions among the materials and environments would occur. In accordance with 10 CFR 71.43(d), the staff reviewed the design drawings and applicable sections of the SAR to evaluate the effects, if any, of intimate contact between the stainless and carbon steel and other components in the package.

The materials used in the construction of the packaging (i.e., carbon steel, stainless steel, depleted uranium metal, lead, tungsten, polyurethane foam, and copper) will not have significant chemical, galvanic, or other reactions in either in air or water environment. To prevent the possible formation of a phase transformation of steel and depleted uranium during hypothetical accident conditions, copper separators are used at all steel-uranium interfaces. Staff also evaluated the cork and the polyurethane foam used to fabricate the package. The cork and the steel interfaces will not cause any chemical, galvanic, or other adverse reactions due to contact during transport. The polyurethane foam contains very little leachable chlorides that will cause any degradation to the container.

On the basis of the review of the statements and representations in the SAR and staff's evaluation, the staff concludes that the structural design has been adequately described and evaluated and that the package is capable of maintaining structural integrity to meet the requirements of 10 CFR Part 71.

2.2.3 Fabrication and Examination

The welding procedures are provided in the drawings contained in Section 1.4 of the SAR, in accordance with the ASME, the British Standard, and the AWS code requirements. In addition, they are in compliance with the AEA Technology QSA, Inc., Quality Assurance Plan approved by the NRC and ISO.

Examination methods and acceptance criteria of the transportation package are described in Section 8 of the SAR, and on the design drawings. The staff reviewed the applicant's fabrication and examination procedures and found them in compliance with 10 CFR 71.31(c).

2.2.4 General Standards for all Packages (10 CFR 71.43)

Minimum Package Size

The smallest overall dimension of the package is 19.75 in (502 mm). This is greater than the minimum dimension of 4 in (10 mm) specified in 10 CFR 71.43(a). Therefore, the package meets the requirements of 10 CFR 71.43(a) for minimum size.

Tamper-Proof Feature

The Model 976 Series packages incorporate a steel seal wire attached to the lid band and bolt. This seal wire is not readily breakable. Therefore, if it is broken during transport, it serves as evidence of possible unauthorized access to the contents. This satisfies the requirements of 10 CFR 71.43(b).

Positive Closure

The applicant showed that the Model 976 Series packages cannot be opened inadvertently. Positive closure is provided by the drum lid sealed with a clamp band and 4 stainless steel bolts. Thus, the requirements of 10 CFR 71.43(c) are satisfied.

2.2.5 Lifting and Tie-Down Standards for All Packages

The transportation package is designed to be lifted by the base of the drum using a hand truck or by other mechanical means. The applicant evaluated the maximum stress on the base of the drum through analysis. The staff evaluated the lifting device and its effect on the transportation package and finds adequate compliance with the requirements of 10 CFR 71.45(a).

The transportation package does not have a system of tie-down devices. Rather, the package is blocked and braced according to standard transportation practices. The staff reviewed the applicants explanation of compliance with standard transportation practices and finds it acceptable with the requirements of 10 CFR 71.45(b).

2.2.6 General Considerations

Test procedures and results are documented in Test Plan 90 (TP90) and Test Plan163 (TP163), provided by the applicant as part of the SAR. To demonstrate compliance with normal conditions of transport, one test specimen was subjected to the compression test, penetration test, and free drop test. The water spray test was not conducted due to the waterproof nature of the package material. To demonstrate compliance with hypothetical accident conditions, nine test specimens (6 in TP90, 3 in TP163) were subjected to the free drop test and puncture test, of which Specimen TP90(F) was not reported and thus was excluded in the SAR.

The unyielding surface used for the free drop tests in the TP90 and TP163 consists of a plain concrete base pad of length 10 ft, width 10 ft, and thickness 4 ft (see Reference Drawing T10261) with a weight of 88,000 lbs. A 4-ft by 4-ft by 1-in thick steel plate is anchored to this concrete pad by 4 anchor bolts. It can test a specimen of weight up to 1,000 lbs. Before and after each testing, the drop pad is visually inspected for damage. The puncture bar is a 6-in diameter by 12-in long mild steel solid bar welded to a steel plate of 10 x 10 x ½ inch with a 1/4 inch circumferential weld. The puncture is bolted down to the thick steel plate by 4 stainless steel bolts of ½ by 13-.3/4 inch long (see Reference Drawing T10119).

Analyses were performed on the transportation package for situations where tests were not conducted. The analysis results were documented in the SAR. To demonstrate compliance with normal conditions of transport, heat, cold, reduced external pressure, increased external pressure, and vibration analyses were performed. To demonstrate compliance with hypothetical accident conditions, thermal and immersion analyses were performed.

The staff reviewed the testing and analysis evaluation methods and found them in compliance with the requirements of 10 CFR 71.41(a).

2.2.7 Normal Conditions of Transport (10 CFR 71.71)

Heat

The applicant evaluated the transportation package with an ambient temperature of 38EC and decay heat of 20 W. The applicant’s analysis determined the maximum surface temperature produced by solar heating of 69EC. In addition, the analysis determined the maximum surface temperature in the shade at an ambient temperature of 38EC to be 40EC. Thermal expansion of the outer drum surface caused by the temperature differential is insignificant and does not hinder the package from maintaining security of the contents. Expansions of the outer drum and cork due to hot/cold temperature differentials are 0.02 and 0.16 inch, respectively, which is within the tolerance of 0.25 in. Thus, no interference even with the shields will occur. Under worst case conditions, each bolt must carry a load of 635 lbf due to thermal gradient induced pressure (7 psi). This translates into a stress of 8,152 psi, which is below the tensile strength of 75,000 psi of the stainless steel bolt. The staff concludes that normal heat conditions of the package meet the requirements of 10 CFR 71.43(g) and 71.71(c)(1).

Cold

The carbon steel components of the Model 976 Series transport packages are susceptible to brittle fracture at very low temperatures. Test Plans 90 and 163 showed that the transportation packages successfully met Type B(U)-96 requirements set under normal as well as hypothetical accident test conditions. The staff concludes that the cold conditions meet the requirements of 10 CFR 71.71 (c)(2).

Reduced External Pressure

The Model 976 Series transportation packages are open to the atmosphere outside of the shield containers. Inside the containers a pressure differential can occur. A thermal gradient caused by a maximum surface temperature of 69EC and a minimum temperature of - 40EC creates an internal shield pressure of 7 psi. The applicant combined this pressure with the 49 CFR (and IAEA TS-R-1) requirement of 8.7 psi to evaluate the bolt stress to come up with 18,300 psi under a reduced external pressure of 15.7 psi. This stress is still below the bolt's yield stress (36,000 psi). Accordingly, the staff determined that the applicant's evaluation of reduced external pressure complies with the requirements of 10 CFR 71.71(c)(3).

Increased External Pressure

The applicant evaluated the maximum stress caused by an external pressure of 20 psi on the Model 855 shield container. Since this container has the largest surface area of the six shield containers, the applicant determined that it would be most effected by pressure and therefore, it was the only one analyzed. The maximum stress in the top plate thus calculated amounts to 4,200 psi, well below the yield stress of the steel top plate (36,000 psi). The staff determined that the applicant's evaluation of increased external pressure of 20 psi complies with the requirements of 10 CFR 71.71(c)(4).

Vibration

The natural frequency of the package's lowest mode is calculated at 28.7 Hz. at which the root mean square acceleration response is 0.502 g. The maximum vibration is 3-4 times of that amount or 1.5 to 2.0 g. which is well below the dynamic forces generated under the 9 m Hypothetical Accident drop test conditions. The staff determined that the applicant's evaluation of vibration to the transport package complies with the requirements of 10 CFR 71.71(c)(5).

Water Spray

The transport packages are constructed of water-resistant materials. The applicant states that the effects of the water spray test would cause negligible degradation to the package. Therefore, the staff concludes that it is unnecessary to comply with the requirements of 10 CFR 71.71(c)(6).

Free Drop

A 4-ft drop test was conducted on test specimen TP90A in accordance with Test Plan 90. TP90A is a replica of the Model 976 Series transportation package with a Model 855 shield container. The Model 855 was the only shield container subjected to the drop test because it is the largest and heaviest of the six shield containers and therefore determined by the applicant to cause the most severe damage.

The test specimen was dropped at an orientation for the potential to cause significant deformation of the closure bolt assembly. One 4-ft drop was conducted at approximately a 45E angle with the closure bolt down. TP90A was chilled to - 40EC to determine the susceptibility of the carbon steel components of the shield container to brittle fracture. The results of the drop test concluded minor damage to the outer drum. The Model 855 shield container was undamaged and used in test specimen TP90B for hypothetical accident testing. Radiation profiles were performed after the hypothetical accident testing and were within regulatory limits for normal transport. The staff concludes that the transportation packages are adequately designed for the normal condition free drop test and complies with the requirements of 10 CFR 71.71(c)(7).

Corner Drop

The package is not used for transporting fissile material and it is not made from fiberboard or wood. Therefore, the staff concludes that it is unnecessary to comply with the requirements of 10 CFR 71.71(c)(8).

Compression

Test specimen TP90A was subjected to a compressive load of 1,465 lb for a period of 24 hours. This load exceeds five times the maximum transportation package weight of 280 lb and 2 psi multiplied by the vertically projected area of the package. There was no damage observed to the test specimen. Radiation profiles were performed after the hypothetical accident testing and were within regulatory limits for normal transport. The staff concludes that the transportation packages are adequately designed for the normal condition compression test and complies with the requirements of 10 CFR 71.71(c)(9).

Penetration

A steel cylinder was dropped from a height of 40 inches onto the closure bolt of test specimen TP90A. The penetration bar impacted as intended. The test resulted in the closure bolt bending and an impression on the bolt threads. There was no loss of structural integrity of reduction of shielding efficiency as a result of the impact. The staff concludes that the transportation packages are adequately designed for the normal condition penetration test and complies with the requirements of 10 CFR 71.71(c)(10).

2.2.8 Hypothetical Accident Conditions (10 CFR 71.73)

Free Drop

Five test specimens were used in the 30-ft (9 m) free drop test in Test Plan 90. Four of the specimens contained Model 855 shield containers and one contained a Model 3056 shield container. Since Model 3056, 3015, and 3018 weigh the same amount, only one was chosen to undergo testing. A test specimen containing a Model 616 shield container was not tested. This test specimen, TP90F, was included in the original testing but excluded from the report, as the applicant is not requesting it for shipment. Therefore, it was not evaluated by the staff.

Test Specimen TP90B contained a Model 855 shield container and was dropped at a 45E angle with the closure bolt down. TP90B was chilled to - 40EC to determine the susceptibility of the carbon steel components of the shield container to brittle fracture. The unit impacted the test pad as intended and the primary impact crushed the closure bolt assembly. The secondary impact caused flattening and denting on the side of the drum. No rips or tears were noted in the steel drum. Upon removal of the drum cover, some of the cork pieces were cracked and/or fractured, however the shield container was undamaged. After examination, the sources had not moved, the locks remained engaged, and the bolts were undamaged.

Test Specimen TP90C contained a Model 855 shield container and was dropped top-down along its axis of symmetry. TP90C was chilled to - 40EC to determine the susceptibility of the carbon steel components of the shield container to brittle fracture. The unit impacted the test pad as intended and the impact caused deformation and bending of the closure ring and top flange of the drum. Upon removal of the drum cover, some of the cork pieces were cracked, however the shield container was undamaged. After examination, the sources had not moved, the locks remained engaged, and the bolts were undamaged.

Test Specimen TP90D contained a Model 855 shield container and was dropped bottom-down along its axis of symmetry. TP90D was chilled to - 40EC to determine the susceptibility of the carbon steel components of the shield container to brittle fracture. The unit impacted the test pad as intended and the impact caused deformation and bending of the bottom flange of the drum. Upon removal of the drum cover, the bottom cork piece was cracked, however the shield container was undamaged. After examination, the sources had not moved, the locks remained engaged, and the bolts were undamaged.

Test Specimen TP90E contained a Model 855 shield container and was dropped at a 45E angle with the closure bolt toward the ground but at the top of the drum. TP90E was chilled to - 40EC to determine the susceptibility of the carbon steel components of the shield container to brittle fracture. The unit impacted the test pad as intended and the primary impact deformed the lower corner of the drum. The secondary impact caused flattening on the side of the drum and a nick in the closure ring and top flange ring weld. No rips or tears were noted in the steel drum. Upon removal of the drum cover, the bottom cork pieces were fractured, however the shield container was undamaged. After examination, the sources had not moved, the locks remained engaged, and the bolts were undamaged.

Test Specimen TP90G contained a Model 3056 shield container and was dropped at a 45E angle with the closure bolt down. Although not particularly susceptible to brittle fracture due to its components being constructed of lead and stainless steel, TP90G was still chilled to - 40EC. The unit impacted the test pad at a smaller angle than anticipated and was dropped a second time. The first drop bent the closure bolt assembly, along with the cover and top rim of the drum. The same test specimen was used for the second drop and impacted the test pad as intended. The closure bolt assembly was further bent, but remained intact and held the cover on the drum. No rips or tears were noted in the steel drum. Upon removal of the drum cover, some of the cork pieces were cracked and/or fractured, however the shield container was undamaged. After examination, the sources had not moved, the retainer nuts and cover remained engaged, and the bolts were undamaged.

Three specimens were assembled in Test Plan 163 for 9 m drop and puncture tests, two Model 976A package with Model 855 inner shield, and one new Model 976F with Model 1911 inner shield. In addition, TP163 also incorporates a modification to the lid closure mechanism by adding 4 bolts which connect the lid to the drum body at 4 equidistant points around the drum periphery. One specimen TP163(A) of Model 976A (with 855 shield container) was dropped at a 45 degree angle in order to compare the test results with Test Plan 90. In the document entitled NUREG/CR-6818, *Drop Test Results for the Combustion Engineering Model No. ABB-2901 Fuel Pellet Shipping Package*, it was identified that a drum orientation of 17.5 degrees was potentially more likely to separate the clamp band from the drum upon impact. Therefore, two specimens, TP163(B) [Model No. 976A] and TP163(C) [Model No. 976F] were dropped at this orientation to test whether this is the worst case scenario as alluded by the report. The test results showed striking different characteristics from the results reported in NUREG/CR-6818. They showed the worst drop orientation is at 45 degrees. In that, the specimen TP163(A)'s lid clamp band was possible to be removed from the drum. In all other orientations tested, the whole package remained as an integral part.

Both test plans did not include a horizontal drop test (i.e., axial direction is horizontal or orientation = 0 degree). In view of the fact that the test results with 45 degree orientation are worse than the case with 17.5 degrees, it is expected that an orientation of 0 degree is even less of a problem. Thus, exclusion of a horizontal drop test is justified.

The staff concludes that the transportation packages were adequately tested to comply with the requirements of 10 CFR 71.73(c)(1).

Crush

The package is used for Type B quantities of special form radioactive material. Therefore, the staff concludes that it is unnecessary to comply with the requirements of 10 CFR 71.73(c)(2).

Puncture

Six puncture tests (five in TP90, one in TP163) were performed on each test specimen. All punctures tests were conducted immediately following the 30-ft free drop tests and in the same orientation as the free drop tests. These orientations were selected because they would cause the most additional damage to the specimens. None of the puncture tests caused enough additional damage (except the removal of the clamp band from the drum) to the specimens to diminish the structural integrity of the packages. The staff concludes that the packages were adequately tested to comply with the requirements of 10 CFR 71.73(c)(3).

Thermal

The applicant did not perform the thermal tests, specified in 10 CFR 71.73(c)(4), on the test specimens. The applicant cited prior satisfactory analyses and tests performed on similar transportation packages as justification for NRC-approval.

Although the drum components are vented to the atmosphere, the buildup of internal pressure within the shield containers caused by temperature differentials is possible. The applicant used a pressure of 14 psig, due to the thermal gradient induced by fire temperature differential (from 68E F to 1,475E F), to calculate the stress on two bolts of the 855 shield container. Since this configuration occupies the largest space within the steel drum and will exert the largest pressure on the bolts, it was analyzed as the most extreme case. The stress calculated in each bolt is 9,483 psi, well below the yield stress of the stainless steel bolt (36,000 psi). The staff concludes that the packages adequately comply with the requirements of 10 CFR71.73(c)(4) under differential thermal expansion conditions.

Immersion - Fissile Material

The package is not used for transporting fissile material. Therefore, the staff concludes that it is unnecessary to comply with the requirements of 10 CFR 71.73(c)(5).

Immersion - All Packages

The primary containment of the special form source material is a small stainless steel capsule described in Section 2.7.6 of the SAR. The applicant performed an analysis to test its vulnerability to an increased external pressure of 21.7 psig required by 10 CFR 71.73(c)(6). Given the capsules' dimensions, yield strength, and Young's Modulus, the external collapsing pressure was calculated to be 1,277 psi. Since this value exceeds that in the regulations, the staff concludes that the primary containment meets the requirements of 10 CFR 71.73(c)(6).

2.3 Evaluation Findings

Based on review of the statements and representations in the application, the staff concludes that the structural design has been adequately described and evaluated to demonstrate its structural capabilities to meet the requirements of 10 CFR Part 71.

3.0 THERMAL

3.1 Objective

The objective of the thermal review is to determine whether the performance of the Model No. 976 Series packages have been demonstrated to meet the requirements of 10 CFR Part 71 under normal conditions of transport and hypothetical accident conditions.

3.2 Areas of Review

3.2.1 Description of Thermal Design

The maximum output activity for the Model No. 976 Series is 1,000 Ci of Ir-192. Accounting for source absorption, this equals a maximum content activity of 2,300 Ci of Ir-192. The corresponding decay heat generation rate for the content activity is approximately 20 Watts. Cooling of the package is through free convection and radiation.

A summary of the various configurations for the Model 976 Series is provided in the table below.

Model No.	Maximum Decay Heat (W)
976A	20
976B	7
976C	16
976D	10
976E	20
976F	20

3.2.2 Normal Conditions of Transport

Heat and Cold

The applicant calculated the maximum surface temperature of the package in the shade, for an ambient temperature of 100EF (38EC) and a decay heat input of 20 watts using textbook equations. The steady state temperature of the package surface was determined to be 117EF (47EC). This temperature is below the allowable temperature limit specified in 10 CFR 71.43(g) (122EF or 50EC) and will not adversely affect the package or contents during normal conditions of transport. Temperatures calculated for the package are well below the melting temperatures of all safety critical components.

The applicant also calculated the maximum surface temperature for the conditions stated in 10 CFR 71.71(c)(1) for an ambient temperature of 100EF (38EC) and solar insolation. The steady state temperature of the package surface was determined to be 190EF (88EC).

The applicant determined that the safety related components of the package are not affected by the cold conditions tests (-40EF or -40EC) in 10 CFR 71.71(c)(2).

Maximum Normal Operating Pressure

The maximum normal operating pressure was calculated by the applicant to be 22.8 psi, which is within the performance envelope of the package.

Confirmatory Calculations

The staff developed a finite element model of the Model 976 for normal conditions of transport. The results were similar to the applicant’s. No issues were identified.

3.2.3 Hypothetical Accident Conditions

30-Minute Thermal Test

The applicant assessed the hypothetical accident condition thermal performance of the Model No. 976 Series packages by comparing the condition of these packages with other packages that were previously tested or evaluated. The estimated surface temperatures during the fire ranged from 149EF (65EC) to 1472EF (800EC), while the estimated shield container temperatures during the fire ranged from 207EF (97EC) to 318EF (159EC).

Based on an evaluation of the thermal tests performed on other similar packages (including Model Nos. 650L and 3605B) the applicant concluded that the performance of the Model No. 976 series of packages would be within acceptable limits.

Maximum Pressures

The outer drum components are vented to the atmosphere. However, some shields do have small cavities with gasket seals. The applicant evaluated the maximum pressures for these designs and determined that these pressures would not affect the package performance.

Confirmatory Calculations

The staff developed a finite element model of the Model No. 976 Series for hypothetical accident conditions (fire). The results were similar to the applicant’s. No issues were identified.

3.3 Evaluation Findings

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

4.0 CONTAINMENT

Containment of the radioactive material is provided by a sealed source capsule, which meets the requirements of special form radioactive material. The source remains within the packaging under normal conditions of transport and under hypothetical accident conditions.

Based on the review of the statements and representation 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

5.1 Review Objective

The shielding review verifies that the applicant provides reasonable assurance that the shielding performance of the package design meets the external radiation requirements of 10 CFR Part 71 under normal conditions of transport and hypothetical accident conditions.

5.2 Areas of Review

5.2.1 Description of Shielding Design

The six configurations of the Model No. 976 Series packages are differentiated based on inner shield design, spacer configurations, and activity capacities. The general design of the package is a steel jacketed lead and/or depleted uranium inner shield container housed within a cork lined, stainless steel, 20-gallon drum. The inner shields used in each version of package are either a shield cavity (to hold source capsules) design or a J-tube (to hold sources on flexible source wires) design. The Model No. 976 series package versions are:

Model No.	Shield Container	Maximum Capacity - Output Activity* (Ci)
976A	855	1,000
976B	3015	350
976C	3056	800

Model No.	Shield Container	Maximum Capacity - Output Activity* (Ci)
976D	3018	500
976E	3078	1,000
976F	1911	1,000

* Maximum activity for Ir-192 is defined as output curies as required in accordance with American National Standard N432-1980, “Radiological Safety for the Design Construction of Apparatus for Gamma Radiography.”

Shield container 855 is a source wire design, consisting of a depleted uranium shield inside a welded steel container with bolted lock assemblies, protective source caps, and a bolted shield cover. Eight titanium J-tubes inside the shield may hold up to eight individual sources. The sources are attached to the end of a source wire assembly and are prevented from movement during transport by means of the bolted lock assemblies, which secure the sources at the bottom of the eight J-tubes. A bolted steel shield cover attached prior to shipment further prevents the lock assemblies from releasing.

Shield container 3015 is a shield cavity design, consisting of a lead shielded pot with a steel casement enclosing the sides and top surfaces of the container. The primary radiation shield is the lead pot. Additional shielding is provided by a depleted uranium lower insert, which holds a tungsten source capsule holder. The capsule holder may be machined to accommodate different source capsule diameters, while maintaining the minimum insert design that complies with the specifications on the drawings in SAR Section 1.4. The sources are held in place by a shield plug assembly, which is secured by the shield cover lid, which is bolted to the container body.

Shield container 3056 is a source wire design, and may hold up to ten sources. Primary radiation shielding is provided by a lead pot modified to use a depleted uranium inner core. A steel cradle or sheath and a flange on the upper insert clamp together the shielding components. Source location and retention is provided by a fabricated insert containing ten J-tubes and source end caps. Each source is secured close to the center of the shield by means of the attached flexible source holder within the J-tube and is closed by the tube cap. The cover protects the source tubes and end caps during shipment.

Shield container 3018 is a source wire design, and may transport up to four sources. The outer shield is a lead pot with a steel casement enclosing the sides and top surfaces of the container. An upper lead insert sits on top of a lower depleted uranium insert. The upper lead insert contains the four J-tubes. The inserts are secured to the shield body by a bolted steel strap. The source wires are secured in the J-tubes by source tube caps. A removable disk, further securing the sources, is attached prior to transportation.

Shield container 3078 is a shield cavity design, and is essentially a welded steel cylinder. Shielding is provided by the depleted uranium pot (depleted uranium is inside the steel cylinder) and the depleted uranium shield plug, which is flush with the top of the pot when fully inserted. The sources are secured by the shield plug, which is bolted to the steel container body by a cover lid prior to shipping.

Shield container 1911 is a shield cavity design. The primary shielding is provided by a lead shield body encased by a welded steel cylinder. Source location and retention is provided by an insert assembly and a shield plug. Three different insert designs may be used within the source cavity to allow for different source loading configurations: (1) depleted uranium plug and insert, (2) lead plug and insert, and (3) tungsten plug and insert. The shield lid is bolted prior to shipping.

5.2.2 Radiation Source

The Model No. 976 Series packages are designed to transport Ir-192 as sealed sources that meet the requirements of special form radioactive material. The activity capacity of the package depends upon the inner shield design used. The SAR drawings of the six package configurations and their corresponding inner shield models depict the minimum thicknesses necessary to meet the shielding requirements in 10 CFR Part 71, assuming maximum radiation capacity loading.

5.2.3 Shielding Evaluation

The applicant measured actual dose rates from test specimen packages to satisfy the shielding requirements in 10 CFR Part 71 for normal conditions of transport (NCT) and hypothetical accident conditions (HAC). To show compliance with the regulatory limits in 10 CFR 71.47 for NCT, a test specimen was subjected to the compression test, the puncture test, and a four-foot drop. To show compliance with the regulatory limits in 10 CFR 71.51 for HAC, test specimens were subjected to the 30-foot drop and then the puncture test. Radioactive sources were inserted into the test packages for the pre-test surveys and post-test surveys. Inactive ‘dummy’ sources were placed in the test packages during the testing.

Dose rate measurements were taken on all six surfaces of the tested packages at the surface of the package and at 1 meter from the package. The applicant applied a capacity correction factor and a surface correction factor to the measured dose rates. The capacity correction factor accounted for difference between the radioactive test source strength and the maximum package capacity listed in the table in Section 5.2.1 of this document. The surface correction factor corrected for the dose-rate measurement geometry. The adjusted dose rates, which accounted for the activity and surface correction factors, were less than the regulatory limits for NCT and HAC specified in 10 CFR 71.47 and in 10 CFR 71.51.

The applicant also performed Microshield V5.05 calculations for the 976C package configuration, which showed good agreement with the measured dose rates.

5.2.4 Confirmatory Calculations

NRC staff performed independent calculations for the 976C package configuration using Microshield v5.05 to confirm the applicant’s conclusions. The applicant’s comparison of the Microshield results against the measured radiation dose rates showed good agreement. The staff's calculations agreed with the applicant's calculations in SAR Section 5.3, Table 5.3.1.a "Microshield Comparison Calculations for the Model 976C Package." The staff also performed Microshield calculations for the 976F package configuration (with the lead insert) as it may transport the highest activity capacity allowed in the 976 (1000 Ci). The Microshield calculations agreed with the applicant's dose rate measurements and confirmed that the regulatory limits for NTC and HAC will not be exceeded.

5.3 Evaluation Findings

Based on review of the application and the staff's confirmatory calculations, the staff concludes that the package meets the external radiation requirements specified in 10 CFR Part 71.

6.0 CRITICALITY

The package does not contain any fissile material.

7.0 PACKAGE OPERATIONS

Section 7 of the application specifies operating procedures for the package. The section includes sections on package receipt, loading, preparation for transport, unloading, and shipping as an empty package. The operating procedures confirm that all sources are securely locked into position before shipment. The procedures also include a physical verification that the sources have been removed before shipment of an "empty" package. The Certificate of Compliance has been conditioned to specify that the package be operated and prepared for shipment in accordance with Section 7 of the application, as supplemented.

Based on the statements and representations in the application, the staff concludes 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 evaluation for approval.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Section 8.1 of the application specifies various acceptance tests which will be performed prior to the first use of the package. These tests include weld examinations, structural and pressure tests, leakage tests of the source capsules, and shielding tests.

Section 8.2 of the application specifies a maintenance program for the package, including leakage tests of the sources, components and material tests. The applicant also includes a plan to verify that appropriate inspections are performed to monitor any wearing of the J-tubes, via contamination wipe test.

The Certificate of Compliance has been conditioned to specify that the package be acceptance tested and maintained in accordance with Section 8 of the application, as amended.

Based on review of statements and representations in the application, the staff concludes 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

The Certificate of Compliance includes the following conditions of approval:

A. Tensile and yield strength for the materials of construction must comply with the values presented in Table 2.2a of the SAR.

B. For "J" tube style shield containers, the flexible cable of the source assembly and source cap must be of sufficient length and diameter to provide positive positioning of the source in the shielded position.

C. The name plate must be fabricated of materials capable of resisting the fire test of 10 CFR Part 71 and maintaining its legibility.

D. In addition to the requirements of Subpart G of 10 CFR Part 71:

    (a) The package shall be prepared for shipment in accordance with the Package Operations in Section 7 of the application, as supplemented; and,

    (b) Each packaging must be acceptance tested and maintained in accordance with the Acceptance Tests and Maintenance Program in Section 8 of the application, as supplemented.

CONCLUSION

Based on the statements and representations in the application, as supplemented, and the conditions listed above, the staff concludes that the design has been adequately described and evaluated and the package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9314, Revision No. 0,
on June 6, 2005.