SAFETY EVALUATION REPORT

Docket No. 71-9337
Model No. 3979A
Certificate of Compliance No. 9337
Revision No. 0

B-28

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SUMMARY

By application dated July 30, 2009, as supplemented October 15, 2009, March 31, and September 30, 2010, Croft Associates Limited requested that the Nuclear Regulatory Commission approve the Model No. 3979A package as a Type B(U) package for the transport of radioisotopes used in a wide range of therapeutic and diagnostic applications and research.

The packaging consists of an inner containment vessel, which also provides shielding, and the outer stainless steel keg and insulating cork packing, which provides impact and thermal protection. The containment vessel has stainless steel inner and outer shells enclosing lead shielding in both the body and the containment vessel lid. The dimensions of the package are approximately 424 mm in diameter at the top and bottom rims, and 483 mm in overall height. The maximum weight of the package and contents is 65 kg.

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 representation 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 10 CFR Part 71.

1.0 GENERAL INFORMATION

1.1. Packaging

The Model No. 3979A packaging consists of an outer stainless steel keg enclosing insulating cork packing, and an inner containment vessel. There are three specific inserts authorized for use in the Model No. 3979A, designated as Shielding Insert Design Nos. 3983, 3984, and 3986. The outer keg provides impact and thermal protection. Containment is provided by the containment vessel. Shielding is provided by the containment vessel and shielding insert.

The keg has a stainless steel outer shell and a stainless steel liner, between which insulating cork is fitted. The keg lid is attached to the body by 8 stainless steel studs and nuts, with a single O-ring weather seal. An inner cork liner is fitted between the keg liner and the top and sides of the containment vessel, consisting of a cork body and cork top, with no cork between the bottom of the containment vessel and the keg liner.

The containment vessel consists of a body and lid. The body has a stainless steel outer wall, base, and flange/cavity wall. The flange/cavity wall is welded to the outer wall to form a cavity into which the lead shielding cast. The base is them welded to the outer wall. The containment vessel lid top and lid shielding casing are stainless steel, with 22 mm of lead cast inside. The containment vessel lid is secured by eight, M-10x1.5x20, alloy steel recessed hexagon socket head cap screws. The containment system is sealed by two concentric ethylene propylene rubber O-rings, and the lid is equipped with a leak test port.

There are three Shielding Inserts designed for use in the Model No. 3979A packaging. Design No. 3983, LS-31x73-Tu, is a tungsten insert with inner cavity size of 31 mm diameter by 73 mm height, with a steel cavity filler. The approximate mass of the insert is 4.9 kg. Design No. 3984, LS-12x65-Tu, is a tungsten insert with inner cavity size of 12 mm diameter by 65 mm in height, with a steel cavity filler. The approximate mass of the insert is 5.8 kg. The third design, Design No. 3986, LS-50x103-SS, is a stainless steel insert with inner cavity size of 50 mm diameter by 103 mm height, with a steel cavity filler. The approximate mass of the insert is 1.0 kg.

The radioactive material may be enclosed in any convenient product container such as a quartz vial or aluminum capsule. Irradiated items may be carried in plastic or metal can or wrapping to minimize the contamination of the insert.

The approximate dimensions and weight of the package are:

Overall package outer diameter	424 mm
Overall package height	483 mm
Containment vessel outer diameter	175 mm
Containment vessel height	204 mm
Containment vessel cavity inner diameter	65 mm
Containment vessel cavity inner height	109 mm
Maximum package weight	65 kg

1.2. Drawings

The packaging is constructed and assembled in accordance with Croft Associates Limited Drawing Nos:

1C-6040, Rev. C	Cover Sheet for Safkeg LS Design No. 3979A (Licensing Drawing)
0C-6041, Rev. B	SAFKEG LS Design No 3979A (Licensing Drawing)
0C-6042, Rev. C	Keg Design No. 3979 (licensing Drawing)
0C-6043, Rev. A	Cork Set for Safkeg LS (Licensing Drawing)
1C-6044, Rev. C	Containment Vessel Design No. 3980 (Licensing Drawing)
1C-6045, Rev. C	Containment Vessel Lid (Licensing Drawing)
1C-6046, Rev. C	Containment Vessel Body (Licensing Drawing)

The shielding inserts are constructed and assembled in accordance with Croft Associates Limited Drawing Nos:

2C-6175, Rev. A	LS-50X103-SS Insert Design No. 3986 (Licensing Drawing)
2C-6172, Rev. A	LS-31x73-Tu Insert Design No. 3983 (Licensing Drawing)
2C-6171, Rev. B	LS-12x65-Tu Insert Design No. 3984 (Licensing Drawing)

1.3. Contents

The contents may be solid, as normal form and as sealed sources meeting the requirements of special form radioactive material, or gaseous form. The decay heat may not exceed 10 watts per package. The contents may include fissile materials provided the mass limits and conditions of 10 CFR 71.15, 71.22, or 71.23 are not exceeded. Specific radionuclides and quantity limits for each radionuclide are applied according to the insert used and the form of the radioactive material. The maximum mass of contents is based on the mass of a steel cylinder that would completely fill the cavity of the insert. Non-fissile or fissile exempt contents are limited by maximum activity on a per radionuclide basis, and by maximum gross mass and net radioactive material mass, except for gaseous contents which are limited by volume. Dose rate considerations are the primary limiting factor for contents.

2.0 STRUCTURAL

The structural integrity of the members of the Safkeg-LS 3979A package was demonstrated by testing of a prototype keg, and finite element analyses of the containment to satisfy the regulatory requirement of 10 CFR 71.

2.1. Description of Structural Design

The SAFKEG 3979A is designed as a general purpose package to transport of a range of non-fissile and fissile nuclides in solid, liquid and gaseous form.

The principal structural members of the SAFKEG-LS 3979A package are the keg (drawing: 0C-6042, Issue A), top and inner cork packing (drawing: OC-6043, issue A) and the containment vessel (drawing: OC-606044, issue A). There are three (3) inserts for the content that can provide additional containment and shielding (drawings: 2C-6175, issue A, 2C-6172, issue A and 2C-6171, issue A). The external dimensions of the package are 448.3 cm (XX in) in height and 42.4 cm (xx in) in diameter.

The keg and outer and inner cork assembly is designed to absorb impacts. The keg is constructed from ASTM A240/A240M, type 304L material. The material density of top and inner cork is 250-290 kg/m3 (XXX #/in3). The containment vessel is design to provide a containment boundary and shielding for the content. The body assembly is formed from the flowing materials: ASTM A479/A479M, TYEP 304L, ASTM A511/A511M, type MT304L, and BS 3909/2 (lead).

First, three full scale test packages with configurations accommodate appropriate instrumentations were tested for steady stated thermal test, drop and penetration tests, and 8000C (XX oF) thermal test. Total of fifteen (15) tests were performed in an acceptable sequence at three test facilities. 1.2 m (4 ft) drop and the 1 m (40 in) penetration test series were performed at the Pipaway Engineering testing facility. 10.2 m (33 ft and 5.6 in) and additional penetration test at -40oC (-40 oF) were performed at the Croft Associates, Ltd testing facility. 800oC (XX oF) thermal test was performed at the Hovel Ltd test facility. HAC drop tests were conservatively performed from a height of 10.2 m (33 ft and 5.6 in) instead of required 9 m (30 ft).

The maximum weight of the package is 62.1 kg (137 lbs) excluding the contents. The maximum contents weight is 5.9 kg (13 lbs). The gross weight of the package is 68 kg (150 lbs). However, the weight of the tested package is 56.16 kg (124 lbs) excluding the contents, and 61.72 kg (136 lbs) including contents. Thus, the weight of the tested package is approximately 10% less than the designed package. The staff performed a cursory analytical check to estimate the impact deceleration values due to free drops through a distance on 9 m (30 ft) and 10.2 m (33.46) for Hypostatical Accident Condition (HAC) only. It should be noted that the following check does not consider the secondary dynamic effects, and the worst pulse duration of 21 msec for HAC from Table 8 of CTR 2009/21, issue A was used to estimate impact decelerations. As shown in the following table due to the differences in weights and drop-distances, the calculated impact deceleration and force values could increase approximately 6.5% and 3.5%, respectively. The calculations are listed in the following table for both unit systems (English and SI Units). The staff concluded that (1) HAC case per 10 CFR Part 71.73 envelopes all of the other drop cases, (2) even though, the SAR did not provide adequate discussion for the differences of the weight of tested package against the maximum gross weight of the package, and drop distance and the required drop distance, the staff concluded that resultant linear elastic condition can be maintained at the lid-rim region for all required regulatory design conditions of NTC and HAC.

HAC								
	if Tested		**Tested**		**if Tested**		**Tested**	
	English Units				SI Units			
W =	150	lbs	136	lbs	68	kg	61.72	kg
h =	30	ft	33.46	ft	9	m	10.2	m
g =	386	in/sec^2	386	in/sec^2	9.8044	m/sec^2	9.8044	m/sec^2
	32.16	ft/sec^2	32.16	ft/sec^2	980.44	cm/sec^2	980.44	cm/sec^2
$v = (2gh)^{1/2} =$	44	ft/sec	46	ft/sec	13	m/sec	14	m/sec
$t_{pulse} =$	0.021	sec	0.021	sec	0.021	sec	0.02	sec
$a = 2(2gh)^{1/2} / t_{pulse} =$	4,393	ft/sec^2	4,639	ft/sec^2	1,328	m/sec^2	1,414	m/sec^2
$a_g = a/g =$	137	g	144	g	135	g	144	g
$F = W/g\ a_g =$	20,477	lbs	19,628	lbs	19,214	Kg	8,903	Kg

The staff performed a cursory check of absorbed energy using difference in dimensions taken from Table 9 of CTR 2009/21, issue A. The worst displacement of 14.48 mm was conservatively assumed of the keg height.

Volume of displaced keg -- $V = h \pi r^2 =$ (1.448 cm) π (41.9/2 cm)^2 = 1,997 cm^3 = .1997 m^3
$V = 0.122$ in^2

Yield Strength of 304L at -40°C from Table 2-9 of the SAR – $S_y = 25{,}000$ psi
Tensile Strength of 304L at -40°C from Table 2-9 of the SAR – $S_u = 70{,}000$ psi

Flow Stress - $SF = (S_y + S_u) / 2 = 47{,}500$ psi

The energy of the keg -- $E = V S_{yf} = 5{,}787$ in-#

Impact force -- $F = A S_y =$

Furthermore, the applicant performed, quasi-static finite element analyses (ABAQUS v6.8) on an half scale mathematical model of the package to determine stress intensity values at the critical locations of the package for NTC and HAC loadings.

The design criteria from the Regulatory Guide 7.6 was applied to determine the effects of combined loads on the containment vessel, and the allowable limits were listed in Table 2-3 of the SAR. Load combination were developed based on the requirements of Regulatory Guide 7.8, were listed in Table 2-1 of the SAR.

2.2. Materials

The exterior body and containment vessel of the SafeKeg is made of 2 stock ASTM A240/240M 304L austenitic stainless steel. This steel is immune to low-temperature nil-ductility issues, and has a low carbon content, reducing the steel's susceptibility to weld sensitization. Bolting on the containment vessel is made to L43 ASTM A320/A320M specifications. This high alloy steel is intended for low-temperature service; the staff finds that is adequate for the application. The Keg Closure Nut on the exterior of the package is specified by an ISO or DIN standard. The Staff typically requests applicants to demonstrate how international standards are comparable to widely recognized American industry standards for safety-related components. The Staff finds in general, however that the operational requirements for materials used to manufacture nuts do not need to be particularly stringent, therefore the staff finds the specified ISO and DIN standards are acceptable for the application.

All welding of the SafeKeg package is done in accordance with Section VIII of the American Society for Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PVC) with visual and liquid penetration testing done in accordance with Section V of the ASME B&PVC. The confinement vessel is not welded, but is machined from a stock of 304L stainless steel. Drop and puncture tests demonstrated that the SafeKeg is constructed in a manner, and with materials which are sufficient for the package to meet the regulatory requirements.

The maximum radiation dose for the elastomeric containment seals is 1.71×10^5 rads, assuming the package was loaded with Ir-192 for one year. This dose is an order of magnitude lower than the 10^6 rads that is typically required to damage elastomeric materials. The Staff finds that radiation damage to the elastomeric seals is not a concern for this package (Page 4-3) since the seals are replaced on an annual basis. Finite element analysis showed that the maximum temperature of the elastomeric seal during accident conditions reached 183°C, which is acceptable for short durations of time.

Shielding is provided by a lead / 4% antimony alloy meeting British Standard 309/2 and (depending on the configuration) Class 3 tungsten alloy meeting ASTM B777 specifications. Although the shielding materials are safety related, the staff finds that in general, nominal specifications for shielding materials (e.g., "lead" or "tungsten") is usually adequate. Typically, applicants specify a minimum and maximum weight for cast shielding materials, in order to detect exclude internal porosity which would affect the efficacy of the shielding component. Section 8.1.6 of the Safety Analysis Report, however, specifies shielding tests which will verify the efficacy of the shielding material. Modeling of the fire test showed a maximum temperature of 182°C for the lead shielding. The staff finds that the shielding materials listed by the applicant are acceptable.

Thermal insulation and additional impact resistance is offered by agglomerated cork, placed between the outer shell of the package and the containment vessel. Physical testing of the package under hypothetical fire conditions caused significant charring of the cork, but containment was not compromised. Thermal modeling indicated a maximum containment temperature of 184°C (Table 3-2,Page 3-3). During a fire a low-temperature lead/tin/bismuth alloy inside a stainless steel fuse plug on the outside of the package melts, allowing combustion gases from the cork to escape. Although the fuse plug is safety related, the staff finds there is no reason to specify an industry standard associated with this component, due to the nature of its operation. The staff also finds that any stainless steel material would be sufficient for this component. Note 2 on licensing drawing 0C-6042 specifies the bounding melting temperatures of the alloy, thereby guaranteeing the critical characteristics of the alloy. The staff finds the use of cork, and the materials used for the fuse plug and low-melting temperature alloy acceptable for the use in the package.

2.3. Fabrication and Examination

The package shall be fabricated in accordance with Subsection NB of ASME Section III, Division 1. All welding shall be performed in accordance with the requirements of ASME Section VIII procedures were specified in XXXXXXXX, and is accordance with the American Society of Mechanical Engineering (ASME) Standard welding code.

Comment [MMS1]: Ata to provide input

TEST?????

2.4. General Requirements for All Packages

Input needed.

2.5. Lifting and Tie-down Standards for All Packages

2.5.1. Lifting Devices

Section 10 CFR part 71.45 (a) requires that the following three (3) regulatory standard to be met for all packages: [1] The lifting attachment a package must be designed with a minimum safety factor of three against yielding, [2] failure of any lifting device under excessive load would not impair the ability of the package, and [3] Any other structural part of the package must be rendered inoperable for lifting the package.

The package has no structural devices designed for lifting the package. The package will be man handled into position and lifted on a truck tail lift or lifted using a forklift truck with drum clamps fitted. These types of handling do not exert stresses to the structure of the package.

2.5.2. Tie-Down Devices

Section 10 CFR part 71.45 (b) requires that the following three (3) regulatory standard to be met for all packages: [1] a static force applied to the center of gravity of the package having a vertical component of 2 times, along the direction in which the vehicle travels of 10 times, and in the transverse direction of 5 times of the weight of the package with its contents, [2] Any other structural part of the package must be rendered inoperable for ting-down the package during transport, [3] failure of the device under excessive load would not impair the ability of the package to meet other requirements of this part.

The package has no specifically designed tie-down devices. The package is secured in either horizontal or vertical position by the use of dunnage, cargo nets or an equivalent system that envelope the package without being attached to it. These types of tie-down do not exert stress levels on the structure of the package.

The staff agreed with the applicant's conclusion that the chosen method of lifting and tie-down standards would not exert substantial stresses on the package structure under normal conditions. Therefore, the requirements of 10 CFR Part 71.45 is not applicable for this package.

2.6. Normal Conditions of Transport

The half-symmetry finite element model of the containment vessel (CV) of the package using ABAQUS was developed to evaluate for the requirement of 10 CFR 71.71. The analysis was performed by VECTRA Group Limited, and the report, 925-3272/R1, rev. 4, was included in appendices of the SAR. The staff performed the review of the ABEQUS input files for geometry, and for all load cases. Load combinations was performed in accordance with Regulatory Guide 7.8, and Table 2-1 in the SAR lists the initial loading conditions and load case identifications of all normal conditions for transport (NCT). Pre-load of 8.12 kN (XXX lbs) was applied to the bolts. Following sections provide the results of the staff review of the package subjected to NCT loading.

2.6.1 Heat [10 CFR 71.71 (c)(1)]

This normal condition for transport of heat case was identified as NTC1. Section 10 CFR Part 71.71 (c)(1) requires that the package is subjected to temperature of 38oC (100oF) in still air. The thermal analysis was conservatively performed to a bounding thermal condition for a containment vessel 110oC (xxxo F) with an internal pressure of 700kPa (xxx psig) gauge. The staff confirmed the loading conditions by reviewing the ABAQUS input file for the NCT1 case. The results of maximum stress intensity levels were compared to the allowable limit that were conservatively taken at 149oC (300oF), and that demonstrate acceptable stress design margins at critical locations, and satisfies the requirements of 10 CFR Part 71.71(c)(1).

2.6.2 Cold [10 CFR 71.71 (c)(2)]

This normal condition for transport of Cold case was identified as NTC2. Section 10 CFR Part 71.71 (c)(2) requires that the package is subjected to temperature of -40oC (-40o F) in still air and shade. In this case, package was evaluated for an ambient temperature of -40oC (-40oF) in still air, zero insulation and zero decay heat with an external pressure of 100 kPa (XXX psi). The staff confirmed the loading conditions by reviewing the ABAQUS input file for the NCT2 case. The results of maximum stress intensity levels were compared to the allowable limits that demonstrate acceptable stress design margins at critical locations, and satisfies the requirements of 10 CFR Part 71.71(c)(2).

Brittle fracture has not been considered because the containment vessel and keg are fabricated from austenitic stainless steel which is ductile even and low temperatures and therefore not susceptible to brittle fracture However, evaluation/discussion for brittle fracture of materials at critical locations, and reduction in bolt preload for the cold condition due to difference in coefficient of thermal expansion of closure-bolts from closure-lid was not provided. The staff performed independent evaluations for these cases that resulted with XXXXXXXXXXXXX , and determined to be acceptable, which satisfies the requirements of 10 CFR 71.71(c)(2).

2.6.3 Reduced External Pressure [10 CFR 71.71 (c)(3)]

This normal condition for transport of Reduced External Pressure case was identified as NTC3 in the SAR. Section 10 CFR 71.71 (c)(3) requires that the package is subjected to pressure of 25 kPa (3.5 #/in2) absolute. As stated in Section 4.3.1 of VACTRA Report 925-3272/R1, rev. 4 in the Appendices of the SAR, the package was evaluated for a temperature of 110oC (xxxoF) with internal pressure of 775.5 kPa (xx #/in2) gauge. The staff confirmed the loading conditions by reviewing the ABAQUS input file for the NCT3 case. The calculations for the containment vessel satisfies the allowable design criteria, and the results with design margins were tabulated in Tables 2-22 and 2-23 for containment vessel and bolts, respectively, in the SAR. It was also concluded that reduced external pressure would not cause any permanent deformation to the containment vessel. However, the staff believes that the internal pressure of 725 kPa (XXX #/in2) gauge should have been applied. Since the structural adequacy of the package has been demonstrated for a design pressure of 775.5 kPa (xx #/in2) gauge, which bounds 775 kPa (XXX #/in2), the requirement of 10 CFR 71.71(c)(4) is satisfied.

2.6.4 Increased External Pressure [10 CFR 71.71 (c)(4)]

This normal condition for transport case for Increased External Pressure was identified as NTC4. Section 10 CFR 71.71 (c)(4) requires that the package is subjected to pressure of 140 kPa (20 #/in2) absolute. The package was subjected to temperature of -29oC (-xxxoF), still air with internal pressure of -140 kPa (xx #/in2) gauge. Internal pressure was conservatively considered to be 0.0 kPa (xx #/in2) absolute. The staff confirmed the loading conditions by reviewing the ABAQUS input file for the NCT4 case. It was also concluded that reduced external pressure would not cause any permanent deformation to the containment vessel. Since the structural adequacy of the package has been demonstrated for an internal design pressure of -140 kPa (xx #/in2) gauge, the requirement of 10 CFR 71.71(c)(4) is satisfied.

2.6.5 Vibration [10 CFR 71.71 (c)(5)]

The normal condition for transport cases for vibration were identified as NTC5 and NTC6 in the SAR.. Section 10 CFR 71.71 (c)(5) requires that the package is subjected to vibration normally incident to transport. Based on the publication XXXXX and 10 CFR 71.45 (b)(1) 2.0 g. The hot vibration analyses were performed for vertical downward acceleration of 10g and 110oC (-xxxoF) with internal pressure of 700 kPa (xx #/in2) gauge. The cold vibration analyses were performed for vertical downward acceleration of 10g and -29oC (-xxxoF) with an internal pressure of -100 kPa (xx #/in2) gauge. The staff confirmed the loading conditions by reviewing the ABAQUS input files for the NCT5 and NTC6 cases.

The calculations for the containment vessel satisfies the allowable design criteria, and the results with design margins were tabulated in Tables 2-24, 2-25, 2-26 for containment vessel and bolts, and buckling conditions respectively, in the SAR.

This satisfies the requirements of 10 CFR 71.71(c)(5).

2.6.6 Water Spray [10 CFR 71.71 (c)(6)]

Section 10 CFR 71.71 (c)(6) requires that the package must be subjected to a water spray test that simulates exposure to rainfall of approximately 5 cm/hour (2 inch/hour) for at least 1 hour. The applicant did not perform this test, and stated that the lid of the keg is fitted with an o-ring seal for weather protection which would prevent water entry.

The water spray test is primarily intended for packaging relying on material that absorb water and/or are softened by water material bounded by water-soluble glue. Packaging outer layers constructed entirely of metal can be shown to meet this regulatory requirement without performing the test by an argument of that they do not retain the water, and no increase in their mass. The staff concluded that the outer package materials of construction are not affected by the water spray test. Therefore, the water spray test of 10 CFR 71.71(c)(6) has negligible effect on the package, and is not required to be performed.

2.6.7 Free Drop [10 CFR 71.71 (c)(7)]

This normal condition for transport cases for free-drop were identified as NTC7, NTC8, NTC9, NTC10, NTC11, NTC12 in the SAR. Section 10 CFR 71.71 (c)(7) requires that between 1.5 and 2.5 hours after the conclusion of the water spray test, 1.2 m (4 ft) free-drop of the package should be performed onto a flat unyielding horizontal surface in a position for which maximum damage is expected. The package was evaluated by performing tests and analytical analyses in three different orientations: CG over side, CG over top end, and CG over top rim edge (corner). The Croft Report CTR 2009/21, Issue A, and VECTRA Report 925-3272/R1, rev. 4 provide results of tests and finite element analyses, respectively. Several modifications were made to the containment vessel, cork and keg to accommodate the wiring for the test equipment. The weight of the tested package was 61.77 kg (XX lbs), which is 3% lighter than the design weight. The tests were performed at a temperature of 14oC (xxxoF). The recorded acceleration values during drop tests were tabulated in Table 2-27 of the SAR.

The staff confirmed the loading conditions by reviewing the ABAQUS input file for the NCT7, NTC8, NTC9, NTC10, NTC11, NTC12 cases. The test results, and calculations for the containment vessel satisfies the allowable design criteria. The calculation results with acceptable design margins were tabulated in Tables 2-28, 2-29, 2-30 for containment vessel and bolts, and buckling conditions respectively, in the SAR.

2.6.8 Corner Drop [10 CFR 71.71 (c)(8)]

This normal condition for transport case was identified as NTCX. Section 10 CFR 71.71 (c)(8) requires that a free drop of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1 ft) onto a flat, essentially unyielding, horizontal surface. This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lbs) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lbs).

The corner drop test, per 10 CFR 71.71(c)(8), does not apply since the package uses no wood or fiberboard, and the package was subjected to 1.2 m (4 ft) and 10.2 m (33 ft and 5.5 in) drop test with minor deformations. Therefore, the staff agrees with the applicant=s assessment in Section 2.6.8 that the tests provide adequate evidence for the package to meet the 0.3 m (1 ft) free drop test requirements of 10 CFR 71.71(c)(8).

2.6.9 Compression [10 CFR 71.71 (c)(9)]

This normal condition for transport case was identified as NTCX. Section 10 CFR 71.71 (c)(9) requires that the package must be subjected, for a period of 24 hours, 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. The compressive load must be the greater of the following: (i) The equivalent of 5 times the weight of the package; or (ii) The equivalent of 13 kPa (2 lbf/in2) multiplied by the vertically projected area of the package. The maximum mass of the package is 68 kg (150 lbs); five (50 times of the mass is 340 kg (748 lbs). The vertical projected area of the package is 0.116 m2 (xx in2) multiply by 13 kPa (2 lbf/in2), which resulted with 1,505 N (338 lbf), which is equal to weight of 154 kg (338 lbs). However, the keg body was tested under a 500 kg (1,100 lbs) load, which is well over the required weight of 340 kg (748 lbs). Table 7 in the Croft Report CTR 2009/21, Issue A lists the measurements taken before and after the compression test. No change in dimensions of the keg were measured. Therefore, The performed compression test provided an adequate evidence that the requirement of 10 CFR 71.71 (c)(9) is met.

2.6.10 Penetration [10 CFR 71.71 (c)(10)]

This normal condition for transport case was identified as NTC??? . Section 10 CFR 71.71 (c)(10) requires that impact of a hemispherical end of a vertical steel cylinder of 3.2 cm (1.24 in) diameter and 6 kg (13 lbs) mass dropped from a height of 1 m (40 in) onto the exposed surface of the package that is expected to be most vulnerable to puncher. The test was performed, and reported in Croft Report CTR 2009/21, Issue A that was resulted with a dent of 8.9 mm (XXX in) in depth and 105 mm (XX in) width in the keg skin and the skin was not punctured. A photograph of the package was provided in the report showing the dent in the skin of the keg.

The performed penetration test provided an adequate evidence that the requirement of 10 CFR 71.71 (c)(10) is met.

2.7. Hypothetical Accident Conditions

Technical basis for free drop tests: the three series of testing, each consisted of at least one 9-m (30 ft) free drop followed by puncture drop testing that is aimed at demonstrating that, XXXXXXXXXXX after a worst case HAC sequence, the package containment boundary would remain leaktight, the payload geometry would not reconfigure beyond those analyzed for criticality control, and the accumulated damage to the impact limiters would remain bounded by the assumptions considered for thermal analysis of the package. The package was evaluated by performing tests and analytical analyses. The Croft Report CTR 2009/21, Issue A, and VECTRA Report 925-3272/R1, rev. 4 provide results of tests and finite element analyses, respectively. Several modifications were made to the containment vessel, cork and keg to accommodate the wiring for the test equipment. The Hypothetical Accident Condition (HAC) tests was performed on the prototype keg after the NTC penetration and drop test. The HAC was performed sequentially in the order of penetration test, free drop tests, puncher test and thermal test. Thus, the keg was tested for the cumulative effects of both the NTC and HAC tests. The recorded acceleration values during free drop tests tabulated in Table 2-27 of the SAR.

2.7.1 Free Drop [10 CFR 71.73 (c)(1)]

Section 10 CFR 71.73 (c)(1) requires that a free drop of the specimen through a distance of 9 m (30 ft) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected. The HAC test cases for free-drop were identified as HAC1, HAC2, HAC3, HAC4, HAC5, and HAC6 in the SAR. HAC free drop tests were conservatively performed through a distance of 10.2 m (10 ft and 5.6 in) instead of 9 m (30 ft). The prototype package was tested in three (3) orientations for CG over top end, CG over side and CG over top rim edge (corner) at -40oC (-40o F) to take into account any brittle failure. However, the weight of the test package was determined to be 61.72 kg (135.8 lbs), which is less than the design mass of 63.63 kg (140 lbs). This difference in weight was discussed in Section 2.2 of CTR 2009/21, issue A. The staff performed independent cursory calculations in section 2.1 of the SER to estimate the percent difference due to tested weight of the package and the drop distance of decelerations and impact force. Again, the staff concluded that based on the review of results of the tests and the stress calculations in the appendices of the SAR as well as the staff's independent calculations, it was concluded that results that were provided are reasonable, and meets the design requirements of 10 CFR Part 71.73.

2.7.2 Crush [10 CFR 71.73 (c)(2)]

Section 10 CFR 71.73 (c)(2) requires that performing a dynamic crush test by positioning the specimen on a flat, essentially unyielding horizontal surface so as to suffer maximum damage by the drop of a 500-kg (1100-lb) mass from 9 m (30 ft) onto the specimen. The mass must consist of a solid mild steel plate 1 m (40 in) by 1 m (40 in) and must fall in a horizontal attitude. The crush test is required only when the specimen has a mass not greater than 500 kg (1100 lb), an overall density not greater than 1000 kg/m3 (62.4 lb/ft3) based on external dimension, and radioactive contents greater than 1000 A2 not as special form radioactive material. For packages containing fissile material, the radioactive contents greater than 1000 A2 criterion does not apply.

2.7.3 Puncture [10 CFR 71.73 (c)(3)]

Section 10 CFR 71.73 (c)(3) requires that a free drop of the specimen through a distance of 1 m (40 in) in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 15 cm (6 in) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 mm (0.25 in), and of a length as to cause maximum damage to the package, but not less than 20 cm (8 in) long. The long axis of the bar must be vertical.

2.7.4 Thermal [10 CFR 71.73 (c)(4)]

Section 10 CFR 71.73 (c)(4) requires that exposure of the package with an average flame temperature of at least 800°C (1475°F) for a period of 30 minutes.

Section 3.0 of this SER provides an evaluation of the thermal performance of the package. Stress analyses for the packaging from differential thermal expansion and pressure increase due to the HAC thermal are presented in Section 2.7.4 of the application.

The staff agrees with the applicant that the stresses generated from the HAC thermal test are well within the allowable limits.

2.7.5 Immersion – Fissile [10 CFR 71.73 (c)(5)]

Section 10 CFR 71.73 (c)(5) requires that for fissile material subject to § 71.55, in those cases where water inleakage has not been assumed for criticality analysis, immersion under a head of water of at least 0.9 m (3 ft) in the attitude for which maximum leakage is expected.

Therefore, the package need not be subjected to the water immersion test of 10 CFR 71.73(c)(5).

2.7.6 Immersion - All Packages [10 CFR 71.73 (c)(6)]

Section 10 CFR 71.73 (c)(6) requires that all packages. A separate, undamaged specimen must be subjected to water pressure equivalent to immersion under a head of water of at least 15 m (50 ft). For test purposes, an external pressure of water of 150 kPa (21.7 lbf/in2) gauge is considered to meet these conditions.

The 21.7 psi (150 kPa) external pressure associated with the 50-ft (15-m) water head test condition is bounded by the deep water immersion test requirements of 10 CFR 71.61. As reviewed in the section next, the containment system is shown capable of withstanding an external pressure of 290 psi (2 MPa) gage without structural failure. Thus, the requirements of 10 CFR 71.73(c)(6) are met.

2.7.7 Deep Water Immersion Test -Special requirements for Type B packages containing more than 105A2. [10 CFR 71.61]

Section 10 CFR 71.61 requires designed so that its undamaged containment system can withstand an external water pressure of 2 MPa (290 psi) for a period of not less than 1 hour without collapse, buckling, or inleakage of water.

Section 2.7.7 of the application considered an external pressure of 290 psig to calculate the hoop, axial, and in-plane shear stresses of XXX psi, XXX psi, and XXXX psi, respectively, for containment shell. Using the ASME B&PV Code Case B284-1 criteria and the applicable HAC safety factor of 1.34, per Regulatory Guide, the applicant showed that all buckling interaction equations check parameters were less than one, as required. The maximum, membrane-plus-bending stress of XXXX psi, which occurs at the bottom closure plate, is well below the allowable of XXXXX psi. Therefore, the containment body will neither breach nor allow water in-leakage. This satisfies the requirements of 10 CFR 71.61 for the deep water immersion test.

2.7.8 Summary

The full-scale package of SAFKEG-LS Design 3979A was used to meet the design requirements of 10 CFR 72. Two (2) Dytran Model Number 3023A mini triaxial accelerometers capable of operating at -40oC (-40o F) were used to determine deceleration values during free drop cases. The accelerometers mounted on the containment vessel lid top to measure the same decelerations, with one being a backup for the other and to provide confidence in the results. The reason for mounting the accelerometers on lid was that this was considered the most susceptible part of the package for the containment boundary that the linear elastic range under all required testing conditions is to be ensured and maintained.

Following was be concluded from the series of tests performed on the

- The containment vessel remained leak-tight
- The dimensions and the weights of the containment vessel did not alter
- The cork was charged to a limited extent.
- The keg remained intact with the keg-lid in place.
- The keg shell was penetrated and welds were intact.

Comment [MMS2]: Note: For gases, they assume a leak rate and limit content to the A2/wk quantity from the leak. See 2nd RAI for input.

Besides performing required tests under 10 CFR 71.71 and 73, quasi-static analyses using ABAQUS v6.8 finite element program on an half scale mathematical model in the vertical plane through the center of the vessel of the Safkeg LS Package Design No. 3979A was performed to determine stress intensity values at the critical cross-sections of the containment vessel under NTC and HAC loadings. The analytical analyses were performed by VECTRA Group Limited, and was included in the Appendix of the SAR. First order brick elements were used throughout the model. At least four (4) elements were used to capture the stress distribution. Friction coefficient of 0.1 was defined between all the sliding parts. Preload of 8.12 kN (XXX lbs) was applied axially to the bolts, but they were free to slide. Boundary conditions XXXXXXXXXXXX. The static analyses were performed to determine the stress intensity leves at the critical locations. However, the dynamic effects were not considered for the impact cases. Design criteria of Regulatory Guide 7.6 was applied to determine the effects of combined loads on to the containment vessel. Load combinations were performed in accordance with Regulatory Guide 7.8 for NCT and HAC. The allowable stress values for bearing stress and for the bolts were taken from ASME Code Section III, Division 3. At critical locations from each load case, minimum design margins were calculated and reported for all loading combinations. The containment vessel inner shell was evaluated for buckling in accordance with the requirements of ASME Code Case N-284-2 for free drop cases. Fatigue analysis was also performed in accordance with Regulatory Guide 7.6, and was determined for temperature and pressure cases. The staff performed extensive review of input files and performed independent hand calculations to confirm the structural integrity of the containment vessel, and the staff concluded that the structural design was adequately described and evaluated to demonstrate its structural integrity to meet the requirements of 10 CFR Part 71.

2.8. 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 and that the package has adequate structural integrity to meet the requirements of 10 CFR Part 71.

3.0 THERMAL

The Croft Safkeg-LS Design No. 3979A package is a Type B(U) package designed for the transport of non-fissile nuclides and limited quantities of fissile nuclides in solid, and gaseous form. Liquid fissile nuclides have been excluded from the application based on the staff's concerns with regard to gas generation and the applicant not currently addressing the issue. The package is composed of a single resealable containment vessel (CV) carried within insulating cork packing in an outer stainless steel keg. Thermal protection of the contents within the CV is provided by the outer cork, top cork, inner cork, and the outer keg skin. All content is contained within inserts which are placed inside the containment vessel. Also the applicant has limited the amount of plutonium shipped to no more than an A2 quantity, thereby avoiding the packaging and thermal testing requirements of 10 CFR 71.64, Special Requirements for Plutonium Air Shipments.

Comment [M3]: Is this defined above?

The thermal evaluation of the package was primarily based on finite element analysis models. The Abaqus version 6.8-1 computer program was used for the thermal analysis of the package. The models created were benchmarked with a self heating test and a furnace test comparable to NCT and HAC, respectively, to confirm the analytical results.

Comment [M4]: Check acronym usage

3.1. Description of Thermal Design

Design features that are significant with respect to heat transfer in the Safkeg-LS 3979A are the stainless steel keg outer skin, stainless steel keg inner liner, the cork liner, the top and side corks, the stainless steel containment vessel, and the lead shielding in the containment vessel. All material shipped is enclosed into tungsten or stainless steel inserts which serve the purpose of convenience handling and shielding. All of these features are axi-symmetric. The keg and the cork provide the containment vessel with protection from impact and fire. Under HAC fire conditions the keg skin is designed to heat up very quickly with the cork providing insulation to the containment vessel, as a result of its low thermal conductivity and ablation properties. The keg body has a fuse plug which melts above 98°C to permit pressure relief of the gas evolution within the keg cavity when the cork heats up during HAC fire. At the request of the staff the applicant performed a sensitivity study of the effect of the air gaps on the NCT and the HAC fire. However, the staff noted that the thermal modeling did not include consideration of the effect of the packaging air gap widths to which the applicant performed a sensitivity study with the air gaps closed and cork conductivity modeled in lieu of air. Also, the staff identified that the thermal modeling didn't include consideration of the inserts nor any temperature effect on the content. As a result of the staff's comment the applicant reanalyzed the package to include the maximum temperature inside the inserts which was determined to be 128°C (NCT) and 198°C (HAC). In addition the Certificate has been conditioned to prohibit loading any solid material with a melting temperature less than 250°C.

Comment [M5]: Pasted final SER from Run to here.

3.1.1 Decay Heat

The package as originally submitted was designed for the transport of non-fissile nuclides and limited quantities of fissile nuclides in solid, liquid, and gaseous form. The contents decay heat was limited to a maximum of 10 W for solids and gases and 5 W for liquids. However, in response to a staff question regading gas generation in the liquid content, the applicant withdrew the liquid as being an authorized content until it has ample time to complete the analysis.

The staff verified that the heat output limits specified in the General Information section for each content type were under the decay heat limits specified.

3.1.2 Summary Tables of Temperatures

Table 3-1 summarizes the maximum temperatures reached under NCT and HAC conditions by the containment vessel cavity with different internal heat loads up to the maximum allowed internal heat load, per content decay heat limitations. Tables 3-2 and 3-3 provide comprehensive temperatures and component locations for NCT and HAC, respectively, and show the allowable material temperature limits for each component. Table 3-3 also summarizes the peak temperatures and the time at which they occur in the package resulting from the HAC thermal test and the period of post test heating of the internal parts of the package. The maximum temperatures calculated are all within the acceptable temperature limits for the package components except for the containment vessel O-ring. The peak temperature of the containment vessel O-ring is 183 C which is above its continuous duty operation of 149 C. The applicant proposes a batch test program to qualify each batch by ensuring the containment vessel remains leaktight after being subjected to 200C for 24 hours and is described in Chapter 8 of the SAR. Refer to the Materials SER for further discussion of the acceptability of this containment vessel seal material including radiation effects.

Table 3-4 shows the maximum design pressure of 8 bar absolute under NCT and 11 bar absolute under HAC conditions. However, pressurization effects for liquid contents due to gas generation and limiting combustible gases in the package to less than 5% by volume over one year have not yet been evaluated.

The staff reviewed these tables and the analyses used to determine the results, and found that the analyses were appropriately utilized.

3.1.3 Evaluation by Analysis

A finite element analysis using the Abaqus version 6.8-1 software was used to thermally model the package. The package is represented by an axi-symmetrical two dimensional geometry used to develop and execute thermal models that simulate the steady-state and transient temperatures arising from the evaluated NCT and HAC environments. Section 3.5.2 of the application provides a detailed report of the modeling and evaluations. The heat sources were appropriately modeled as heat fluxes at the containment vessel inner wall. The correct material properties were applied to the different components in the model. The conduction, convection, and radiation heat transfer modes were used adequately to simulate heat transfer throughout the package. The boundary conditions were also properly applied for both NCT and HAC. Furthermore, the thermal model was benchmarked against a prototype package tested under a self heating and furnace test. The tests were representative of NCT and HAC, respectively.

3.2. Material Properties and Component Specifications

The materials that affect the package's heat transfer capabilities are the Stainless Steel Type 304, Lead, and the Cork. The material properties used for the finite element analysis were determined by the staff to be representative of the package materials of construction. The stainless steel components of the package include the containment vessel and the keg. The containment vessel also contains lead shielding. The seals on the containment vessel lid are made from Ethlylene Propylene. The maximum temperatures reached by each component are given in Tables 3-2 and 3-3 for NCT and HAC, respectively. Each component is below its maximum allowable service temperature under NCT and HAC conditions except for the seal material which is discussed above and in the material evaluation SER. The minimum allowable service temperature of each component was also verified by the staff to be less than or equal to minus 40°C.

3.3. Thermal Evaluation under Normal Conditions of Transport

As previously mentioned, the applicant has used a finite element model to determine the temperatures of the package under NCT. Sections 3.3, 3.3.1, and 3.5.2 (SERCO/TAS/5388/001 Thermal Analysis of the SAFKEG LS Design) of the application provide details of the finite element steady state and transient analyses. Section 3.3.1 of the application evaluates the package under the conditions specified in 10 CFR 71.43(g). The evaluation shows that the maximum temperature of the accessible surface is 43°C which is reached on the keg lid. This meets the regulatory limit of 50°C. Figure 3-4 and 3-5 display the transient temperatures of the significant package components, and Figure 3-6 displays the maximum temperatures throughout the package under NCT. The peak temperatures experienced during NCT conditions with insolation are shown in Table 3-2 along with the allowable maximum temperatures for each component. Each component has a large thermal margin with the smallest being the containment seal with a thermal margin at 34°C. For the NCT cold evaluation all the package components were within their allowable service limits when evaluated at a thermal equilibrium temperature of -40°C.

The staff reviewed the analyses used to determine the results, and found that the analyses were appropriately utilized.

3.3.1 Maximum Normal Operating Pressure

Section 3.3.2 of the application provides an assessment of the maximum normal operating pressure in practice. The only pressure increases within the package are expected to come from the rise of component temperatures during NCT. The pressure is expected to rise ~30% according to Boyle's and Charles' Laws. Therefore, the maximum pressure expected during NCT is less than 2 bar absolute. The gaseous contents initially present in the package are not expected to significantly increase the pressure of the package under any condition. Liquid content are not part of this application and as such have not been evaluated for hydrogen generation. However, the temperatures are such that the liquid contents would not boil, thus there is no pressure increase due to the vapor pressure. The staff has determined that the package does not exceed the maximum design pressure of 8 bar absolute.

3.4. Thermal Evaluation under Hypothetical Accident Conditions

As stated in the application, Section 3.4 presents the predicted system temperatures and pressures for the package under the hypothetical accident condition (HAC) thermal test specified in §71.73(c)(4). The HAC thermal test was also performed using finite element analysis, similar to the model used for the NCT test. Section 3.5.2 provides a detailed report of the model. The HAC transient analysis is continued for a sufficient time after the end of the fire to ensure that all package components have reached their peak temperatures.

The staff also reviewed the analysis used to determine these results, and found that the analyses were appropriately utilized.

3.4.1 Initial Conditions

The initial temperature distribution for the HAC evaluation is taken at the end of a 12 hour period of insolation under NCT with a maximum content decay heat of 10 W at an ambient temperature of 38°C in the package's vertical orientation. All components are at their maximum temperatures as shown in Table 3-2. The staff finds that these conditions are the appropriate initial conditions for the HAC analysis.

3.4.2 Fire Test Conditions

As stated in the application, the thermal evaluation of the package for the HAC thermal test is performed by analysis. The analytical model is similar to the NCT thermal model. The keg surface emissivity is increased to reflect the expected surface conditions during the fire per §71.73(c)(4). During the heating phase all exterior surfaces of the keg were assumed to receive heat by forced convection and radiation from the furnace simulating a fully engulfing fire. The fire temperature was set at 800°C with an emissivity coefficient of 1.0. The transient analysis included 30 minute fire test followed by a 12 hour cooling period. The staff finds that the conditions used are acceptable.

In addition, the applicant performed a confirmatory thermal test using a prototype test specimen that had been subjected to the free drop and puncture testes. The thermal test provided confirmation that the package design meets the performance requirements in 10 CFR Part 71.

3.4.3 Maximum Temperatures and Pressure

The maximum temperatures of the package components for the HAC thermal test are summarized in Table 3-3. The results show that the maximum temperatures of the package components are all considerably lower than the maximum allowable temperatures. The smallest temperature margin for the HAC thermal test occurs in the containment vessel lid seal, which reaches a maximum temperature of 183°C versus a HAC temperature limit of 204°C. As discussed above containment seal material is batch tested to leaktight criteria after 24 hours at 200C. The lead in the containment vessel body is not permitted to melt and there is a 70°C margin between the maximum temperature reached and the melting temperature of the lead.

Comment [M6]: RAI 3-15

Remove the temperature limit of 204C from Table 3-3 for the containment vessel lid seal and replace it with the batch test temperature of 200C from Chapter 8. Also, the Note 1 associated with this seal temperature limit should reference the batch testing requirements for this seal.

10CFR71.35 requires (a) a demonstration that the package satisfies the standards specified in subparts E and F.

The applicant has excluded liquid content from this application, including any materials that would change phase from a solid to a liquid, Therefore, no analysis is required pressure increases due to vaporization. The maximum pressures in the containment vessel under NCT and HAC are shown in Table 3-4 and they bound the associated actual expected pressures.

The staff reviewed the results of the temperature and pressure analysis and found that they were acceptable.

3.4.4 Maximum Thermal Stresses

The maximum thermal stresses are discussed in structural chapter are are shown to be within their allowable limits.

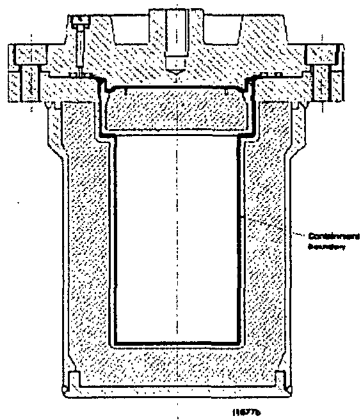
3.5. Evaluation Findings

Based on 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

4.1. Description of the Containment System

The containment boundary of the Safkeg-LS 3979A package is formed from the containment vessel (CV) flange/cavity wall, lid top and containment seal O-ring, as shown in Figure 4-1.



5.0

Figure 4-1 of CTR 2008/10, Rev. 2

The lid top is sealed to the flange/cavity wall by the containment seal O-ring which is fitted in a face seal configuration with the O-ring recessed into the flange. The lid top is held in position with 8 alloy steel closure screws which screw into the containment vessel flange/cavity wall and lid and are tightened to a torque of 10 ± 0.5 Nm. On tightening the closure screws a uniform and repeatable compression of the O-rings is provided.

The closure screws are recessed into the lid top to physically protect them from damage. There is also a shear lip in the lid top and flange protecting the screws from shear failure due to transverse impact loads. The closure screws are positive fasteners, that cannot be opened unintentionally, or by any pressure that may arise within the package.

There are no valves or pressure relief devices present in the containment boundary and the package does not rely on any filter or mechanical cooling system to meet the containment requirements. There is a weld present in the containment boundary as shown on Detail A of Drawing No. 1C-6044, Issue C and Detail B of Drawing No. 1C-6045, Issue C. However, the weld is needed to hold the lead shielding in position, and does not fulfill any containment requirement.

The containment system is designed and fabricated in accordance with ASME B&PV Code Section III, Subsection NB. The complete specifications such as closure screw torques, materials of construction, O-ring specifications and design dimensions for the containment system are given in drawings 1C-044, Issue C, 1C-6045, Issue C, and 1C-6046, Issue C, in Section 1.3.2 of CTR 2008/10, Rev. 2.

The flange/cavity wall and lid top are machined from solid stainless steel 304L. The containment O-ring is manufactured from Ethylene Propylene (EPM). All the materials have been selected for compatibility with each other, the inserts, and the payload, in order to avoid chemical, galvanic, or other reactions, as indicated in section 2.2.2.

EPM was been selected as the containment O-ring material as EPM offers a temperature range of -40°C to 150°C and is able to withstand short excursions to 200°C for 2 hours.

Figure 4-2, of CTR 2008/10, Rev. 2 shows the two additional O-ring seals fitted to the CV: a test point seal, and a test seal. These seals are present to facilitate the leak test of the containment seal during the pre-shipment leak test. The test point is a tapped hole that allows connection of a pressure drop leak tester to the interspace volume between the test seal and the containment seal. The test seal is located close to the containment seal to provide a small interspace volume thus increasing the sensitivity of the pressure rise leakage test. The inserts as specified in section 1.2.2.2 are also fitted with an O-ring seal. The test point seal, the test seal, and the insert seal are not relied upon for containment.

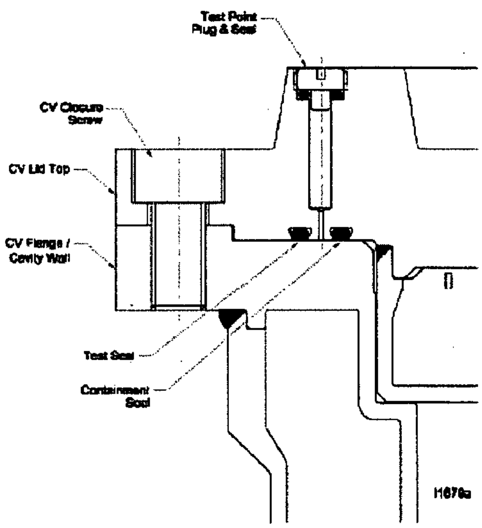


Figure 4-2 of CTR 2008/10, Rev. 2

(This section was written using Section 4 and Section 4.1 of CTR 2008/10, Rev. 2)

4.1 Containment under Normal Conditions of Transport (Type B Packages)

The maximum internal pressure of the containment vessel under NCT is taken as the design pressure of 7 bar gauge.

Section 4.2 of CTR 2008/10, Rev. 2, the applicant states, "The Safkeg-LS 3979A package has been designed specifically to meet the criteria for leaktight during NCT and to be testable to demonstrate that the CV containment boundary is leaktight for the design, testing, fabrication, and maintenance leak tests. Leaktight is defined as demonstration of a leakage rate of ≤ 10^{-7}

ref.cm^3/s as specified in ANSI N14.5." Under NCT the shielding inserts provide confinement of the radioactive material, but the containment is ensured by the CV seal in the CV.

In section 4.2.5 of CTR 2009/21, Issue C, the applicant states that, "A helium leak test was carried out prior to assembly of the keg on the containment vessel in accordance with ANSI N14.5-1997 as detailed in CP 390. The pass rate set for the test was 2×10^{-7} cm^3/s with a sensitivity of 5×10^{-8} cm^3/s helium at an upstream pressure of 1 atmosphere absolute and a downstream pressure of 0.01 atm or less."

In section 5.16 of CTR 2009/21, Issue C, the applicant states that, "The helium leak test carried out prior to the NCT and HAC tests is detailed in Reference 15 [TR 09/03/17]. The tested leak rate was 0.05×10^{-10} cm^3/sec which meets the acceptance criteria of 2×10^{-7} cm^3/sec.

The helium leak test carried out after the NCT and HAC tests is detailed in TR 09/03/30 (Ref. 28 of CTR 2009/21, Issue C). The tested leak rate was 1.92×10^{-10} cm^3/sec which meets the acceptance criteria of 2×10^{-7} cm^3/sec.

The results of the leak tests demonstrate that the containment vessel remained leak tight before and after the NCT and HAC tests. This indicates that the tests did not affect the containment vessel and its sealing system."

The staff verified that the helium leak test was performed on the entire containment boundary (CTR 2010/08, Issue A), that the package is leaktight, and the containment boundary is not affected by the NCT tests.

4.2 Containment under Hypothetical Accident Conditions (Type B Packages)

The maximum internal pressure of the containment vessel under HAC is taken as the design pressure of 10 bar gauge.

Section 4.3 of CTR 2008/10, Rev. 2, the applicant states, "The Safkeg-LS 3979A package has been designed specifically to meet the criteria for leaktight during HAC and to be testable to demonstrate that the CV containment boundary is leaktight for the design, testing, fabrication, and maintenance leak tests. Leaktight is defined as demonstration of a leakage rate of $\leq 10^{-7}$ ref.cm^3/s as specified in ANSI N14.5."

In section 4.2.5 of CTR 2009/21, Issue C, the applicant states that, "A helium leak test was carried out prior to assembly of the keg on the containment vessel in accordance with ANSI N14.5-1997 as detailed in CP 390. The pass rate set for the test was 2×10^{-7} cm^3/s with a sensitivity of 5×10^{-8} cm^3/s helium at an upstream pressure of 1 atmosphere absolute and a downstream pressure of 0.01 atm or less."

In section 5.16 of CTR 2009/21, Issue C, the applicant states that, "The helium leak test carried out prior to the NCT and HAC tests is detailed in Reference 15 [TR 09/03/17]. The tested leak rate was 0.05×10^{-10} cm^3/sec which meets the acceptance criteria of 2×10^{-7} cm^3/sec.

The helium leak test carried out after the NCT and HAC tests is detailed in TR 09/03/30 (Ref. 28 of CTR 2009/21, Issue C. The tested leak rate was 1.92×10^{-10} cm^3/sec which meets the acceptance criteria of 2×10^{-7} cm^3/sec.

The results of the leak tests demonstrate that the containment vessel remained leak tight before and after the NCT and HAC tests. This indicates that the tests did not affect the containment vessel and its sealing system."

In addition to the pre/post NCT and HAC helium leakage tests, the applicant evaluated there would be not escape of krypton-85 exceeding 10 A_2 in 1 week (10CFR71.51). This evaluation was done in CS 2009/06, Issue A and CS 2009/07, Issue A.

The staff verified that the helium leak test was performed on the entire containment boundary (CTR 2010/08, Issue A), that the package is leaktight, and the containment boundary is not affected by the HAC tests.

4.3 Special Requirements for the Shipments of Plutonium by Air

The applicant has **not** evaluated the Safkeg-LS 3979A to 10 CFR 71.64, 71.74, and 71.88 for plutonium air shipments. The contents listed in Table 1-4-7 and 1-4-8 do include plutonium.

Therefore, the applicant is restricted from shipping plutonium by air.

4.4 Leakage Rate Tests for Type B Packages

Section 7.1.3 of CTR 2008/10, Rev. 2 discusses the **pre-shipment** leak test on the containment boundary. This test will be performed in accordance with ANSI N14.5 by using the gas pressure rise or gas pressure drop methods. According to section 7.1.3 of CTR 2008/10, Rev. 2, and the sensitivity of the test will be done at 10^{-3} ref.cm^3/s, which is in accordance with ANSI 14.5 guidelines.

Section 8.2.2 of CTR 2008/10, Rev. 2 discusses the **periodic** and **post maintenance** leak tests. This test will be performed in accordance with ANSI N14.5 by using the evacuated envelope (gas detector) method. According to section 8.2.2, the test sensitivity will be 5 X 10^{-8} which will detect the 1 X 10^{-7} ref. cm^3/s leak rate, per ANSI N14.5. This leakage test will be done after replacement of the containment seal, repair of the containment sealing surface, and/or ?repair or replacement of the containment vessel lid or body as well as within 12 months prior to package use. Staff verified that the periodic and post maintenance helium leak test are performed on the entire containment boundary (CTR 2010/08, Issue A).

Staff notes that Section 8.2.3.3 of CTR 2008/10, Rev. 2 states, "O-rings shall be procured in accordance with drawing 1C-6044." Therefore, no repairs may be made to damaged containment vessel seals for return to service.

Section 8.1.4 of CTR 2008/10, Rev. 2 discusses the **fabrication** leak test. This test will be performed in accordance with ANSI N14.5 by using the evacuated envelope method. According to section 8.1.4, the test sensitivity will be 5 X 10^{-8} which will detect the 1 X 10^{-7} ref. cm^3/s leak rate, per ANSI 14.5. This section of the SAR also states that the Inserts (not part of the containment boundary) will be leak tested. Staff verified that the fabrication helium leak test is performed on the entire containment boundary (CTR 2010/08, Issue A).

4.5 Evaluation Findings

Based on 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 package design meets the containment requirements of 10 CFR Part 71.

5 SHIELDING

The objective of this review is to verify that the Croft Safkeg-LS Design No. 3979A Type B(U) transportation package meets the external radiation requirements of 10 CFR Part 71 under normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

The staff shielding review evaluated the Safkeg shielding features to provide adequate protection from the radioactive contents within. This review looked at the methods and calculations employed by Croft to determine expected gamma and neutron radiation at locations near the cask surface and at specific distances away from the cask.

5.1 Description of the Shielding Design

5.1.1 Design Features

The 3979A containment vessel (CV) body is fabricated from three pieces of stainless steel: the flange/cavity wall, the outer wall, and the base. The flange/cavity wall is welded to the outer wall to form a cavity into which the lead shield is cast. This cast-in-place shield is the primary gamma shield for the package. The steel of the CV provides some additional shielding. The lid and body are stepped to reduce streaming pathways.

The CV cavity will be filled with one of three inserts, which themselves have a smaller cavity in which radioactive material will be placed. The LS-12x65-Tu and the LS-31x73-Tu are both tungsten inserts with a radionuclide mass limit of 30g and 200g respectively. A third, stainless-steel insert, the LS-50x103-SS design, has a radionuclide mass limit of 800g. Each of these inserts provides additional radiation shielding.

No credit is taken for the product container in shielding and containment analyses.

5.1.2 Summary Table of Maximum Radiation Levels

The maximum NCT and HAC dose rates are reported in Table 5-1. The applicant has assumed that the external dose rate is the maximum allowed under 10 CFR 71.47. The package is not planned to be transported via exclusive use shipments. Due to the geometry of the package, a surface dose rate of 200 mrem/h or less will correspond to a 1 m dose rate less than 5 mrem/hr.

5.2 Source Specification

Both neutron and gamma sources were analyzed for transport in the Safkeg-LS 3979A. The maximum permissible source activity is listed per nuclide in Tables 1-4-1 through 1-4-7. A worst-case configuration was determined by a series of reference calculations. These calculations were designed to account for solid sources allowed in the container. The conservative assumptions used in the analysis change depending on the type of source and insert to be used.

5.2.1 Gamma Source

The bounding configuration of a solid and gas sources was analyzed with a 1000 Ci Ir-192 point source in the CV cavity. The dose rate results from the point source analysis are summarized in Table 5-3. The location resulting in the highest external dose rate in all configurations, including analysis with the two tungsten inserts, is the bottom center of the container cavity. This analysis is conservative as the use of a point-source ignores self-shielding. The source is concentrated at a point closest to an external surface rather than distributed throughout the CV cavity. No shielding is assumed to be provided by the sample container.

The results of this Monte Carlo analysis yield scale factors for the various nuclides to determine the total source activity that will result in a 200 mrem/hr surface dose rate. Activity limits by nuclide are listed in Table 5-5, whereas tables 1-4-1 through 1-4-7 are grouped by source material state, type and package insert required for shipment.

An additional calculation was performed to determine the dose rate at the position of the o-ring seal for material analysis.

The point-source assumption is conservative under hypothetical accident conditions. Since there are no liquid sources, no further analysis is necessary.

5.2.2 Neutron Source

The only neutron-emitting source material permitted is Plutonium. This is required to be in solid, metal form. Contents will be limited by the CoC to be in compliance with the General License provisions in 10 CFR 71 subpart C.

The staff concludes that the applicant's radiation source configuration is conservative for the shielding analysis and described in sufficient detail.

5.3 Shielding Model

The cask is made of an inner and outer stainless steel shell, with a layer of lead in between. The inserts will be either steel or tungsten and provide additional shielding. The elemental composition and mass fraction of the materials as modeled is presented in Table 1 of enclosure SERCO/TAS/003191/001.

A table of authorized materials is presented and limited by total activity. The source material itself will provide some shielding which is conservatively ignored. Other conservative simplifications were used in the model: small chamfers and rounding at corners is modeled in the vicinity of the CV o-rings; nuts and bolts are omitted but the central hole at the top of the CV is modeled; the small air gaps at the lid/body interface are modeled explicitly; cork and o-ring material are modeled as void.

Monte Carlo models were made to determine the bounding point-source location for shielding analysis. In this test case, a 1 kCi point source of Ir-192 was modeled and it was determined that placing the source at the bottom center of the empty CV cavity with the corresponding location of maximum external dose being the bottom of the cask.

The staff has determined that the shielding model is described in sufficient detail to conduct a review of the package shield design.

5.4 Shielding Evaluation

5.4.1 Methods

The Appendix, listed as section 5.6 in the SAR, contains the discussion of the shielding analysis and references the model specifications for the shielding evaluation. The details of the analysis are contained additional enclosures: CTR2009/22 and SERCO/TAS/003191/001. All relevant shielding design features of the Safkeg-LS 3979A were modeled in the three dimensional Monte Carlo analysis used with a reference point source.

MCBEND version 10A_RU1 was the Monte Carlo transport code used in the analysis of this package. ANSWERS Software Services of Serco prepared the enclosure detailing the Monte Carlo analyses which used a continuous cross-section library based on the UK Nuclear Data Library. MCBEND is an acceptable code to use in this application and the cross-section libraries are appropriate in this analysis.

The surface tally was divided into 16 axial, 4 radial regions with the three outermost radial rings further divided azimuthally into 12 regions. A similar division was done at 1m from the package surface with 23 axial divisions. The gamma dose-rate conversion factors are based on recommendations of ICRP74. The Monte Carlo tallies are integrated over a multi-group energy scheme and folded into flux to give dose-rates.

Subsequent MicroShield analyses were performed for each nuclide to determine the relative dose rates. MicroShield is initially used with the 1000 Ci I-192 source and compared to the reference MCBEND analysis. The model is then modified so the results match those of the Monte Carlo calculations.

The neutron dose rate is based on published dose conversion factors and is detailed in Appendix A of enclosure CTR2009/22.

MicroShield does not assess beta or x-ray radiation directly. Secondary radiation was calculated using the equations in Cember to estimate the photon flux from Bremsstrahlung radiation and imported into MicroShield, together with the beta energy line, to predict the worst case dose rate.

5.4.2 Input and Output Data

A sample output file was provided, however none of the shielding model input files were included in the SAR.

5.4.3 Flux-to-Dose-Rate conversion

Dose conversion factors are taken from IAEA SS37 and Cember's "Introduction to Health Physics."

5.4.4 External Radiation Levels

A summary of the radiation levels on the package surface and at 1m are presented in Table 5-1.

5.4.5 Confirmatory Analyses

The staff reviewed the applicant's shielding models and determined that the conservative assumptions and analysis methods are appropriate to this shielding design package.

The staff performed MicroShield calculations to compare the relative dose rates from select nuclides and staff results are within reasonable agreement with the applicant's analysis.

The staff concludes that the design of the shielding system for the Crofts Safkeg-LS 3979A package is in compliance with 10 CFR Part 71 and the applicable design criteria have been satisfied. The evaluation of the shielding system provides reasonable assurance that the Safkeg-LS 3979A will provide safe transportation of radioactive materials. This finding is based on staff confirmation of relative dose rates, confirmation of the reference source dose rate, as well as considerations of the applicant's conservative analyses and modeling assumptions in the SAR.

5.5 Evaluation Findings

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

6 CRITICALITY

6.1 Fissile Material Meeting the General License Conditions

The CoC limits fissile material in the package to the quantity allowed under the General License Conditions of 10 CFR 71.22 and 71.23, or the exempt quantity limitations of 10 CFR 71.15.

6.2 Evaluation Findings

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

7 PACKAGE OPERATIONS

7.1 Package Loading

[Reviewer's input]

7.2 Preparation for Transport

[Reviewer's input]

7.3 Package Unloading

[Reviewer's input]

7.4 Preparation of Empty Package for Transport

[Reviewer's input]

7.5 Other Procedures

[Reviewer's input]

7.6 Evaluation Findings

Based on review of 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 its evaluation for approval.

8 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM REVIEW

Section 8 of the application 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

Section 8.1 specifies the following acceptance tests for each packaging:

(insert bulleted listing)

8.2 Maintenance Program

Section 8.2 specifies the following maintenance should be performed annually for each package:

(insert bulleted listing)

(Provided by Matt) *The maintenance program includes periodic visual inspection of* the welds and fasteners on the keg outer shell and containment vessel body and lid. The threads in the closure of the containment vessel and inserts will also be checked. Prior to shipping, the O-rings on the confinement vessel are examined and helium leak testing of the containment vessel is performed. O-rings on both the containment vessel and the inner insert are replaced annually at a minimum. The staff finds the maintenance program adequate for ensuring the safe operation of the package.

8.3 Evaluation Findings

Based on review of the 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

In addition to the authorized contents listed in Sections 1.2 and the drawings listed in Section 1.4 of this safety evaluation report, the CoC includes the following conditions of approval:

Condition No. 6: 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, dated 30 September 2010, in Section 7.0 of the application.

(b) The package must meet the Acceptance Tests and Maintenance Program, dated 30 September 2010, in Section 8.0 of the application.

Condition No 7: Air transport of plutonium is not authorized.

Condition No. 8: The package authorized by this certificate is hereby approved for use under the general license provisions of 10 CFR 71.17.

Condition No. 9: Expiration date: November 30, 2015.

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. 3979A package meets the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9337, Revision No. 0
on ________________.