CONTENTS

4 CONTAINMENT

The containment boundary of the SAFKEG-HS 3977A package is identified and discussed in this chapter. The design, materials selected and the method of fastening are discussed with regards to meeting the containment requirements during the operation of the package. The ability of the package to provide the required containment during Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) as defined in 10 CFR 71.71 and 10 CFR 71.73 [4.1] respectively is presented. The criteria that verify the containment requirements during fabrication, maintenance and use are presented within this section.

4.1 Description of the Containment System [71.33 (a)(4)]

The containment boundary of the Safkeg-HS 3977A package is formed from the containment vessel flange/cavity wall, lid top and containment seal O-ring for both the standard and split CV lid versions, as shown in Figure 4-1 and Figure 4-2. 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 welds, 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.

The containment system is designed, fabricated, examined, tested and inspected in accordance with ASME B&PV Code Section III, Subsection NB [4.2]. 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-5944, 1C-5945, 1C-5946, 1C-7504, 1C-7505 and 1C-7506 in Section 1.3.2

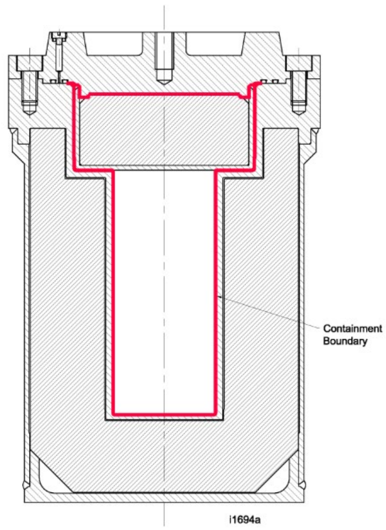

Figure 4-1 Package Containment Boundary with a Standard CV Lid

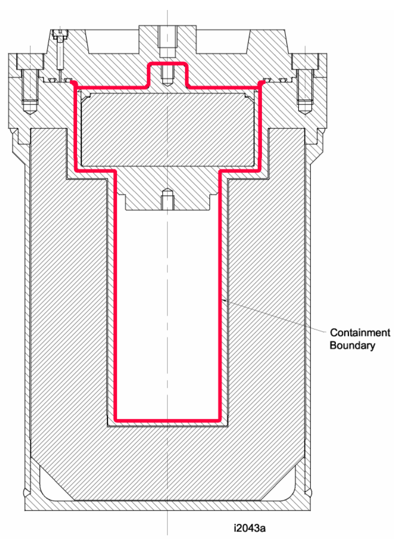

Figure 4-2 - Package Containment Boundary with a Split CV Lid

The flange/cavity wall and lid top are machined from 304L solid stainless steel. The containment O-ring is manufactured from the Fluoroelastomer, Viton GLT. The materials of construction of the containment system are evaluated in Section 2.2.2. 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.

Viton GLT has been selected as the containment O-ring material because it offers a temperature range of -40°C to 205°C [4.3]. The radiation dose to the containment seal, assuming that the package is loaded with maximum contents as specified in Section 1.2.2 for a full year, is estimated to be << 10^4 Gy (10^6 rad). This estimate is based on the dose rate data presented in Section 5.5.4.1.1 for Cs-137 contents. It is judged that Cs-137 would produce the highest dose rate to the containment seal (which is outside the shielding) as it has a penetrating radiation. The maximum dose rate at the containment seal for each of the three inserts specified in Section 1.2.2 for the maximum Cs-137 contents, limited by the package maximum allowable surface dose rate, is given in Table 4-1.

For CT-6 (Thorium Target) the following apply.

The dose rate at the CV containment seal at time of packing (24 hr from EOB) have been calculated (see Atkins document 5183326, SARP Section 5.6.2) as 5.4E-7 Mrad/hr (0.0054 Gy/h). The absorbed dose in a period of 1 year at the dose rate at 24 hr from EOB at the CV containment seal would be 0.0047 Mrad (47 Gy). The Viton containment seal would not be damaged by 0.0047 Mrad – see Parker catalogue which indicates concern for doses of 10 Mrad.

Table 4-1 Safkeg-HS - Dose rate at the containment seal - based on Cs-137

Contents	CT-1				CT-2				CT-3			
Insert	HS-12x95-Tu Design No 3985				HS-31x114-Tu Design No 3982				LS-50x103-SS – Design # 3986			
	Source		Dose rate at containment seal		Source		Dose rate at containment seal		Source		Dose rate at containment seal	
			Sv/h	R/h			Sv/h	R/h			Sv/h	R/h
Calculated dose rate (1)	3000	Ci	1.60E-03	1.60E-01	3000	Ci	4.10E-03	4.10E-01	3000	Ci	2.89E+00	2.89E+02
Package limit	3.89E+03	Ci			8.58E+03	Ci			4.68E+02	Ci		
Dose rate for CT limit			2.07E-03	2.07E-01			1.17E-02	1.17E+00			4.51E-01	4.51E+01
			Sv	Rrad			Sv	Rrad			Sv	Rrad
Dose in 1 year	8760	hrs	1.82E+01	1.82E+03			1.03E+02	1.03E+04			3.95E+03	3.95E+05

Notes:

(1) From Table 5-10, Section 5.5.4.1.1

(2) The dose rate for CT-4 were calculated for nearly identical Insert 3986

The Parker Handbook reports that "Practically all elastomers suffer no change of their physical properties at radiation levels up to 10^6 rad". Therefore it is concluded that the containment O-ring seal will not be unduly affected by the radiation from the contents of the package. It is noted that the containment O-ring seal is required to be replaced during the periodic maintenance activity (Section 8.2) (maximum period of 1 year).

Figure 4-3 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 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.

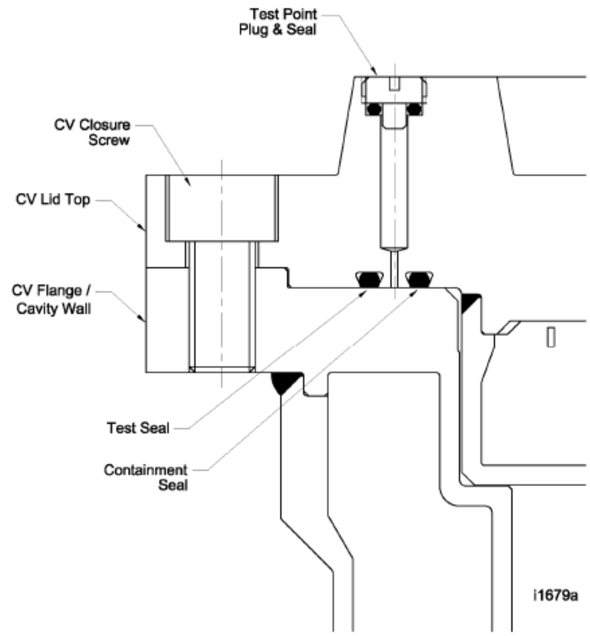

Figure 4-3 Leak Test Seal Arrangement

4.2 Containment under Normal Conditions of Transport (NCT) [71.51 (a)(1)]

4.2.1 Maximum internal pressures under NCT

The maximum internal pressure of the containment vessel under NCT is taken as the design pressure of 800kPa abs (8.0 bar abs) (see Section 3.3.2).

4.2.2 NCT Containment Criterion

The Safkeg-HS 3977A package has been designed specifically to meet the criteria for leak tightness during NCT. The CV containment boundary is tested to demonstrate it is leaktight at the testing, fabrication, and maintenance of the design. Leaktight is defined as demonstration of a leakage rate of $\leq 10^{-7}$ ref.cm^3/s as specified in ANSI N14.5 [4.5].

The contents are carried within inserts for Contents Types CT-1, CT-2, CT-3, CT-4, CT-5 and CT-6 ss specified in Section 1.2.2.

For solid and liquid radioactive material, under NCT the shielding inserts provide confinement of the radioactive material (solid or liquid) within the shielding (see Sections 4.2.4 and 4.3.2).

For CT-1, CT-2, CT-4 and CT-5, the shielding calculations are based on the contents being retained within the insert specified for the particular contents. For CT-6 the contents being retained within the CV cavity by the form of the material and the #4109 insert with it's O-ring confinement seal.

However, containment is provided by the containment seal in the CV.

For gaseous contents in CT-3 and CT-6, it is assumed that the gas leaks through the containment seal at a leakage rate of 10^{-7} ref.cm^3/s and the gas contents are limited to ensure that the leakage rate would not exceed the regulatory limit of $10^{-6}A_2$/hr.

4.2.3 Structural Performance under NCT

The structural performance of the containment boundary of the CV has been demonstrated by prototype testing and analysis.

A prototype Safkeg-HS 3977A package was subjected to the NCT and HAC tests, as reported in Sections 2.6 and 2.7, in an uninterrupted test series, the containment seals were shown to be leaktight on conclusion of the tests.

The structural analysis reported in Sections 2.6 and 2.7 showed that there would be no permanent deformation of any of the containment system components under NCT conditions.

4.2.4 Containment of Radioactive Material under NCT

The structural performance of the containment boundary of the CV has been demonstrated by prototype testing and analysis.

A prototype Safkeg-HS 3977A package was subjected to the NCT and HAC tests, as reported in Sections 2.6 and 2.7, in an uninterrupted test series. Following the tests, the containment vessel was leakage tested in accordance with ANSI N14.5 and the containment system seals were found to be leaktight (having a leakage rate of $\leq 10^{-7}$ ref.cm^3/s).

The structural analysis reported in Sections 2.6 and 2.7 showed that there would be no permanent deformation of any of the containment system components under NCT, therefore there would be no effect which could cause any reduction in the effectiveness of the containment system.

The contents are carried within inserts for Contents Types CT-1, CT-2, CT-3, CT-4 and CT-5 as specified in Section 1.2.2 or directly in the CV cavity for Contents Type CT-6.

For solid and liquid radioactive material in Contents Types CT-1, CT-2, CT-4 and CT-5 as specified in Section 1.2.2, under NCT the shielding inserts (together with the user defined product containers) provide confinement of the radioactive material (solid or liquid) within the shielding.

For solid radioactive material in Contents Type CT-6 as specified in Section 1.2.2, under NCT the CV cavity and insert with its seal provide confinement of the radioactive material within the shielding. The form of CT-6, being a thorium metal in a metal housing, also provides confinement of the radioactive material within the CV.

Thus the shielding calculations are based on the contents being retained within the insert specified for the particular contents.

For gaseous radioactive gas is assumed to leak from shielding inserts (and the user defined product containers) and fill the cavity of the CV. The gas is assumed to leak from the CV at the containment seal at the leakage rate to which the containment is proved [i.e. 10^{-7} ref.cm^3/s].

4.3 Containment under Hypothetical Accident Conditions (HAC) [71.51 (a)(2)]

4.3.1 Maximum internal pressures under HAC

The maximum internal pressure of the containment vessel under HAC is taken as the design pressure of 1100kPa abs (11.0 bar abs) (see Section 3.3.2)

4.3.2 HAC Containment Criterion

The Safkeg-HS 3977A package has been designed specifically to meet the criteria for leak tightness 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 [4.5].

The contents are carried within inserts for Contents Types CT-1, CT-2, CT-3, CT-4, CT-5 and CT-6, as specified in Section 1.2.2.

For solid and liquid radioactive material in Contents Types CT-1, CT-2, CT-4 and CT-5 as specified in Section 1.2.2, under HAC the shielding inserts (together with the user defined product containers) provide confinement of the radioactive material within the shielding.

For solid radioactive material in Contents Type CT-6 as specified in Section 1.2.2, under HAC the CV cavity and #4109 insert with its seal provide confinement of the radioactive material within the shielding. The form of CT-6, being a thorium metal in a metal housing, also provides confinement of the radioactive material within the CV.

Thus the shielding calculations are based on the contents being retained within the insert specified for the particular contents.

For gaseous radioactive material, under HAC the gas is assumed to leak from shielding inserts (and the user defined product containers) and fill the cavity of the CV lid. The gas is assumed to leak from the CV at the containment seal at the leakage rate to which the containment is proved i.e. 10^{-7} ref.cm^3/s.

4.3.3 Structural Performance under HAC

The structural performance of the containment boundary of the CV has been demonstrated by prototype testing and analysis.

A prototype Safkeg-HS 3977A package was subjected to the NCT and HAC tests, as reported in Sections 2.6 and 2.7, in an uninterrupted test series. Following the tests, the containment vessel was leakage tested in accordance with ANSI N14.5 and the containment system seals were found to be leaktight (having a leakage rate of $\leq 10^{-7}$ ref.cm^3/s).

The structural analysis reported in Sections 2.6 and 2.7 showed that there would be no permanent deformation in any of the containment system components under HAC. Therefore there would be no effect which could cause any reduction in the effectiveness of the containment system.

The structural performance of the confinement boundary of the inserts has been demonstrated by the prototype tests reported in Section 2. These tests, on the inserts that are designated for liquid contents, showed that the inserts provide complete confinement of liquid contents under the HAC 9m drop test.

4.3.4 Containment of Radioactive Material under HAC

4.3.4.1 Containment of solid and liquid contents

The thermal evaluation in Section 3.4 shows that the seals, bolts and containment system materials do not exceed their temperature limits under HAC.

The testing and analysis reported in Section 2 show that the containment system would be unaffected by HAC and provide complete containment for all solid and liquid contents.

The containment system has been shown to be unaffected by HAC and the seals are within their working temperature for the HAC thermal test: it is therefore concluded that the containment system meets the requirement for providing containment of the solid and liquid radioactive contents, within the allowable leakage limits under HAC.

The tests reported in Section 2 showed that the inserts that are designated for liquid contents, provide complete confinement of liquid contents under the HAC 9m drop test. Assurance of the ability of the inserts to provide confinement for liquid contents during shipment and under HAC is given by the requirements specified in Section 7 for leak testing the inserts that carry liquid before each shipment.

4.3.4.2 Containment of gaseous contents

Containment of gases is based upon the assumption that the closure of the containment system (i.e. the containment seal and the CV lid and top flange) would leak at the leakage rate to which the containment is proved i.e. 10^{-7} ref.cm^3/s.

The maximum amount of the radioactive gases that may be carried has been calculated based upon the allowable leakage rate limits specified in 10 CFR71 and the assumed leak in the containment seals of 10^{-7} ref.cm^3/s. The calculation of the size of a single leak having a leakage rate of 10^{-7} ref.cm^3/s is given in report CS 2012/04 (Section 4.5.2). The calculated hole diameter, for a single leak path in the 3 mm O-ring, with a hole length of 0.26 cm, is 1.1 x 10^{-4} cm.

The gas leakage rates for gas contents in CT-3 (in terms of mass flow and A_2/hr and A_2/week) are given in report CS 20012/05 (Section 4.5.2).

The gas leakage rates for the gas in the thorium target in CT-6 (in terms of mass flow and A2/hr and A2/week) are given in report CS 20018/01 (Section 4.5.2).

The allowable leakage rates under HAC are taken as no escape of Kr-85 exceeding 10 A_2, and no escape of other radioactive material exceeding a total amount of A_2 in a week, as given in 10 CFR 71.51 (a)(2) [4.1].

4.4 Leakage Rate Tests for Type B Packages

4.4.1 Fabrication Leak Rate Test

The materials and components used to manufacture the containment boundary are required to be helium leak tested during fabrication with a pass rate of 10^{-7} ref.cm^3/s. These tests ensure that the fabricated components and the materials used, meet the required level of containment prior to the approval of the package for use.

The requirements for the fabrication leak rate test are specified in Section 8.1.4.

The confinement capability of the inserts is assured by the requirements specified in Section 8.1.4.

4.4.2 Maintenance Leak Rate Test

If any maintenance activities are undertaken on the containment boundary, a helium leak rate test is required to confirm that any repairs or replacements have not degraded the containment system performance. The required leak rate has a pass rate of $\leq 10^{-7}$ ref.cm^3/s.

The requirements for the maintenance leak rate test are specified in Section 8.2.2.

The confinement capability of the inserts is assured by the requirements specified in Section 8.2.2.

4.4.3 Periodic Leak Rate Test

A periodic helium leak rate test is required to be carried out annually with a pass rate of $\leq 10^{-7}$ ref.cm^3/s. This test confirms that the containment boundary capabilities have not deteriorated over an extended period.

The requirements for the periodic leak rate test are specified in Section 8.2.2.

The confinement capability of the inserts is assured by the requirements specified in Section 8.2.2.

4.4.4 Pre-shipment Leak Rate Test

Prior to shipment, each package is required to be leak rate tested using the gas pressure rise or gas pressure drop method, with a pass rate of $5x10^{-4}$ ref.cm^3/s. This test confirms the CV is correctly assembled prior to shipment.

The requirements for the pre-shipment leak rate test are specified in Section 7.1.5.

The confinement capability of the inserts used for Contents Types CT-1, CT-2, CT-3 and CT-4 is assured by the requirements specified in Section 7.1.2.

The confinement capability of the inserts used for Contents Type CT-5 is assured by the requirements specified in Section 7.1.3.

The confinement capability of the insert used for Contents Type CT-6 (see Figure 1-3c) used for Contents Type CT-6 is assured by the requirements specified in Section 7.1.4.

4.5 Appendix

4.5.1 References

[4.1] Title 10, Code of Federal Regulations, Part 71, Office of the Federal Register, Washington D.C.

[4.2] ASME III Division 1 – Subsection NB, Class One Components, Rules for Construction of Nuclear Facility Components, ASME Boiler and Pressure Vessel Code, 2001 edition, the American Society of Mechanical Engineers, New York, New York

[4.3] Parker Hannifin Corporation, Parker O Ring Handbook, ORD 5700/USA, 2001

[4.4] Bronowski, D. R., Performance Testing of Elastomeric Seal Materials Under Low- and High-Temperature Conditions: Final Report, SAND94-2207, Sandia National Laboratories, June 2000

[4.5] ANSI N14.5, American National Standard for Radioactive Materials - Leakage Test on Packages for Shipment, American National Standards Institute, Inc., 1997

4.5.2 Supporting Documents

Document Reference	Title
CS 2012/04	SAFKEG-HS # 3977A - CV seal leak size for leaktight condition
CS 2012/05	SAFKEG-HS 3977A - Gas contents limit for leaktight condition
CS 2018/01	SAFKEG-HS 3977A - Gas contents limit for leaktight condition - Thorium target