0.1 SAR REVISION STATUS

<table>
<tr><td rowspan="3">Title</td><td rowspan="3">SAFKEG-HS 3977A
Docket No. 71-9338</td><td>Number</td><td>CTR 2008/11</td></tr>
<tr><td>Issue</td><td>Revision 10</td></tr>
<tr><td>File Reference</td><td>[CTR2008-11-R10-Sc0-v1-Contents]</td></tr>
<tr><td rowspan="2">Compiled</td><td></td><td>Checked</td><td></td></tr>
<tr><td>S Bryson</td><td></td><td>R A Vaughan</td></tr>
<tr><td rowspan="2">Approved</td><td></td><td rowspan="2">Date</td><td rowspan="2">09 September 2016</td></tr>
<tr><td>R A Vaughan</td></tr>
<tr><td colspan="4">Croft Associates Ltd F4 Culham Science Centre Abingdon Oxon OX14 3DB UK Tel 44 (0)1865 407740</td></tr>
</table>

0.2 SUPPORTING DOCUMENT REVISION STATUS

Page/Document Reference	Issue Status	Title
Section 0 – SUPPORTING DOCUMENT REVISION STATUS		
Page 0-1	Rev 6	
Page 0-2	Rev 10	
Page 0-3	Rev 10	
Page 0-4	Rev 10	
Page 0-5	Rev 10	
Page 0-6	Rev 10	
Page 0-7	Rev 10	
Page 0-8	Rev 10	
Page 0-9	Rev 10	
Page 0-10	Rev 10	
Page 0-11	Rev 10	
Page 0-12	Rev 10	
Page 0-13	Rev 10	
Page 0-14	Rev 10	
Page 0-15	Rev 10	
Section 1 - GENERAL INFORMATION		
Page 1-1	Rev 5	
Page 1-2	Rev 7	
Page 1-3	Rev 7	
Page 1-3a	Rev 7	
Page 1-4	Rev 7	
Page 1-5	Rev 7	
Page 1-5a	Rev 7	
Page 1-6	Rev 7	

Page/Document Reference	Issue Status	Title
Page 1-7	Rev 7	
Page 1-7a	Rev 7	
Page 1-8	Rev 7	
Page 1-9	Rev 7	
Page 1-9a	Rev 7	
Page 1-10	Rev 7	
Page 1-10a	Rev 7	
Page 1-11	Rev 10	
Page 1-12	Rev 7	
Page 1-13	Rev 6	
Page 1-13a	Rev 9	
Page 1-14	Rev 7	
Page 1-15	Rev 5	
Page 1-16	Rev 5	
Page 1-17	Rev 5	
Page 1-18	Rev 5	
Page 1-19	Rev 8	
Page 1-20	Rev 5	
Page 1-21	Rev 5	
Page 1-22	Rev 9	
Page 1-23	Rev 5	
Page 1-24	Rev 5	
Page 1-25	Rev 5	
Page 1-26	Rev 5	
Page 1-27	Rev 5	
Page 1-28	Rev 5	

Page/Document Reference	**Issue Status**	**Title**
Page 1-29	Rev 5	
Page 1-30	Rev 6	
Page 1-31	Rev 5	
Page 1-32	Rev 5	
Page 1-33	Rev 7	
Page 1-34	Rev 7	
Page 1-35	Rev 7	
Page 1-36	Rev 6	
Page 1-37	Rev 7	
Page 1-38	Rev 7	
Documents in Section 1.3 Appendix		
Documents in Section 1.3.2 Calculation Model Drawings		
0C-5949	Issue A	Safkeg-HS Construction
1C-5997	Issue A	Containment Vessel HS Lid Construction
1C-5999	Issue A	Containment Vessel HS Body Construction
3C-6850	Issue A	HS-12x95-Tu Insert Design No.3982 (construction)
3C-6851	Issue A	HS-31x114-Tu Insert Design No. 3985 (construction)
3C-6852	Issue A	HS-55x128-SS Insert Design No. 3987 (construction)
Documents in Section 1.3.3 Licensing Drawings		
1C-5940	Issue G	Cover sheet for Safkeg-HS design no. 3977A (licensing drawing)

Page/Document Reference	Issue Status	Title
0C-5941	Issue E	Safkeg-HS design no. 3977A (licensing drawing)
0C-5942	Issue C	Keg design no. 3977 (licensing drawing)
0C-5943	Issue B	Cork set for Safkeg-HS (licensing drawing)
1C-5944	Issue C	Containment vessel design no. 3978 (licensing drawing)
1C-5945	Issue D	Containment vessel lid (licensing drawing)
1C-5946	Issue E	Containment vessel body (licensing drawing)
2C-6173	Issue D	HS-12x95-Tu Insert Design No 3982 (Licensing drawing)
2C-6174	Issue D	HS-31x114-Tu Insert Design No 3985 (Licensing drawing)
2C-6176	Issue E	HS-55x128-SS insert design no 3987 (licensing drawing)
2C-6920	Issue A	Silicone Sponge Rubber Disc
1C-7500	Issue B	Cover sheet for Safkeg-HS design no. 3977A - Mallinckrodt Version
0C-7501	Issue B	Safkeg-HS design no. 3977A - Mallinckrodt Version
0C-7502	Issue A	Keg design no. 3977 - Mallinckrodt Version
0C-7503	Issue A	Cork set for Safkeg-HS - Mallinckrodt Version
1C-7504	Issue A	CV design no. 3978 - Mallinckrodt Version

Page/Document Reference	Issue Status	Title
1C-7505	Issue A	CV lid - Mallinckrodt Version
1C-7506	Issue A	CV body - Mallinckrodt Version
1C-7507	Issue A	Containment vessel plug – Mallinckrodt version
2C-7508	Issue B	HS-50x85-SS insert design no 4081
2C-7509	Issue A	Snap Ring
2C-7510	Issue A	Tungsten Liner
Documents in Section 1.3.4 Supporting Documents		
PCS 038	Issue G	Package Contents Specification for Safkeg-HS - Package Design No 3977A
Section 2 - STRUCTURAL EVALUATION		
Page 2-1	Rev 7	
Page 2-2	Rev 7	
Page 2-3	Rev 7	
Page 2-3a	Rev 7	
Page 2-4	Rev 7	
Page 2-5	Rev 7	
Page 2-6	Rev 5	
Page 2-7	Rev 5	
Page 2-8	Rev 5	
Page 2-9	Rev 5	
Page 2-10	Rev 5	
Page 2-11	Rev 5	

Page/Document Reference	**Issue Status**	**Title**
Page 2-12	Rev 5	
Page 2-13	Rev 5	
Page 2-14	Rev 5	
Page 2-15	Rev 5	
Page 2-16	Rev 5	
Page 2-17	Rev 5	
Page 2-18	Rev 9	
Page 2-19	Rev 9	
Page 2-19a	Rev 9	
Page 2-20	Rev 5	
Page 2-21	Rev 7	
Page 2-22	Rev 5	
Page 2-23	Rev 5	
Page 2-24	Rev 7	
Page 2-25	Rev 7	
Page 2-26	Rev 7	
Page 2-27	Rev 7	
Page 2-28	Rev 7	
Page 2-29	Rev 5	
Page 2-30	Rev 5	
Page 2-31	Rev 5	
Page 2-32	Rev 5	
Page 2-33	Rev 5	
Page 2-34	Rev 5	
Page 2-35	Rev 5	
Page 2-36	Rev 5	

Page/Document Reference	**Issue Status**	**Title**
Page 2-37	Rev 5	
Page 2-38	Rev 5	
Page 2-39	Rev 7	
Page 2-40	Rev 5	
Page 2-41	Rev 5	
Page 2-42	Rev 5	
Page 2-43	Rev 5	
Page 2-44	Rev 5	
Page 2-45	Rev 5	
Page 2-46	Rev 5	
Page 2-47	Rev 7	
Page 2-47a	Rev 7	
Page 2-48	Rev 5	
Page 2-49	Rev 5	
Page 2-50	Rev 5	
Page 2-51	Rev 5	
Page 2-52	Rev 5	
Page 2-53	Rev 5	
Page 2-54	Rev 5	
Page 2-55	Rev 5	
Page 2-56	Rev 5	
Page 2-57	Rev 10	
Page 2-58	Rev 7	
Page 2-59	Rev 5	
Page 2-60	Rev 5	
Page 2-61	Rev 5	

Page/Document Reference	Issue Status	Title
Page 2-62	Rev 5	
Page 2-63	Rev 5	
Documents in Section 2.12.2, Appendix		
CTR 2010/02	Issue A	Prototype Safkeg-HS 3977A/0002 NCT and HAC Regulatory Test Report
SERCO/TAS/002762/01	Issue 1	Compression Testing of Cork
Vectra, L20008/1/R1	Rev 0B	Stress Analysis of Safkeg HS 3977A Containment Vessel
CS 2012/02	Issue A	SAFKEG HS 3977A – Maximum Pressure in CV
CS 2012/03	Issue A	SAFKEG HS 3977A – Package Density
Section 3 - THERMAL EVALUATION		
Page 3-1	Rev 5	
Page 3-2	Rev 5	
Page 3-3	Rev 5	
Page 3-4	Rev 5	
Page 3-5	Rev 9	
Page 3-6	Rev 9	
Page 3-7	Rev 9	
Page 3-8	Rev 9	
Page 3-9	Rev 9	
Page 3-10	Rev 9	
Page 3-11	Rev 9	
Page 3-12	Rev 9	
Page 3-13	Rev 9	

Page/Document Reference	Issue Status	Title
Page 3-14	Rev 9	
Page 3-15	Rev 10	
Page 3-16	Rev 10	
Page 3-17	Rev 10	
Page 3-18	Rev 10	
Page 3-19	Rev 9	
Page 3-20	Rev 9	
Page 3-21	Rev 10	
Page 3-22	Rev 9	
Page 3-23	Rev 10	
Documents in Section 3.5.2, Appendix		
SERCO/TAS/5388/002	Issue 2	Thermal Analysis of the Safkeg HS Design
CS 2012/01	Issue A	SAFKEG HS 3977A – Maximum Temperature of CV Inserts
CS 2016/31	Issue A	Maximum Pressure in Containment Vessel 3978 Under NCT and HAC
MURR Report		Hydrogen Generation Analysis – MURR Technical Note
MURR Report	2 Apr 16	Analysis Of The Possibility Of, And Consequences From, Hydrogen Deflagration And Detonation Resulting From Radiolysis-Produced Hydrogen In An Iodine-131 Radiopharmaceutical Solution
MURR Report	19 Jul 16	Additional Contents Request for Croft Packaging, MURR
CS 2016/27	Issue A	Temperature of Mo-99 Contents in the HS Package

Page/Document Reference	Issue Status	Title
Mallinckrodt Report	V2.2	Radiolytic Gas Formation in Mallinckrodt Produced Mo99 Solutions
Section 4 - CONTAINMENT		
Page 4-1	Rev 7	
Page 4-2	Rev 7	
Page 4-2a	Rev 7	
Page 4-3	Rev 5	
Page 4-4	Rev 5	
Page 4-5	Rev 7	
Page 4-6	Rev 5	
Page 4-7	Rev 5	
Page 4-8	Rev 9	
Page 4-9	Rev 5	
Documents in Section 4.5.2, Appendix		
CS 2012/04	Issue A	SAFKEG-HS 3977A - CV seal leak size for leaktight condition
CS 2012/05	Issue A	SAFKEG-HS 3977A - Gas contents limit for leaktight condition
Section 5 - SHIELDING EVALUATION		
Page 5-1	Rev 7	
Page 5-2	Rev 7	
Page 5-3	Rev 7	
Page 5-4	Rev 7	
Page 5-5	Rev 7	
Page 5-6	Rev 7	
Page 5-7	Rev 7	
Page 5-8	Rev 8	

Page/Document Reference	Issue Status	Title
Page 5-9	Rev 8	
Page 5-10	Rev 7	
Page 5-11	Rev 7	
Page 5-12	Rev 7	
Page 5-13	Rev 7	
Page 5-14	Rev 7	
Page 5-15	Rev 7	
Page 5-16	Rev 7	
Page 5-17	Rev 8	
Page 5-18	Rev 8	
Page 5-19	Rev 9	
Page 5-20	Rev 8	
Page 5-21	Rev 7	
Page 5-22	Rev 7	
Page 5-23	Rev 9	
Page 5-24	Rev 9	
Page 5-25	Rev 9	
Page 5-26	Rev 9	
Page 5-27	Rev 9	
Page 5-28	Rev 7	
Documents in Section 5.5.2, Appendix		
CTR2011/01	Issue D	SAFKEG HS 3977A: Package Activity Limits Based on Shielding
CTR2013	Issue C	Uncertainties Associated with the Proposed Shielding Calculation Method for the SAFKEG-HS 3977A Package
AMEC/SF6652/001	Issue 2	Monte Carlo Modelling of Safkeg HS Container

Page/Document Reference	Issue Status	Title
AMEC/CRM37327/TN_001	Issue 1	HS Container Shielding Assessment with I-131
AMEC/CRM37327/TN_001	Issue 1	HS Container Shielding Assessment with Mo-99
Section 6 - CRITICALITY EVALUATION		
Page 6-1	Rev 5	
Page 6-2	Rev 5	
Documents in Section 6.9, Appendix		
None	-	
Section 7 - OPERATING PROCEDURES		
Page 7-1	Rev 7	
Page 7-2	Rev 9	
Page 7-3	Rev 9	
Page 7-4	Rev 9	
Page 7-5	Rev 9	
Page 7-6	Rev 9	
Page 7-6a	Rev 9	
Page 7-7	Rev 8	
Page 7-7a	Rev 8	
Page 7-8	Rev 9	
Page 7-9	Rev 7	
Page 7-10	Rev 7	
Page 7-11	Rev 7	
Documents in Section 7.5, Appendix		

Page/Document Reference	Issue Status	Title
None	-	
Section 8- ACCEPTANCE TESTS AND MAINTENANCE PROGRAM		
Page 8-1	Rev 5	
Page 8-2	Rev 9	
Page 8-3	Rev 9	
Page 8-4	Rev 9	
Page 8-4a	Rev 7	
Page 8-5	Rev 9	
Page 8-5a	Rev 9	
Page 8-6	Rev 7	
Page 8-7	Rev 8	
Page 8-7a	Rev 7	
Page 8-8	Rev 9	
Page 8-9	Rev 5	
Page 8-10	Rev 7	
Page 8-11	Rev 7	
Page 8-12	Rev 9	
Documents in Section 8.3, Appendix		
None	-	

1.2.2 Contents

1.2.2.1 Contents - General

The Safkeg-HS 3977A package is designed as a general purpose package for radioactive material that requires shielding. The package is designed for radioactive material that emits neutrons, alpha, beta and gamma radiation.

The contents may be in solid, liquid or gaseous form.

The contents may also include inorganic non-radioactive materials associated with the radioactive materials, such as contents holders or fixtures and packing materials. No organic/hydrogenous materials are allowed in the cavity of the CV.

Fissile materials are permitted within the limits specified in Tables 1-3-7 and 1-3-8.

Pyrophoric materials are permitted under the conditions specified.

As the maximum contents are > 3,000 A_2, the package is designated as Category I as defined in NUREG 1609 [1.1].

The contents are limited so that the surface dose on the external surface of the package is less than or equal to 10 mSv/hr under exclusive use.

The contents heat limit is 30 W for solid or gaseous contents and 5W for liquid contents.

The contents will be carried in a product container appropriate for the contents and chosen by the shipper.

The product containers will, in all cases, be carried in shielding inserts as specified in the licensing drawings in section 1.3.3. Contents Types 1 to 7 will be carried in a CV using the standard lid design with Contents Type 8 carried in a CV with the split lid design.

The maximum mass of all material (radioactive contents, product capsules or containers, shielding inserts, and all associated items such as product container holders and packing) inside the CV is 9.29 kg (21 lbs).

Various restrictions and limits of quantity of radionuclides apply according to the insert used and the form of the radioactive material (solid, liquid or gas). These restrictions and contents limits are detailed in Section 1.2.2 in the tables for the different Contents Types (defined as CT-1, etc).

The maximum pressure assumed for the CV under NCT is 7 barg (102 psig) and 10 barg (145 psig) under HAC: this is the design envelope.

2.7.2 Crush [71.73 (c)(2)]

The crush test is not required as the package has a density of 2,968 kg/m^3. The calculation of the density of the package is described in CS 2012/03 [Section 2.12.2].

2.7.3 Puncture [71.73 (c)(3)]

10 CFR 71.73 (c) (3) requires that a package is dropped from 1m onto the upper end of a solid, vertical, cylindrical mild steel bar mounted on an essentially unyielding, horizontal surface. The package must be dropped onto the bar in the orientation in which the maximum damage is expected.

In order to fulfill this requirement a prototype package was dropped onto a steel punch with a diameter of 150 mm and 150 mm in length in 3 different orientations on its side, on the top rim and finally on the top of the keg. The test procedure and results of the puncture tests are reported in the report CTR 2010/02 (Section 2.12.2) and summarized in this section.

The package was dropped onto the punch in orientations expected to cause the maximum damage to the package. The puncture tests were carried out with the package at -40^{o}C after the 10.2m drop test series. This test allowed the effects of brittle fracture during the punch test to be assessed.

The penetration drops on the bottom end and the top rim resulted in minimal damage to the keg. The side penetration drop resulted in a dent of 11 mm in depth in the side of the keg. No tearing or penetration of the keg skin was observed.

2.7.4 Thermal [71.73 (c)(4)]

10 CFR 71.73 (c) (4) requires that the package can withstand a 30 minute fire with an average flame temperature of 800^{o}C. The requirement was demonstrated by carrying out a thermal analysis on a HS package. This analysis has been bench marked using an actual thermal test on a similar package the 3979A LS package. The thermal results have been reported in Section 3.10.2. The analyses of the structural design during the thermal test are presented within this section.

2.7.4.1 Summary of Pressures and Temperatures

During the thermal test the keg skin reaches a maximum temperature similar to that of the fire (800^{o}C). The containment vessel insulated from the full effect of the fire by the cork reaches a maximum temperature of 208^{o}C with a heat load of 30W from the contents. The temperature each component reaches during the HAC thermal test is within it maximum allowable service temperature. The maximum pressure reached during the HAC fire is 9.46 barg (section 3.4.3). The containment vessel maximum internal pressure during the HAC fire is assumed to be 10 bar or 1000 kPa gauge for the design evaluation.

3.3.2 Maximum Normal Operating Pressure [71.33 (b)(5)]

The MNOP is 7 bar (700 kPa) gauge.

For solid contents emitting 30W, under NCT the maximum temperature of the CV is 163°C and the maximum temperature of the Shielding Insert and air within the CV is 173°C. Assuming the content were loaded at 20°C and a pressure of 1 bar abs, the pressure at the maximum temperature of the Shielding Insert, calculated according to Boyle's and Charles' Laws, would be 1.63 bar (163 kPa) gauge (see Calculation Sheet CS 2012/02),which is well within the design envelope.

With regards to the liquid content the maximum normal operating pressure is calculated using the maximum temperature during NCT, the free volume of the containment vessel cavity and vials and all possible sources of gas generation and gases that are present on loading the containment vessel. For I-131 this includes gases present in the CV on loading, Xe-131 generation and radiolytic decomposition over a 28 day period.

For the I-131, under NCT maximum temperature of the CV is 78°C and the maximum temperature of the Shielding Insert and air within the CV is 80°C. (Section 3.1.3, Table 3-1). There is no pressure increase due to the vapour pressure of the liquid contents (the liquid contents are aqueous with a boiling point of 100°C) as the temperature is < 100°C.

The maximum free volume of the containment vessel cavity is 216 cm^3. This corresponds to the free volume that surrounds the insert, the volume around the containment vessel lid up to the seals and the free volume inside the insert and product bottles.

MURR have conservatively calculated that each I-131 vial will generate 89 cm^3 of Hydrogen over 28 days as detailed in the technical note listed in section 3.5.2. If 2 vials are shipped this equates to 178 cm^3 of hydrogen. In a free volume of 216.4 cm^3 along with heating of the gases on loading this would lead to a MNOP of 1 barg, which is below the design pressure of 7 barg. The generation of Xe-131 only leads to an increase in pressure of $4x10^{-6}$ bar, therefore it can be neglected from the calculation of the MNOP. MURR are limiting shipment time of I-131 to 10 days therefore the MNOP will be lower than 1 barg calculated.

For Mo-99 the maximum temperature of the contents within the insert is 84.56°C as calculated in CS 2016/28 (section 3.5.2). This temperature assumes a constant 5W heating over the course of a year, however in reality the thermal power of the contents decreases over time. The maximum free volume of the containment vessel is 233 cm^3. This corresponds to the free volume inside the insert, product bottle, the free volume that surrounds the insert and the volume around the containment vessel lid up to the seals.

Pressure will build up in the CV via radiolysis, heating of the gases in the CV and saturated vapour pressue. The Mo-99 contents generate hydrogen due to radiolysis. The Mo-99 producer has carried out experiments, to determine the radiolytic gas generation of the Mo-99 solution contained in the stainless steel bottles described in section 1 of this SAR.

Using this information and taking into account all these mechanisms the highest pressure was calculated in CS 2016/31 (section 3.5.2), this was 5.97 barg for a solution with an activity of 60 Ci/ml and a dispensed product volume of 16.667 ml. This pressure is below the bounding maximum pressure for NCT operating conditions.

The bounding temperatures and pressures for the package are as follows.

NCT Operating Condition	CV
Assumed Max. Temperature	160°C
Max. Pressure	800kPa (8.0 bar) abs
Min. Temperature	-40°C
Min. Pressure	0 kPa (0 bar) abs

The producer of the Mo-99 performed mass spectrometer measurements of the gas samples obtained during the radiolytic gas generation calculations. Of the 2 samples tested the results were 1.8% and 0.8% hydrogen by volume of the pure evolved gas. This is an average of 1.3%, with a 2σ uncertainty of 1.4%. So the concentration of hydrogen in the pure evolved radiolysis product is conservatively estimated to be 2.7% by volume. This is well below 5% by volume and therefore does not constitute a risk of flammability or ignition.

The hydrogen generation calculations for the I-131 contents for a shipment time of 10 days indicate the hydrogen concentration is 26%. Under normal conditions of transport (NCT) all hydrogen will be trapped in the product container within the insert, and no source for ignition exists. If somehow the product container fails, and the hydrogen escaped into the insert, and then the insert were to leak as well, into the containment vessel, and somehow ignition were to occur, the total energy release would be less than 966 Joules (231 calories).

The energy content of combustion of evolved hydrogen is negligible compared to the heating of the cask from the decay of I-131. For example, the decay heating rate of 200 Ci of I-131 was previously calculated to be 0.656 watts or 0.656 J/sec which would release 966 Joules of energy in less than one-half hour. Thus, the heating created by ignition of all of the hydrogen generated over 10 days would be negligible compared to the heating of the package by the decay of I-131.

These calculations and experiments indicate that hydrogen ignition in the case of I-131 liquid contents is not a credible source of risk to the public, see section 3.5.2.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

3.4.1 Initial Conditions

The initial conditions used for the thermal model of the fire test are taken at the end of a 12 hour period of insolation under Normal Conditions of Transport with a content decay heat of

30 W. All components are at their maximum temperatures as shown in Table 3-2. A series of NCT and HAC drop and penetration tests was carried out on a prototype package (see Section 2.12.2). These tests caused denting of the top and bottom skirts of the package with minimal damage to the keg body.

These 'skirts' are not significant to the thermal performance and it is judged that the damaged 'skirt' would provide greater protection in a fire than an undamaged 'skirt' (since, when bent over, it will provide shielding of the top and bottom of the keg from the fire). The finite element model used to model the fire accident was therefore unchanged from that used to model Normal Conditions of Transport.

3.4.2 Fire Test Conditions [71.73 (c)(4)]

The thermal assessment of the package under fire conditions has been carried out using a finite element model and validated against a fire test carried out on a prototype Safkeg-LS 3979A package. The model and analysis used is described in detail in section 5 of the Report SERCO/TAS/5388/002 (Section 3.5.2).

3.4.3 Maximum Temperatures and Pressure

The maximum temperatures experienced by the components of the Safkeg-HS 3977A package calculated under a HAC fire test, with an ambient temperature of 38°C and insolation, are given in Table 3-3. The temperature each component reaches during the HAC thermal test is within it maximum allowable service temperature.

At the end of the heating phase the external surface of the keg is close to the temperature of the fire (800°C). Figure 3-6 shows the predicted temperature on the exterior surface of the keg. The outer skin of the keg heats up and cools down rapidly because it is insulated from the inner containment vessel by the cork. The temperature of the keg lid changes more slowly than that of the side or base because the lid is thicker than the outer shell and therefore has a greater thermal capacity.

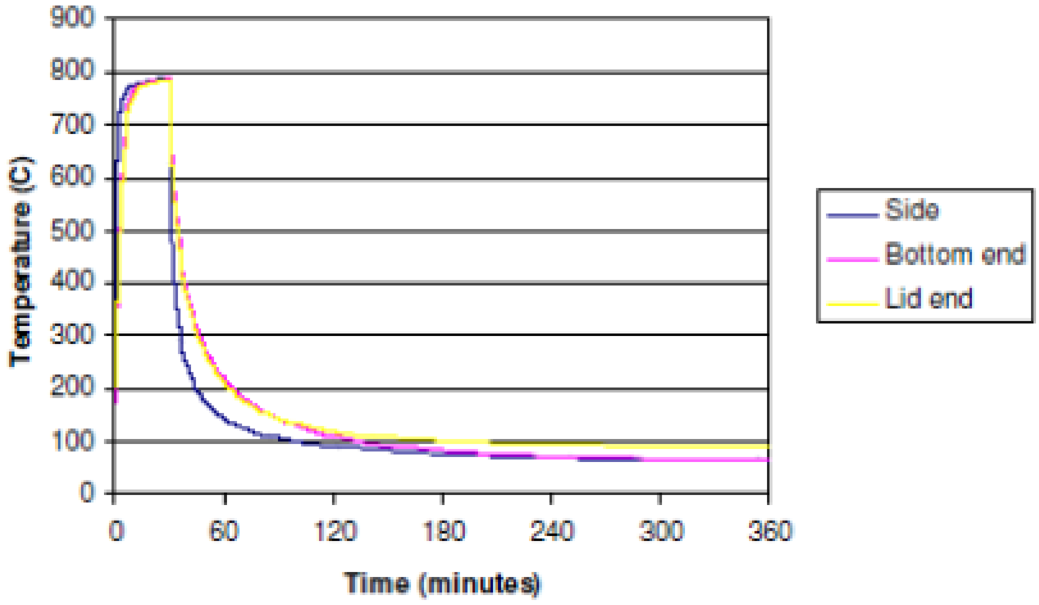

Figure 20 – Predicted Temperature on the Outside of the Keg during the Fire Accident – Internal Heat Load of 30W

Figure 3-6 Predicted Temperature of the Outside of the Keg during the Fire Test and 30W heat load

For Mo-99 liquid contents emitting 5W, under HAC the maximum temperature of the CV is 132°C and the maximum temperature of the contents is 143.82°C (CS 2016/28 section 3.5.2). Assuming the pressure at NCT is calculated as the maximum of 5.37 barg, the pressure at the maximum temperature of the contents, calculated according to Boyle's and Charles' Laws, would be 6.26 bar gauge. However, the vapour pressure of the liquid contents (the liquid contents are aqueous) would be 3.2 bar gauge (from steam tables). Therefore the maximum pressure within the CV would be 9.46 bar gauge (CS 2016/31, section 3.5.2)which is within the design envelope provided below. The temperatures reached are within the bounding conditions for the package which are as follows:

HAC Operating Condition	CV
Assumed Max. Temperature	200°C
Max. Design Pressure	10 bar (1,000 kPa) gauge 11 bar (1,100 kPa) abs
Min. Temperature	-40°C
Min. Pressure	-1 bar (-100 kPa) gauge 0 bar (0 kPa) abs

3.4.4 Maximum Thermal Stress

As discussed in section 2.7.4.3 the NCT heat calculations bound the HAC test results. The resulting stresses from the NCT heat results are discussed in section 2.6.1.3 and 2.6.1.4. All the stresses calculated are within the allowable limits for the containment vessel.

3.4.5 Accident Conditions for Fissile Material Packages for Air Transport [71.55(f)]

Not applicable – air shipment of fissile material is not specified.

3.5.2 Supporting Documents

Document Reference	Title
AMEC/6335/001	Thermal Analysis of the SAFKEG HS Design
CS 2012/01	SAFKEG-HS 3977A – Maximum temperature of CV inserts
CS 2016/31	Maximum Pressure in Containment Vessel 3978 Under NCT and HAC
	Hydrogen Generation Analysis – MURR Technical Note
	Analysis Of The Possibility Of, And Consequences From, Hydrogen Deflagration And Detonation Resulting From Radiolysis-Produced Hydrogen In An Iodine-131 Radiopharmaceutical Solution
	Additional Contents Request for Croft Packaging, MURR, 19th July 2016
CS 2016/27	Temperature of Mo-99 Contents in the HS Package
V2.2	Radiolytic Gas Formation in Mallinckrodt Produced Mo99 Solutions

8.1.8 Miscellaneous Tests

Not applicable.

8.2 Maintenance Program

The maintenance program for the SAFKEG 3977A packaging applies to periodic maintenance, and to packagings that have failed the pre-shipment inspection specified in Section 7.1.1. It ensures the continued performance of the package throughout its lifetime.

The maintenance program includes periodic testing, inspection and replacement schedules. Criteria are also included for the repair of components and parts on an 'as needed' basis. A summary of the maintenance requirements is given in Table 8-1.

This section provides the minimum requirements required in order to maintain the package. From these requirements each organization, authorized to perform maintenance, shall prepare specific instructions and checklists, in accordance with that organization's Quality Assurance Program, that will ensure compliance with the requirements of Section 8.2.

Non-conforming components shall be rejected and controlled for rework, or scrapped and replaced. Components that are reworked or replaced shall meet the specifications given in the general arrangement drawings in the Certificate of Compliance.

The maintenance organization is required to notify the SAR owner of any instance in which the packaging fails to meet the criteria of Section 8.2 is found during maintenance.

The periodic maintenance activities, as specified in Section 8.2, shall have been performed not more than 1 year prior to shipment.

8.2.1 Structural and Pressure Tests

Structural and pressure testing do not form part of the periodic maintenance requirements.

8.2.2 Leakage Tests

8.2.2.1 Containment Vessel

Maintenance leakage testing of the containment vessel shall be in accordance with the evacuated envelope (gas detector) test A.5.4 in ANSI N14.5 [8.3]. The helium leak test procedure shall be written and approved by a level III examiner [8.4]. The test shall use a suitable helium leak detector. The test sensitivity shall be 5 x 10^{-8} ref.cm^3/s and the test pass rate shall be 1 x 10^{-7} ref.cm^3/s. The O-rings shall be coated with a light film of silicone O-ring lubricant for lubrication, and replaced if damaged.

The leakage rate testing shall be performed during the periodic maintenance tests, this shall not exceed 12 months prior to package use. The leakage rate test shall also be performed after the following maintenance activities: