0.1 SAR REVISION STATUS

Title	SAFKEG-HS 3977A Docket No. 71-9338	**Number**	CTR 2008/11
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0.2 SUPPORTING DOCUMENT REVISION STATUS

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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-131Radiopharmaceutical 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
Mallinckrodt Report	V2.2	Radiolytic Gas Formation in Mallinckrodt Produced Mo99 Solutions

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CS 2017/02	A	Maximum Pressure in Containment Vessel 3978 Under NCT and HAC With I-131 Contents
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CS 2012/05	Issue A	SAFKEG-HS 3977A - Gas contents limit for leaktight condition
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None	-	

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 product containers, and all possible sources of gas generation and gases that are present on loading the containment vessel.

For I-131 the maximum temperature of the contents is 80°C (Section 3.1.3, Table 3-1). The maximum free volume is 216 cm^3 when 2 glass vials containing a maximum of 10 ml each of solution are loaded into the 3987 insert. Pressure will build up in the CV due to heating of the air present in the CV on loading, Xe-131 generation, saturated vapour pressure and radiolytic decomposition over a 10 day period for both the liquid and PTFE liner. Using the free volume, temperature and taking into account all the pressure rise mechanisms, calculations were performed and are presented in CS 2017/02 (section 3.5.2). These calculations demonstrate that a maximum pressure of 2.68 barg is reached for the I-131 contents. This pressure is below the bounding design pressure of 7 barg (8 bara).

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 air in the CV and saturated vapour pressure. 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 3-8 shows the predicted temperature of the inner containment vessel seal during and after the thermal test. The lid seal reaches a maximum temperature of 192°C after 3 ½ hours. A similar maximum temperature is experienced by the depleted uranium shielding this temperature is well below its melting point of 1130°C.

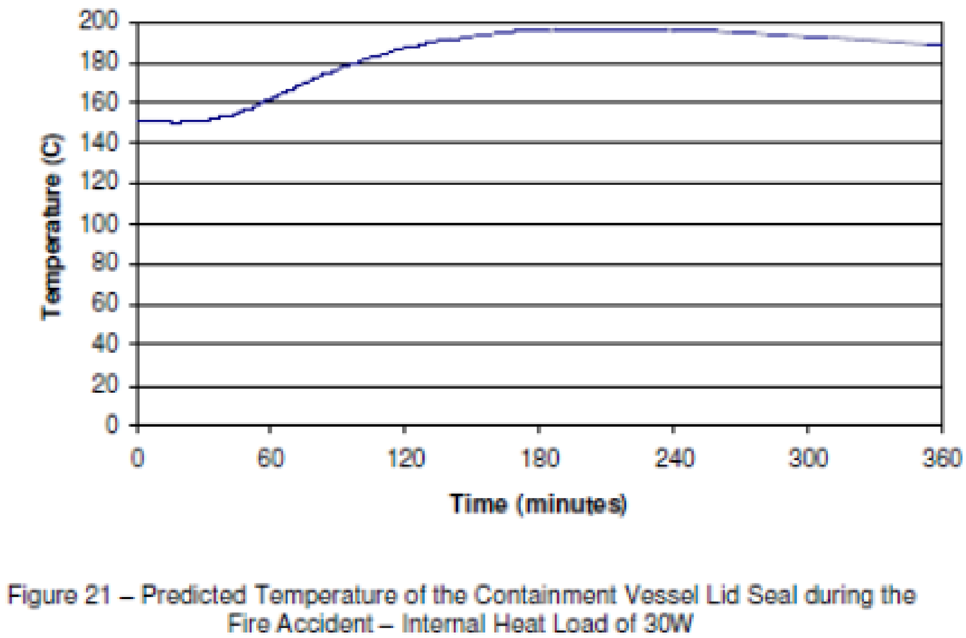

Figure 3-8 Predicted Temperature of the Containment Vessel Lid Seal during the Fire Test with a 30 W source

The Design Pressure of the CV is 10 bar (1,000 kPa) gauge.

For solid contents emitting 30W, under HAC the maximum temperature of the CV is 208°C and the maximum temperature of the Shielding Insert and air within the CV is 218°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 1.8 bar (180 kPa) gauge (see Calculation Sheet CS 2012/02 in section 2.12.2), which is well within the design envelope.

For I-131 liquid contents emitting 5W, under HAC the maximum temperature of the CV is 132°C and the maximum temperature of the insert is 134 °C (Section 3.1.3, Table 3-1). Assuming the pressure at NCT is calculated as the maximum of 2.68 barg, the pressure at the maximum temperature of the CV, calculated according to Boyle's and Charles' Laws, would be 3.09 bar gauge. However, the vapour pressure of the liquid contents (the liquid contents are aqueous) would be 2 bar gauge (from steam tables). Therefore the maximum pressure within the CV would be 5.09 bar gauge which is well within the design envelope (CS 2017/02, Section 3.5.2).

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
CS 2017/02	Maximum Pressure in Containment Vessel 3978 Under NCT and HAC for I-131 Contents

7.1.2 Loading of Contents with A Standard Lid Containment Vessel

NOTE: The standard lid containment vessel shall only be loaded with insert design numbers 3982, 3985 or 3987.

1) The containment vessel cavity shall be checked to ensure it is dry and clean before loading with the radioactive contents.

2) The contents shall be limited as required by the Certificate of Compliance. The contents shall be chemically compatible (i.e. not chemically reactive) with their immediate packaging and the containment boundary (e.g. tungsten, Silicon O-ring).

3) From the contents type to be shipped, determine the insert required for the shipment in accordance with the Certificate of Compliance. The model/serial numbers of the insert body and lid shall be checked to ensure that the number marked on the body matches that on the lid: where the model/serial numbers of the insert (body and lid) do not match, these assemblies shall be removed from service.

4) Visually inspect the insert to be used for the shipment for any damage. Check that the lid screws freely by hand onto the body. If there is any damage or the closure does not operate correctly carry out a maintenance operation according to Section 8.2.3. FOR SOLID CONTENTS ONLY: Check that the O-ring is present and undamaged. If the O-ring is not present or if it is damaged, it shall be replaced.

5) If I-131 is being shipped in insert 3987. Thoroughly inspect the PTFE liner, there shall be no stainless steel visible within the insert cavity, if any stainless steel is visible remove this insert from service. Check for any dust in the cavity and remove if present. Remove the insert seal shown in Figure 1. Close the insert and leak test the liner seal using the bubble method. The test sensitivity shall be 10^{-3} ref.cm^3/s and the acceptance rate shall be no visible stream of bubbles. If the leak test fails remove the insert from service and raise an NCR. If the liner seal passes the bubble leak test insert a new insert seal.

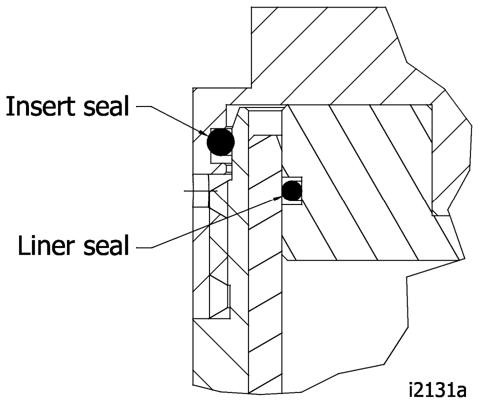

Figure 1 - Insert No 3987 Seal Detail

6) Check that the contents meet the restrictions for its content type as listed in the Certificate of Compliance.

7) If the content is Special Form, check the Special Form certificate to ensure it is current.

8) If loading liquid contents the insert seal shall be tested in accordance with the criteria specified in ANSI N14.5 [7.4], using a bubble method. The test sensitivity shall be 10^{-3} ref.cm^3/s and the acceptance rate shall be no visible stream of bubbles.

9) If the insert fails the bubble leak test. Inspect the insert O-ring and replace as necessary. Repeat the leak test in accordance with step 8. If the leak test continues to fail, remove the insert from service and raise an NCR.

10) Load the contents into the insert and screw the insert lid tight ensuring that the match marks on the lid and the body meet to form a straight line.

11) Load the insert into the containment vessel and place the silicone sponge rubber disc onto the insert.

12) The lid shall be fitted to the containment vessel and the containment bolts tightened to a torque of 10 ± 0.5 Nm.