HS Container Shielding Assessment with I-131

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1. Background

Previous reports (References 1 and 2) present the results of MCBEND (Reference 3) calculations of external dose rate from a various point sources in different locations within the Safkeg HS container, both with and without a tungsten insert.

This report presents the results of MCBEND calculations for the same HS container, but with a different stainless steel insert (HS-55x138-SS) with a PTFE liner (References 4 and 5), carrying a source as defined below:

- I-131 source
- Source geometry approximated as a point source
- Activity 7.4 TBq

Calculations were carried out to determine the worst case source position causing the highest surface dose rate under normal operating conditions. The following configurations were included:

- Point source centred at the bottom of the insert cavity with the insert resting on the base of the HS cavity.
- Point source eccentred at the mid height of the insert cavity with the insert resting on the base of the HS cavity.
- Point source centred at the top of the insert with the insert raised to the top of the HS cavity
- Point source eccentred at the top of the insert with the insert raised to the top of the HS cavity

For each configuration, calculations were carried out to determine the following:

- The maximum dose rate on contact with the Safkeg HS container, on the top, side and bottom surfaces.

For the worst-case source position, the highest surface dose rate was determined under Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC). The NCT and HAC are determined by tests on the package as described in Reference 6.

The NCT are those after, amongst others, a penetration test and a 1.2m drop test. The 1.2m drop test produced minimal damage to the package. The penetration test produced a dent of depth ~8mm and diameter ~290mm in the side of the package. However, there were no rips or tears in the steel skin of the package. Thus there was no loss of steel shielding in NCT. There was some compression of the cork shock absorber.

The HAC are those after, amongst others, a 10.2m drop test and a 1m punch test. The 10.2m drop test produced significant damage to the top skirt of the package, as shown in Photographs 27-29 of Reference 4. The skirt was crushed to approximately the level of the lid. There is also visual evidence that the top steel annulus (between the lid and the outer skin) has buckled. The 1m punch test produced a dent in the side of the package of depth 11mm but, as for the penetration test, there was no breach of the skin. After the HAC tests the containment vessel and insert were undamaged. Thus the HAC resulted in the outer skin height being reduced to that of the lid. The top steel annulus may not have been intact due to buckling and will be conservatively assumed to have been lost. The cork shock absorber did not survive the drop test intact.

Dose rates were calculated using dose conversion factors based on ANSI/ANS-6.1.1 1977. Bremsstrahlung was taken into account in the calculations.

2. Geometry and Source Terms

The geometry of the MCBEND model is shown in Figure 1. Note that the top sources were modelled with the insert raised up to the top of the HS cavity, whereas the bottom centred source was modelled with the insert at the bottom of the HS cavity as shown. As shown in Figure 1, the model does not include the cork shock absorber, for simplicity and conservatism. This is consistent with previous work. This model was used for the initial calculations.

As described in the previous section, the NCT do not involve any loss of steel shielding. Since the MCBEND model does not include the cork shock absorber any degradation of the cork will not affect the calculated dose-rates. Thus the dose-rates obtained using the initial MCBEND model bound those during NCT.

As described in the previous section, the HAC involve loss of the top skirt of the steel shielding and will be conservatively assumed to result in loss of the top steel annulus, between the lid and outer skin. The degradation of the cork will not affect calculated dose-rates since the cork is not present in the initial model. Thus the HAC was modelled by reducing the height of the outer steel skin to that of the lid and by removing the top steel annulus from the model.

The gamma-ray source spectra from I-131 were taken from JEF2.2 data using the JANIS4.0 tool (Reference 7) and are shown in Table 1. The dominant decay product from I-131 is Xe-131, which is stable. 1.086% of decays result in Xe-131m, which then decays to Xe-131, emitting some gamma-rays. However, the intensity is very low (1.96%) so these have been ignored.

I-131 decay also produces a beta source. The end energy of the beta source is 0.8069MeV. For simplicity it was assumed that all of the beta particles are emitted at the maximum energy. This is very conservative.

3. Results

Initial Model

The results of the calculations using the initial model are shown in Table 2. The maximum dose-rate occurs when the source is in the top corner of the cavity and is located at the top corner region of the package, just above the top steel annulus (See Figure 1). The maximum gamma-ray dose-rate from the gamma-ray source is 205 microSv/hr.

The gamma-ray dose-rate due to the beta source was calculated for this source position and was found to be insignificant compared to the dose-rate from the gamma-ray source (0.4 microSv/hr compared to 205 microSv/hr). Since the beta source was itself very conservative (all the beta particles being assumed to be emitted at the maximum possible energy) it is concluded that dose-rates arising from the beta source are negligible and these were not considered further.

Normal Conditions of Transport

As described above, dose-rates from the initial model, which does not include cork, are judged to bound those arising from Normal Conditions of Transport. Thus the maximum surface dose-rate in Normal Conditions of Transport is 205 microSv/hr.

Hypothetical Accident Conditions

The results from the model of the package in Hypothetical Accident Conditions are shown in Table 3. Since the worst source position was found to be the top corner of the cavity only that calculation was run. The maximum surface dose-rate, still located just above the top steel annulus, is 218 microSv/hr.

4. References

1 D J Picton, Monte Carlo Modelling of Safkeg HS Container, AMEC/SF6652/001 Issue 2, August 2013.

2 D J Picton, Monte Carlo Modelling of Alternative Point Sources in the Safkeg HS Container, Technical Note AMEC/SF8665/TN_001 Issue 1

3 MCBEND - A Monte Carlo Program for General Radiation Transport Solutions. User Guide for Version 11. ANSWERS/MCBEND/REPORT/008, Issue 2, May 2015

4 HS-55x138-SS Insert Design No 3987 (Licensing Drawing) Croft Dwg 2C-6176 Issue A, 2012

5 AutoCad Dwg layout of modified SS insert in HS CV - Autocad 2014.dwg, 2015

6 S H Marshall, Prototype Safkeg HS 3977A/0002 NCT and HAC Regulatory Test Report, CTR 2010/02 Issue A, March 2012

7 JANIS 4.0 http://www.oecd-nea.org/janis/

Gamma-Ray Energy (MeV)	Intensity
0.722893	1.80400%
0.642703	0.21970%
0.636973	7.26800%
0.502991	0.36090%
0.404804	0.05645%
0.36448	81.24000%
0.35838	0.00917%
0.325781	0.25100%
0.32464	0.02218%
0.31808	0.07963%
0.30241	0.00454%
0.29583	0.00071%
0.284298	6.05800%
0.27249	0.05645%
0.23217	0.00141%
0.17721	0.26510%
0.08592	0.00009%
0.080183	2.62100%

Table 1 Gamma-rays produced by I-131 decay

Source Position	Source Particle	Maximum Surface Gamma-Ray Dose-Rate	sd	Position of maximum
		(microSv/hr)	(%)	
Bottom of cavity, centred	Gamma	72	0.3	Bottom
Side of cavity, halfway up cavity	Gamma	49	0.6	Top
Top of cavity, centred	Gamma	173	0.2	Side
Top corner of cavity	Gamma	205	0.4	Top corner (above top steel annulus)
	Beta	0.4	9.0	Top corner (above top steel annulus)

Table 2 Maximum Surface Dose-Rates for Initial Model and Normal Conditions of Transport

Source Position	Source Particle	Maximum Surface Gamma-Ray Dose-Rate	sd	Position of maximum
		(microSv/hr)	(%)	
Top corner of cavity	Gamma	218	0.3	Top corner (above top steel annulus)

Table 3   Maximum Surface Dose-Rate for Hypothetical Accident Conditions

Figure 1: MCBEND model for Safkeg HS container with stainless steel insert
Note that the stainless steel insert is raised to the top of the HS cavity in top source cases. In other cases the insert is in the position shown.