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September 20, 2017

Mr. Michael Conroy
Radioactive Materials / Research and Development
Division of Engineering and Research
Office of Hazardous Materials Safety
U.S. Department of Transportation
1200 New Jersey Ave., S.E.
Washington, D.C. 20590

RE: Request for additional information for review of Nordion F-522 package

Dear Mr. Conroy,

Please find attached, responses to the request for additional information (RAI) as detailed in the letter from NRC to Mr. Rick Boyle, dated July 19, 2017. These responses are in support of our request for DOT endorsement of the F-522 transport package.

We have provided responses to all questions except Mt-5. For that question we are requesting clarification from NRC. In our opinion, paragraph 614 does not relate to post-fire thermal strength of the foam, therefore, no assessment has been provided for the post-fire strength of the foam. We do not view this as a requirement of the cited paragraph, 614. We ask that you seek clarification from the NRC on this question.

Responses to the remaining questions are appended to this letter.

Should you have any questions, please do not hesitate to contact me at (613) 592-3400 extension 2658, or e-mail at greg.fulford@nordion.com.

Yours truly,

Greg Fulford
Nuclear Transportation Specialist
Nordion

Encl.

Responses to NRC RAI in support of F-522 review

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For continuity, I have listed the NRC question (Q) before each of our responses (R).

Q Mt-1. Revise package drawings to include: (i) tolerances of dimensions and (ii) material specifications of receptacles.

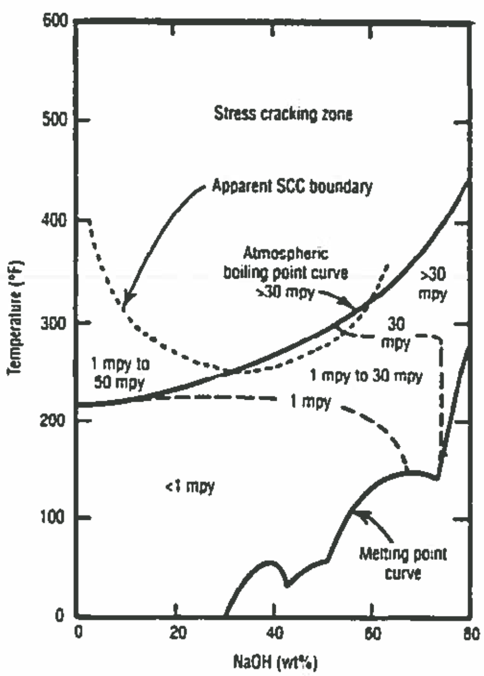
This information is needed to determine compliance with the requirements of paragraph 501 of IAEA SSR-6.

R Mt-1. Tolerances for critical dimensions and clarification of materials have been added to the information drawing, F652201-001. See the attached draft version of the information drawing. A final version will be provided once approved.

Q Mt-2. Provide information on the potential susceptibility to caustic stress corrosion cracking (SCC) of leak proof insert made of stainless steel with alkaline solutions based on NaOH or NH_4OH.

This information is needed to determine compliance with the requirements of paragraphs 501, 614, 618 and 620 of IAEA SSR-6.

R Mt-2. In steady state conditions, the maximum temperature of the NaOH solution is [redacted] within the leakproof insert (LPI) as shown in section 4.4 of Appendix 6 of IS/TR 2650 F522. This temperature is below the SCC line in the graph provided in the Materials Technology Institute, Technical Awareness Bulletin, Caustic Stress Corrosion Cracking, No 13.



Nordion has a history of shipping NaOH solutions within our LPIs for over 30 years without incident or signs or of stress corrosion cracking. Additionally, the LPIs are inspected routinely after every shipment for any sort of corrosion. Nordion has not observed any corrosion during routine maintenance of the LPIs.

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Q Mt-3. Clarify very high temperature rise of remaining nitrogen after pyrophoric reaction of Rubidium in terms of package radiological safety such as content form (e.g., vaporization).

This information is needed to determine compliance with the requirements of paragraphs 305 and 618 of IAEA SSR-6.

R Mt-3. The high temperature of the Nitrogen is extremely conservative for the purposes of the pressure calculation in that section. This temperature is not realistic and is instead chosen to provide an extreme safety margin for the pressure calculation.

This calculation does not take into account the mass of the target shell, the target holder or the leak proof insert. When just the mass of the LPI is taken into account, the temperature would increase by 2°C as shown in the response to Mt-4 below.

Q Mt- 4. Clarify that the assessment of chemical reactions made by the applicant for Rubidium is equally used for the pyrophoricity assessment of Sr-82.

This information is needed to determine compliance with the requirements of paragraphs 305 and 618 of IAEA SSR-6.

R Mt-4. The 2°C increase specified in the report is based the stoichiometric reaction of rubidium with oxygen and moisture in atmospheric air within the F-248 LPI.

Assumptions

- The volume of the insert is [redacted]
- The targets and source holder have no volume.
- 40.4 mL oxygen (0.002 moles) is present (20% of the volume of air)
- The targets each contain [redacted] of rubidium metal. A maximum of 2 targets yields [redacted]
- The air in the insert is saturated at 35 °C. This yields 8 mg maximum water content in 202 mL of saturated air (CRC Handbook of Chemistry and Physics 1985-1986, 66th Edition. pp. E-37)
- It is conservatively assumed that all reactants are instantaneously consumed resulting in an instantaneous release of energy.

Reactions

There are several reactions of interest

[redacted]

Reaction b) is neglected as Reaction c) is the more conservative route (lower heat of formation).

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The worst case in terms of energy output will be limited by the amount of oxygen present, since there is ample rubidium to consume all reactants (60g = 0.7 moles or one target = 0.35 moles):

All available water consumed as per Reaction a) (-195 kJ/mole x (0.008g/18) = - 0.087 kJ)
The oxygen - 0.002 moles is consumed by c) (-271 kJ/mole x 0.002 = - 0.542 kJ)

For a total of – 0.629 kJ or 629 J or 150 calories

Since the oxygen is consumed in the reaction, only the remaining nitrogen (162 ml) expands. when 4.18 Joules is added to 1 g of dry air the temperature raises by 1 °C, applying 629 J results in a temperature rise of the remaining nitrogen to 150 °C instantly. This is an extremely conservative assumption.

Effect on LPI

The LPI has a mass of approximately [redacted] The specific heat of stainless steel is 470 J/kgK. The transfer of 629 J to the stainless steel will cause its temperature to increase by: ΔT = [redacted]

Q Mt-5. Provide assessments on post-fire thermal stability for mechanical strength of Foam. The applicant assessed the effect on the density of the Foam and the depth of char during regulatory fire conditions based on tests done by General Plastics (SAR, Appendix 14). The applicant concluded that the density change is minimal and would not affect drop tests. Foam (polymer) is thermally stable in terms of strength (such as elastic modulus) at less than approximately 120 °C (Sanchez, E.M.S., C.A.C. Zavaglia, and M.I. Felisberti. "Unsaturated Polyester Resins: Influence of the Styrene Concentration on the Miscibility and Mechanical Properties." Polymer 41 (2000): 765-769). The applicant provided appropriate data on mechanical properties within 121 °C (250 °F) (General Plastics). However, the applicant did not address post-fire mechanical strength of Foam.

This information is needed to determine compliance with the requirements of paragraph 614 of IAEA SSR-6.

R Mt-5. As stated in the cover letter, Nordion is seeking further clarification from NRC.

Q Th-1. Provide more information of the thermal model used in the post-fire cooldown analysis.

This information is needed to determine compliance with the requirements of paragraph 728(a) of IAEA SSR-6.

R Th-1. For the post-fire cooldown, the following assumptions were made:

- Outer surface emissivities were lowered from [redacted] used during the fire test.
- Natural convection was assumed for the outer surfaces with the conservative assumption that the package was sitting in perfectly still air.
- The heat transfer coefficients were re-calculated at each time step by the flow simulation code as the package cooled. See below a graph of the heat transfer coefficient for the 40W case at the different time steps:

[redacted]

Q Th-2. Provide transient temperatures of the leak proof insert (LPI) cavity for F-522 loaded with (a) liquid Mo-99 and (b) solid Mo-99 during the HAC fire, including both 30-minute fire and its post-fire cooldown.

This information is needed to determine compliance with the requirements of paragraph 728(a) of IAEA SSR-6.

R Th-2. For each requested cases, the information is provided in the temperature curves below:

[redacted]

The maximum temperature for the LPI is [redacted] for the 40 W case and [redacted] for the 4 W case.

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Q Co-1. Clarify whether the vacuum liquid bubble test is suitable as a leak test method for the F-248 leak proof insert (LPI).

This information is needed to determine compliance with the requirements of paragraphs 510 and 511 of IAEA SSR-6.

R Co-1 This is an error in Section 5.3 of IS/DS 2651 F522. Nordion practice involves performance of a routine helium leak test sensitive to 10^{-8} std cc/s. The DMOS will be updated to reflect this change. A marked up copy is provided along with this response. A finalized copy will be provided once approved.

Q SH-1. Provide additional information and justification on the modeling of the F-522 using MICROSHIELD.

This information is needed to determine compliance with the requirements of SSR-6 relating to allowable maximum radiation level in paragraphs 526, 527, 648(b), 659(b)(i).

R Sh-1. We have attached the microshield reports for each isotope that should clarify the modeling of each isotope. In each case, the buildup was calculated using the depleted uranium shielding material and the source was modeled as a point source. The software version was Microshield 10.0 using the ICRP-38 library.

Furthermore, an actual shielding test was performed using a Co-60 source in section 3.1 of Appendix 4 and provides agreement with the Microshield results. As per the regulations, the transport packaging will also not be shipped if the dose exceeds the regulatory requirements.

Q Sh-2. Provide additional information on the activity for the Mo-99 content and the modeling of this source in MICROSHIELD.

This information is needed to determine compliance with the requirements of SSR-6 relating to allowable maximum radiation level in paragraphs 526, 527, 648(b), 659(b)(i).

R Sh-2. This discrepancy is caused by a typographical error in Section 4.1, Appendix 4 of IS/TR 2650 F522. The correct radiation levels should add the Mo-99 and I-132 contributions accurately. This error will be corrected in IS/TR 2650 F522.

Surface dose rate: [redacted]
Transport Index:

These are both below the values in the document.

Q Sh-3. Provide additional information on the impurities allowed for the Mo-99 content and how "equivalency" is determined.

This information is needed to determine compliance with the requirements of SSR-6 relating to allowable maximum radiation level in paragraphs 432, 526, 527, 648(b), 659(b)(i).

R Sh-3. The full categorization (impurity profile) for the Mo-99 contents is currently ongoing. For the purposes of shielding calculations, the method of I-132 equivalency was used. Based on Nordion's experience, I-132 (2.39 MeV max γ) has the highest gamma energy of decay of all suspected impurities.

The surface dose contribution from each impurity will be compared to that of I-132 and an equivalency can be formed. For example, a potential impurity could be I-133 and when its surface dose contribution is compared to I-132 for a similar activity, a dose ratio and activity equivalency can be formed as seen in the table below:

Isotope	Radial surface dose rate for 1000GBq	Surface dose ratio with I-132	I-132 equivalent activity
I-132	[redacted]		
I-133			

The dose contribution factor for I-133 is [redacted] times smaller than that of I-132.

We would also like to stress that regardless of impurity contents and daughter products within the containers, the dose rates on the surface of the packages will always be below the regulatory limits of 2 mSv/hr and the Transport Index below 10.

Q Sh-4. Provide additional information on the activation of rubidium and justify that the source term was modeled conservatively.

This information is needed to determine compliance with the requirements of SSR-6 relating to allowable maximum radiation level in paragraphs 432, 526, 527, 648(b), 659(b)(i).

R Sh-4. The other nuclides that would be present in the distribution are not meant to be ambiguous and were included in the shielding assessment of the SAR (Table 3 of Appendix 4). These other nuclides are all impurities from the proton irradiated rubidium based target material and associated target shells. The isotopic profile is presented in the table below.

Bounding the individual isotopes to activity level would be unnecessarily restrictive to the activity contents with no additional safety provided as the package must still meet the regulatory requirements for surface dose rate and Transport Index. Due to the variability of the isotopic profile as it relates to the irradiation parameters (time, decay, flux etc), having a fixed limit for all isotopes allows for small changes in the contents while maintaining safe regulatory limits.

Two daughter products were not provided due to significance as part of the original assessment, Fe-55 and Kr-83m. For both isotopes, their energies are low and their contribution to the shielding assessment is negligible so they are not included.

Isotope	Half-Life (d)	Activity [TBq] at EOB	Activity [TBq] (EOB+2 d)	Predicted Surface mrem/h (per TBq)	Predicted TI (per TBq)	Predicted surface mrem/h (EOB)	Predicted TI (EOB)	Predicted surface mrem/h (EOB + 2 d)	Predicted TI (EOB+ 2d)
[redacted]									

Table 3: Radial Surface Radiation Levels for Rubidium Metal Targets