Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

The NRC Request for Additional Information (RAI) identifies information needed by the staff with regard to its review of the Robatel Technologies Safety Analysis Report, Revision N°2, dated September 18, 2013. The RAI questions are grouped by chapter number and title from the Safety Analysis Report, along with the Robatel Technologies Response. The response addresses the question where applicable, references the locations in the SAR and/or supporting documents where revised information can be located.

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

Chapter 1 – General Information:

<u>RAI 1-1 Question:</u>

Correct the error in the licensing drawing RT100 PE 1001-1.

There are two places on the licensing drawing RT100 PE 1001-1 that reference "DETAIL 3." From the drawing, it is apparent that these two references are related to two very different parts of the packaging design. The applicant needs to correct this error.

This information is required by the staff to determine compliance with 10 CFR 71.43.

<u>RAI 1-1 response:</u>

The reference to detail 3 located at (F; 15) has been revised on drawing RT100 PE 1001-1. The reference is now labeled "DETAIL OF THE FUSIBLE PLUG".

The drawing RT100 PE 1001-2 is also revised because it is linked to RT100 PE 1001-1. Both drawings must have the same revision number.

<u>SAR Impact:</u>

The SAR is updated to reflect the revision of drawings RT100 PE1001-1 and RT100 PE 1001-2 to Rev H.

<u>Calculation Impact:</u>

These calculation packages are updated to reflect the drawing revision as follows:
RTL-001-CALC-CN-0101 R5 -> R6
RTL-001-CALC-SH-0201 R4 -> R5
RTL-001-CALC-SH-0301 R3 -> R4
RTL-001-CALC-ST-0201 R4 -> R5
RTL-001-CALC-ST-0202 R3 -> R4
RTL-001-CALC-ST-0203 R5 -> R6
RTL-001-CALC-ST-0401 R5 -> R6
RTL-001-CALC-ST-0402 R3 -> R4
RTL-001-CALC-ST-0403 R3 -> R4
RTL-001-CALC-TH-0102 R5 -> R6
RTL-001-CALC-TH-0201 R5 -> R6
RTL-001-CALC-TH-0202 R5 -> R6

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

Chapter 2 – Structural Evaluation:

None

Chapter 3 – Thermal Evaluation:

RAI 3-1 Question:

Clarify the potential combustion of paper, within the package, under an HAC fire.

Following the staff's review of Figures 24 and 36 of Calculation No. RTL-001-CALC-TH-0201, provided as part of an RAI response, the applicant showed the HAC inner shell surface temperatures of about 275°C for pin damages on the top impact limiter (Figure 24) and on the cask body side (Figure 36). Such temperatures are above the auto-ignition point of 232°C for paper, one of the package content materials.

The applicant is required to demonstrate that the auto-ignition of the paper will not occur or that its reaction is not significant for the package; otherwise, the paper should not be allowed as part of the content materials.

This information is required by the staff to determine compliance with 10 CFR 71.51, 71.71, and 71.73.

RAI 3-1 response:

The applicant acknowledges in Chapter 3, Section 3.2.3 (Content Properties), that filters may be constructed from thermoplastics (nylon, polyester, polypropylene) or paper, and shoring made of wood may be contained in the package. Although it is unlikely that temperatures under HAC will approach the auto-ignition temperatures of the contents, an analysis is performed to evaluate the effect of combustion on the packaging components and the package contents.

Solid polymeric materials, including cellulosics such as wood and paper, undergo both physical and chemical changes when heat is applied. Thermal decomposition is a process of extensive chemical species change caused by heat whereby the thermal decomposition of a solid material generates gaseous fuel vapors, which can burn above the solid material. The process is self-sustaining when the burning gases feedback sufficient heat to the material to continue the production of gaseous fuel vapors or volatiles. These volatiles react with the oxygen in the air to generate heat, and part of this heat is transferred back to the polymer to continue the process.

Although the thermal evaluation predicted the maximum temperature of the packaging exceeds the auto-ignition temperature of paper, the applicant considered significant combustion of paper to be improbable due the inert atmosphere and sealed container, preventing in-leakage of air during the accident conditions of transport. Radiative heat transfer to ignite the paper or wood would require higher temperatures of a longer duration than predicted for the inner container wall. Furthermore, in cellulosic materials, there is an important semi-physical change that always occurs on heating: desorption of water. As the water is both physically and chemically adsorbed, the temperature and rate of desorption will vary with the material. The activation energy for physical desorption of water is 30 to 40 kJ/mole, and it starts occurring at temperatures somewhat lower than the boiling point of water (100°C).

However, in the event that auto-ignition of paper occurs, this would also provide a piloted ignition source for other polymeric materials in the package contents. An evaluation has been done to determine the quantity of wood or paper, assuming 100 percent cellulosic composition, or polyethylene that would undergo complete combustion. This thermal decomposition is assumed to begin at the peak gas temperature of 137°C and continue until all the available oxygen is consumed. All heat of combustion is assumed to transfer by radiation to the inner steel containment, and the temperature of the gases is assumed to be the same as that of the inner steel containment. The maximum temperature of the gas and inner steel containment does not exceed 150°C.

Combustion in a sealed container is limited by the amount of air present to support the chemical reaction for the thermal decomposition of the fuel. Heat from the exothermic combustion reaction will increase the temperature of the contents and packaging. The maximum temperature in a sealed container will determine the maximum pressure, along with some additional pressure from emitted gases. The sealed inner containment of the RT-100 cask contains only enough air (5.75 kg) for combustion of approximately 1.127 kg of cellulosic material, paper or wood, and 0.390 kg of polyethylene.

The temperature increase and gases generated by the combustion of polyethylene, paper and wood that occur after the fire will result in pressure increase that approaches but does not exceed the 100 psia (689.4 KPa) limit specified in the RT-100 SAR Chapter 2, Section 3.1.4, Summary Tables of Maximum Pressures. The partial pressure of water vapor contributes about two-thirds of the total pressure, and water vapor pressure is sensitive to the temperature of gases in the containment. The gas temperature reaches a maximum due to the heat input from the fire and internal combustion of content materials within 30 minutes after the fire event and decreases during the cooldown following the fire event. The water vapor pressure will decrease approximately 1.5 psi per 1°C decrease in temperature.

The temperature and pressure increases due to paper combustion do not impair the ability of the containment seal to keep the cavity leaktight per ANSI N14.6, because the seal temperature stays below 150°C during all the fire accident case (per table 3.1.3-2 of the SAR).

A section is added to the SAR to address the potential combustion of contents, 3.4.3.2.6 *"Total Pressure Accounting for Combustion of Contents"*.

<u>SAR Impact:</u>

Addition of Section 3.4.3.2.6 *"Total Pressure Accounting for Combustion of Contents"*.
Revision of Section 3.4.3.2 *"Maximum Accident Condition Pressure"* to note a fourth component of the maximum pressure, thermal decomposition of the contents.
Addition of reference RTL-001-CALC-TH-0301, Revision 0.

<u>Calculation Impact:</u>

Calc No. RTL-001-CALC-TH-0201, Rev. 3 to be updated.
Addition of RTL-001-CALC-TH-0301, Revision 0

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

RAI 3-2 Question:

Provide the maximum temperatures of the cover plate EPDM O-rings during NCT and HAC.

Page 3-6 of the application includes the maximum temperatures of the primary lid and secondary lid O-rings. The cover plate O-ring temperatures should also be provided in order to verify their acceptable operation during NCT and HAC.

This information is required by the staff to determine compliance with 10 CFR 71.71 and 71.73.

RAI 3-2 response:

The maximum acceptable temperature for all EPDM O-rings is 150°C.

The port cover plate is not specifically modelled in ANSYS. Its location is on the primary lid, close to the primary lid closure bolts. The cover plate is thermally insulated by the upper impact limiter.

The highest temperature reported on the primary and secondary lid occurs during the HAC pin puncture damage to the top impact limiter. The location is on the closure bolts (where the puncture bar penetrates the impact limiter), with a maximum temperature of 133.1°C (reported in table 3.1.3-2).

Since the temperature of 133.1°C bounds all calculated temperatures in the lids and cover plate assembly, the maximum temperature of the cover plate containment O-ring during HAC is considered to be 133.1°C.

The NCT maximum temperature of the components surrounding the cover plate occurs during the Hot Case 1, located at the upper impact limiter, which is 72.5°C (reported in table 3.1.3-1). Thus the maximum temperature of the cover plate containment O-ring during NCT is considered to be 72.5°C. Since Hot Case 1 is the bounding upper temperature of this O-ring, the other NCT cases are not considered.

SAR Impact:

Section 3.1.3 is updated to address the maximum temperatures taken into account in NCT and HAC for the quick disconnect valve cover plate O-ring.

Tables 3.1.3-1, 3.1.3-2, and 3.1.3-3 are updated to add the max temperatures of the quick disconnect valve cover plate O-ring and its maximum acceptable temperature during NCT and HAC.

Calculation Impact:

None

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

<u>RAI 3-3 Question:</u>

Change “ambient” with “package surface” in Section 3.4.1.2, Section 3.4.2.2, and Calculation Package RTL-001-CALC-TH-0201.

The applicant should modify the sentences (a) “heat transfer to the ambient by forced convection” with “heat transfer to the package surface by forced convection” and (b) “heat transfer to the ambient by radiation, emissivity = 0.9” with “heat transfer to the package surface by radiation, emissivity = 0.9” on page 3-31(Section 3.4.1.2), page 3-43 (Section 3.4.2.2) and page 20 of Calc. No. RTL-001-CALC-TH-0201 (Rev. 3). This modification will clarify the heat transfer direction during the fire transient.

This editorial change is required to determine compliance with 10 CFR 71.35 and 71.73.

<u>RAI 3-3 Response:</u>

Sections 3.4.1.2 and 3.4.2.2 of the SAR are updated to clarify the direction of heat transfer, and explain the differences in emissivity values used in the calculation.

The following is a summary of the fire transient boundary conditions:

- Environment temperature, 800°C (1472°F)
- No solar insolation, 0 W/m^2
- Forced convection, heat transfer coefficient = 10 W/m^2
- Radiation from the environment to package surface, flame emissivity = 0.9
- Internal heat load as a uniform heat flux, 13.04 W/m^2

The cool-down analysis is performed for 216,000 seconds (2.5 days) with the following boundary conditions:

- Environment temperature, 38°C (100°F)
- Solar insolation applied as constant, 776 W/m^2 for flat surfaces and 388 W/m^2 for curved surfaces.
- Natural convection, heat transfer coefficient = 5 W/m^2
- Radiation from package surface to the environment, package emissivity = 0.8
- Internal heat load as a uniform heat flux, 13.04 W/m^2

<u>SAR Impact:</u>

Sections 3.4.1.2 and 3.4.2.2 of the SAR were updated.

<u>Calculation Impact:</u>

Page 20 of Calc No. RTL-001-CALC-TH-0201 is updated to Revision 6 to clarify the direction of heat transfer, and to explain the differences in emissivity values used in the calculation.

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

Chapter 4 – Containment Evaluation:

RAI 4-1 Question:

Confirm whether alpha emitters in the contents would contribute to the flammable gas generation analysis.

The flammable gas generation analysis relies on G values for water subject to gamma radiation, per Table 4.4-1. However, Table 5.5.2-1 indicates a number of alpha emitters, including Po-210, Cm-244, Cf-252, etc., which could result in increased G values for water, as noted in Table D.1 of NUREG/CR-6673.

A list of alpha emitters in the loaded contents, and decay products of the loaded contents, should be provided.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 4-1 response:

The contribution of alpha emitters to flammable gas generation depends on the contents being shipped. Resin beads and filters shipped from commercial reactors contain a high percentage of gamma in relation to alpha emitters. Typical examples of historical shipment data is provided with RT100-REF-01-01 *"Historical WCS Cask Summaries by Waste Category"*. On the other hand, TRU wastes contain a high percentage of alpha in relation to gamma emitters.

Previously, the gas generation analysis was performed using the G Values based only on alpha radiation for resin beads and gamma radiation for water. The bounding value for resins was taken from NUREG/CR-6673 because it would bound waste that were primarily alpha, such as TRU waste.

However, as described in NUREG/CR-6673 Section D.7.23:
"Most G values for ion-exchange resins were much lower than the bounding values indicated. If an ion-exchange resin is to compose a major portion of a waste shipment, determining the relevant G values for that particular material may be useful."

Using this guidance, the analysis is revised to reflect the current contents of commercial resins and filters, which have very little alpha radiation.

Historically, shipments of commercial resins and filters have consisted of approximately 90-100% gamma radiation. To bound these shipments, the revised calculation has assumed a decay energy distribution of 80% gamma and 20% alpha radiation. SAR Table 4.4-5 has been developed, and the loading curve shown in Figure 4.4.4-1 (and repeated as Figure 7.5-1) has been revised to reflect this content specification. If contents exceed a 20% alpha loading, a separate calculation must be performed (i.e., the loading curve cannot be used), as further described in response to RAI 7-3.

Section 4.4 of the SAR and Section 6.4.1 of Calculation RTL-001-CALC-SH-0301 Rev. 4 have been updated to take into consideration the effective G values for the gamma-alpha decay energy distribution assumed for resins and filters. The alpha energy contribution to total thermal output from ionic resins and filters from commercial nuclear power waste streams is expected to be low (i.e. less than 20%), and need not be listed by individual radionuclides. The effective G values used in the updated calculations set the G value (before temperature effects are taken into consideration) equal to the ratio of 20% of the G value provided for alpha emitting radiation (information provided by NUREG-CR/6487) and 80% of the G value provided for typical resins and filters due to primarily beta and gamma sources (information provided by EPRI NP-5977). The resultant G values are then adjusted to account for the maximum normal conditions temperatures as described in response to RAI 4-5.

The loading curve has been revised to reflect the new effective G Values and temperature effects. The details and limitations of this curve are further described in response to RAI 7-3, and the temperature effects on the G Values are further described in response to RAI 4-4.

<u>SAR Impact:</u>

Revision of Section 4.4 *"Hydrogen Gas Generation"*, including subsection 4.4.1 *"Determination of Bounding G Values"*.
Revision of Table 4.4-1, and addition of Tables 4.4-2, 4.4-3, 4.4-4, and 4.4-5.
Revision of Figure 7.5-1 (also located in Chapter 4 as Figure 4.4.4-1).
Addition of Chapter 4 Reference 22, RT100-REF-01-01 *"Historical WCS Cask Summaries by Waste Category"*

<u>Calculation Impact:</u>

RTL-001-CALC-SH-0301 Section 6.4.1

<u>RAI 4-2 question:</u>

Clarify the limitations of water allowed in the content and specify, within the Chapter 7 Package Operations, the need to determine the amount of water in the content.

Page 4-20 of the application states both that the resin is dewatered and that resin beads could have moisture content up to 55% by weight. In addition, the response to RAI 4-7 indicates there is no restriction on moisture content, although page 4-21 indicates a limitation by assuming a ($0.99{*}0.25{*}V_{waste} + 0.01{*}V_{waste}$) water volume in the calculations. The ambiguity should be clarified since the amount of water has an effect on the quantity of flammable gas generated. In addition, confirm the 55% by weight moisture content is numerically compatible with the assumed ($0.99{*}0.25{*}V_{waste} + 0.01{*}V_{waste}$) water volume.

This information is required by the staff to determine compliance with 10 CFR 71.43.

<u>RAI 4-2 response:</u>

Organic ion exchange resins contain from 50% ~ 66% water (moisture) as they are delivered from the manufacturer (EPRI NP-5977, *"Radwaste Radiolytic Gas Generation Literature Review"*, Chapter 5, Page 12). This is essentially the same condition of the resin as it is disposed of in a "dewatered" form. In addition to the moisture content within the resins, dewatered resin shipments typically contain no more than 1% by volume of "free water".

The "free water" content of waste in the package is not the primary contributor of hydrogen generation. This is because the G-value for water (0.68) is less than the G-values for the resins (1.45) and secondary container (polyethylene, 5.1).

The derivation of these G-values and the effect of temperature are further described in response to RAI 4-4. Increasing the amount of "free water" between the resins would decrease the effective G-value, thereby reducing the amount of hydrogen generation per unit energy. The G-values for resins, as noted in Table 5.3 of EPRI NP-5977, are for resins with high moisture contents (i.e, swollen resin).

The assumption of 25% volume of "free water" was used to demonstrate the effect of reduction in void volume on the allowable wattage (***W***), as shown in the equation below, based on Equation 6 of a paper presented by J. Chang at the WM2011 Conference, "*Evaluation of Hydrogen Generation and Maximum Normal Operating Pressure for Waste Transportation Packages*".

$$W = \frac{C_H \times V_{VOID}}{G_{EFF} \times C_F \times t \times C}$$

Where C_F, C, and t are constants, C_H is set at 0.05, and V_{VOID} represents the free gas volume. Assuming a 25% volume of "free water" reduces the free gas volume within the waste to about 11%, from 36%, based on the packing fraction. This amounts to a 69.45% reduction in free gas volume of the waste.

As detailed in response to RAI 7-1, a condition for using the loading curve presented in Section 7.5 of the SAR is that the maximum free water by volume within the waste be less than 25%.

SAR Impact:

Section 7.5 of the SAR is revised, with the addition of Table 7.5.1-1 noting limitation of "Free Water" volume.

Calculation Impact:

None

RAI 4-3 Question:

Clarify that the flammable gas generation calculation methodology, presented in Section 4.4, bounds the materials that are permitted within the package cavity.

Chapter 1 indicates that content and shoring can contain wood and thermoplastics, including polyethylene and polypropylene. However, Table 4.4-1, which is used to determine flammable gas generation, does not include wood and polypropylene.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 4-3 response:

G-values for wood and polypropylene have been added to Table 4.4-1 and discussed in Section 4.4 of the SAR.

Shoring material (wood or thermoplastics) can be neglected in this calculation because it is located outside of the secondary container, as described in Section 1.2.2.3 of the SAR. It is assumed that all the energy not absorbed by the contents is absorbed by the secondary container, modeled as polyethylene.

The G-value for polyethylene bounds the G-values for all other secondary container materials, as shown in revised Table 4.4-1. The flammable G-value of 4.1 at 298 K for polyethylene bounds the flammable G-value for wood (cellulose) of 3.2 at 298 K. Polyethylene also bounds the flammable G-value for polypropylene of 3.4 at 298 K. The G-value for polyethylene was taken from NUREG/CR-6673 and bounds both alpha and gamma radiation.

After the temperature adjustment detailed in Section 4.4.1.3 of the SAR, wood has a slightly higher G Value (5.56) than polyethylene (5.06). However, wood has a significantly higher total gas G Value (17.72 vs. 5.06), which offsets the impact of flammable gas generation by generating more than 2 moles of non-flammable gas for every mole of flammable gas. Additionally, the wood would be present only in limited quantities as shoring material on the outside of the secondary container.

<u>SAR Impact:</u>

Revision of Section 4.4 to explain the bounding G-value for polyethylene, and revision of Table 4.4-1.

<u>Calculation Impact:</u>

RTL-001-CALC-SH-0301 Sections 5.7 and 6.4.1, and Table 5-10

<u>RAI 4-4 Question:</u>

Provide the G values, used in Section 4.4 and Figure 7.5-1, that reflect the conditions inside the package.

There is a temperature dependency on radiolysis, as discussed in NUREG/CR-6673. Sections 3.3.2.2 and 3.4.3.2.2 of the application indicate cavity temperatures greater than 298°K, which is the temperature basis for the G values reported in Table 4.4-1. Depending on the activation energy of the materials, the higher temperatures during transport could result in a radiolytic gas generation that is twice the gas generation at 298°K.

This information is required by the staff to determine compliance with 10 CFR 71.43.

<u>RAI 4-4 response:</u>

Temperature effects for the G values used in the updated hydrogen generation calculations are now taken into consideration. The maximum inner shell temperature is assumed to be 80 °C, which bounds the maximum inner shell NCT temperature of 73.1 °C shown in Table 3.1.3-1 of the SAR. The G values at 80 °C were determined from the Arrhenius equation given in NUREG/CR-6673:

$$G_{T_2} = G_{T_1} e^{\left[\left(\frac{E_a}{R}\right)\left(\frac{T_2 - T_1}{T_2 T_1}\right)\right]}$$

where: T_1 – is 298 K,
T_2 – is transport temperature (353 K),
G_{T2} – G value at 353 K,
G_{T1} – G value at 298 K,
E_a – activation energy of the hydrogenous material, and
R – gas constant

The temperature effect on the bounding G-Values used in the calculations is given in Table 1. Additional information has been provided in Section 4.4.1.3 *"Operating Temperature G Value Adjustment"* discussing the effects of temperature on the G values of hydrogenous materials.

Table 1. Temperature Effect on G-Values [molecules/100eV]

Material	Effective G-Value at T_1 (298 K) [molecules/100eV]	Effective G-Value at T_2 (353 K) [molecules/100eV]	Activation Energy [kcal/mol]
H_2O	0.68	0.68	0.0
Polyethylene	4.10	5.06	0.8
Resin or Filter	0.84	1.45	2.1

SAR Impact:

Revision of Section 4.4 *"Hydrogen Gas Generation"*, and addition of subsection 4.4.1.3 *"Operating Temperature G Value Adjustment"*
Revision of Table 4.4-1, and addition of Tables 4.4-2, 4.4-3, 4.4-4, and 4.4-5.

Calculation Impact:

RTL-001-CALC-SH-0301 Section 6.4.1

RAI 4-5 Question:

Correct typographical errors associated with leakage rates and flammable gas generation, including Section 4.3, Section 4.4, and Table 8.3-2. The tables and equations in these sections are especially important, as they form the basis of calculations performed by package users if content is not within the range set forth in Figure 7.5-1.

- The equation on the bottom of page 4-9 is missing a pair of parenthesis around the (Fc+Fm) term.
- It appears that equation 4.4 should define the hydrogen mole fraction as:

$$X_H = n_H/n_o+n_{\text{total gas}}.$$

- In the top equation of equation 4.5, the third term in the denominator should be $(D_w\ G_{TW}\ (2t))/(100\ A_N)$ rather than $(D_c\ G_{TW}(2t))/(100\ A_N)$.

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

- Per Section 3.3.2, the radiolysis of water generates hydrogen and oxygen. Confirm that not including oxygen as part of the net gas generated is conservative in the flammable gas generation calculations and make note of that in Table 4.4-1. In addition, provide water's G (net gas), G_T value in Table 4.4-1.
- It appears that the footnote for Table 8.3-2 refers to leak rates from Table 4.3.1-2 rather than Table 4.3-3. If so, this notation should be corrected in order to aid leakage test personnel.

This information is required to determine compliance with 10 CFR 71.43.

<u>RAI 4-5 response:</u>

Equations noted in Chapter 4 have been corrected. These errors were only editorial – no derived equations or calculation results were erroneous. Table 8.3-2 is corrected to reference Table 4.3.1-2.

Section 3.3.2.4 of the SAR, "Pressure Due to Generation of Gas", assumed that the radiolysis of water generates only hydrogen and oxygen gases. This assumption was made in order to maximize the pressure increase due to gas generation.

In Section 4.4 of the SAR, only hydrogen gas was considered as a byproduct of the reaction. This results in the fraction of flammable gas to the total gas generated (α) of 1.0 in Equation 4.4.

$$X_H = \frac{n_H}{n_0 + n_{net}} = \frac{\frac{D_H}{100}\frac{\alpha G_T t}{A_N}}{\frac{P_0 V}{R_g T_0} + \frac{D_H}{100}\frac{G_T t}{A_N}}$$

Including oxygen in the total gas generation from the radiolysis of water would decrease the mole fraction of hydrogen (***X***X_H) in the free gas volume. This is because the alpha term would be less than 1.0. Thus, maintaining the value of 1.0 would yield the most conservative result.

Table 4.4-1 was updated to include the G(net gas) value for water, with the addition of a footnote for water explaining that the G_T value is set to the G_{FG} value.

<u>SAR Impact:</u>

Corrections to Equations in Chapter 4, revision of Table 4.4-1, and correction to the footnote to Table 8.3-2.

<u>Calculation Impact:</u>

Equations in calculation package RTL-001-CALC-SH-0301 are corrected.

Chapter 5 – Shielding Evaluation:

RAI 5-1 Question:

Provide clarifications for (1) the distribution (homogenous or heterogeneous) of the sources inside the contents, and (2) the criteria used to define what constitutes or not a “significant variation.” Justify why the pre-shipment measurement could assure the homogeneity of the source distribution. Delete statements on “reasonable assurance.”

In the staff’s first RAI letter, dated March 28, 2013, RAI 5-2 requested the applicant to confirm if the packaging is used to transport only sources that are uniformly distributed inside the contents, as assumed in the shielding analyses. In its response to this RAI 5-2, the applicant stated the following: “The contents of the RT-100 will consist of dewatered resins and filters. The material is not intended to be shipped as a “point source.” Waste Generators are required to perform sampling prior to shipment. This sampling verifies the homogeneity of the material.” Such a statement did not answer staff’s question.

Also, as part of its response to this RAI 5-2, the applicant further stated: “Prior to shipment, the waste generators are required to provide the complete waste stream characteristics and characterization in the form of a waste profile. This waste profile ensures that the material is in compliance with the receiving facilities Waste Acceptance Plan and includes any analytical data process knowledge, radiological activities, *anticipated* dose rates of the material, and the chemical/physical make-up of the waste. The maximum isotopic unit activity of any waste samples is used in the Loading Table for the entire contents of a package. This provides *reasonable assurance* that the RT-100, when loaded, *will not have significant variation* in the homogeneity of its contents, that could result in a dose rate at the package surface or one meter from the vehicle boundary that exceeds the dose limits in 10 CFR 71.47 b(2).” An applicant cannot claim “reasonable assurance,” i.e., a term used by regulators, to establish the licensing basis for the package design. Also, the applicant did not define what constitutes a “significant variation” in the homogeneity of the contents.

In addition, in its response to RAI 5-2, the applicant stated: “The dose rate measurements required by NRC and DOT before shipment are used to indirectly verify (not to make the primary determination) that there are no significant variations in package contents.” It is not clear how the pre-shipment dose rate measurements can be used to determine the uniformity of the source in the contents, as pre-shipment measurement is not a means to demonstrate compliance with the regulations (see Regulatory Issue Summary RIS 13-04, “Content Specification and Shielding Evaluations for Type B Transportation Packages,” for further clarification).

The applicant needs to provide (1) the nature of the contents with regard to source distributions (homogenous or heterogeneous), and the criteria used to define what constitutes a “significant variation.” The applicant needs to justify how a pre-shipment measurement can assure the homogeneity of the source distribution. The applicant needs to delete all references to “reasonable assurance.”

This information is required by the staff to determine compliance with 10 CFR 71.47 and 71.51.

RAI 5-1 response:

The contents do not need to be homogeneous; rather, the source strength density (Ci/g) must be less than the limits specified in Table 5.5.3-1 and 5.5.3-2 at any point within the waste volume. Compliance with the Source Strength Density Limits for each nuclide is ensured by characterization of contents by the shipper prior to loading cask. This characterization of the contents ensures that the bulk density of resins and filters is less than 1.0 g/cc (Total weight/occupied volume of the containment), and the source strength density is less than the maximum allowed, that is, sum of fractions for radionuclides [actual content activity (Ci/g)/maximum allowable concentration (Ci/g)] is less than 1.0. The content complies with the requirements by meeting all the requirements of the loading table provided in section 7-6. This characterization is consistent with the technique used in the NRC Branch Technical Position on Concentration Averaging and Encapsulation. A notable difference is that no credit is taken for concentration averaging in the waste.

Conventional ion exchange resins consist of a cross-linked polymer matrix with a relatively uniform distribution of ion-active sites throughout the structure. A cation exchange resin with a negatively charged matrix and exchangeable positive ions (cations) is shown in Figure 1. Ion exchange materials are sold as spheres or sometimes granules with a specific size and uniformity to meet the needs of a particular application. The majority are prepared in spherical (bead) form, either as conventional resin with a polydispersed particle size distribution from about 0.3 mm to 1.2 mm (50-16 mesh) or as uniform particle sized (UPS) resin with all beads in a narrow particle size range. In the water swollen state, ion exchange resins typically show a specific gravity of 1.1-1.5. The bulk density as installed in a column includes a normal 35-40 percent voids volume for a spherical conventional resin product. Bulk densities in the range of 560-960 g/l (35-60 lb/ft^3) are typical for wet resinous products. [Reference: Dow Liquid Separations, Fundamentals of Ion Exchange]

The loading limits for each radionuclide are based on the minimum source strength density Ci/g that is allowed by the regulatory dose limit. This limit assumes that the bulk density of the contents does not exceed a density of 1 g/cm3. The distribution of the source strength density does not need to be uniform throughout the contents. Any content loading with density less than 1 g/cm3 with a source strength density not exceeding the limit will result in a dose rate that meets the regulatory limits.

SAR Impact:
TBD

Calculation Impact:
TBD

RAI 5-2 Question:

Explain the three range approach used in the shielding analyses and justify why it is reliable and produce conservative results.

In its response to RAI 5-6, the applicant changed its method for shielding analysis of low energy particle emitter contents. A new method named “Three Range Approach” is introduced. In its response to the RAI, the applicant indicated that the new approach is explained in Section 5.4.2 of the application, but the staff was unable to find any explanation on how this new approach works and why it can produce reliable results. The only information provided in Section 5.4.2 of the application appears to be a list of three groups of energy ranges. The application does not elaborate on why the energy range was split into three groups and what problem this regrouping may attempt to resolve. The applicant needs to provide detailed information on this new approach, including details on how it works, its technical basis, and all appropriate justifications for its reliability and accuracy.

This information is required by the staff to determine compliance with 10 CFR 71.47 and 71.51.

<u>RAI 5-2 response:</u>

The *"three range approach"* is a general procedure that can use any specified energy ranges to develop the dose rate response for the gamma energies of interest in a shielding evaluation. The term *"three range approach"* was used in the application to describe the selection of three energy ranges to optimize the variance reduction in the MCNP calculations.

The general procedure can be summarized in the three following steps: (1) Simulate geometry and contents of the package using MCNP to estimate dose rates for a 1 Ci source term, (2) Calculate gamma dose rates for each reference gamma energy under NCT and HAC, and (3) Determine the maximum permissible source strength density for each nuclide.

In performing step 3 of the procedure we no longer interpolate between the two nearest energy lines, but instead use the next higher energy response. This change addresses concerns that linear interpolation may not be bounding for all nuclides, since the true energy dependent response curve may not be concave up for the entire energy range considered. The only exception to this is for photon energies between 1.0 and 1.022 MeV. Because pair production interactions cause a decrease in the dose rate response in this energy range, it is conservative to handle photon energies where pair production is not possible with the response from the 1.0 MeV energy line. In addition, all photon energies below 0.3 MeV will be assigned the response from the 0.3 MeV line in order to bound all possible responses from low energy photons. Some isotopes, such as Co-60, will be modeled using their specific energy lines to minimize the conservatism imposed by rounding up to the next highest energy (1.17 MeV to 1.2 and 1.33 MeV to 1.4).

The energy grouping approach was chosen to facilitate variance reduction in MCNP. The methods for variance reduction are further described in response to RAI 5-4.

<u>SAR Impact:</u>

Revision of Section 5.4

<u>Calculation Impact:</u>

TBD

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

RAI 5-3 Question:

Correct the following error in Table 5.1.2-1 and explain why incorrect regulatory requirements were cited.

Table 5.1.2-1 cited 0.1 mSv/hr at 2 meters from the projected plane of the edge of a flatbed as the regulatory requirement of 10 CFR 71.47(b)(2). However, the regulatory requirement for this dose rate limit is prescribed in 10 CFR 71.47(b)(3). A similar error occurred in the initial application in which some sections indicated that the package design meets the requirements of 10 CFR 71.47(a) and other sections of the application indicated the package was designed to meet the 10 CFR 71.47(b) requirements. The applicant needs to correct this error and explain why this type of error repeated from the initial submittal to the revised SAR.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 5-3 response:

The intent was to cite the regulatory dose rate limits for exclusive use for the surface and 2 meters from the package. The citation is corrected to state 10 CFR 71.47 (b) for exclusive use.

SAR Impact:

TBD

Calculation Impact:

TBD

RAI 5-4 Question:

Demonstrate that the response method used is accurate and reliable with focus on mid- and low-energy particles and prove that all MCNP shielding calculations have converged properly.

In the previous letter requesting additional information, RAI 5-6 requested the applicant to demonstrate that the approach it used in determining the maximum allowable content is reliable and accurate. The applicant's response, however, did not answer the question. In its response, the applicant did not address the fundamental question on the interdependency of the dose rate to particle/energy response relation and the media through which the particles traverse, i.e., whether the dose rate/particle/energy response is still valid if the assumed content changes. The applicant needs to provide the technical bases for the approach used in the shielding analysis and demonstrate that this approach is accurate and reliable for the package shielding analyses.

In addition, the staff's confirmatory calculations using the applicant's models indicated that most of the low mid-to-low energy particle MCNP calculations do not converge with the time specified in the models and the applicant confirmed this during a meeting. Hence, the results presented to the NRC in the application might have been erroneous and misleading. The applicant needs to provide results that are accurate and reliable.

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

This information is required by the staff to determine compliance with 10 CFR 71.47 and 71.51.

RAI 5-4 response:

Media impact on dose rate:

The effect of the media composition is addressed in SAR Section 5.3.2 *"Material Properties"* and calculation RTL-001-CALC-SH-0201 Section 7.7.2 *"Content Density and Material Variation"*. The MCNP calculations for the final dose rate response functions utilize a waste material of polystyrene at a density of 0.65 g/cm^3. The studies described in the SAR and calculation consider the effect on predicted dose rate of other waste materials (charcoal, nylon, and zeolite). Additionally, the sensitivity of the dose rate response to a range of waste densities (0.325 to 1.0 g/cm^3) was also considered. The maximum source strength densities were developed using the final dose rate response functions adjusted using the correction factors identified in Section 7.7.2 of the calculation to account for the bounding material and density values.

The maximum allowable source strength density (Ci/g) decreases slightly with increasing waste material density. The density used in the evaluation represents the bulk density of the contents. The bulk density of dewatered resins is typically less than 1 g/cm^3. As a result, the calculated dose rates determined through the use of the limiting source strength density values would be greater than the actual dose rate for materials with a density less than 1 g/cm^3.

Accuracy and reliability of calculated results (convergence):

In the previous submitted analyses, all dose rate tallies had proper convergence (fsd < 0.10) except for portions of the impact limiter surfaces. This was due in part to the fact that the weight windows were being optimized to the entire radial or axial surfaces.

In the figures on the following pages, the dose rate responses for two nuclides are plotted in axial dimension of the RT-100 cask for the cask surface, impact limiter surface, and 2 meter from transport vehicle tally. The two nuclides that are plotted are Co-60 (1.1 – 1.4 MeV response) and Cs-137 (0.6 - 0.7 MeV response). The purpose of these plots is to show that the maximum dose rates for these surfaces are not from tallies that have fsd > 0.10. The tallies with fsd > 0.10 are not in streaming paths, or any dose rate peaks, so tally convergence in these areas is not important for determining maximum dose rates from the RT-100 cask.

The dose rate response for the upper impact limiter for Co-60 is plotted in Figure 1. From Figure 1 it is clear that the peak dose rate locations are captured by the tally, and the upper end of the upper impact limiter does not contain a peak location. This same figure is presented for Cs-137 in Figure 2. The same conclusions can be drawn.

Furthermore, the limiting source strength densities are based on the dose rates at 2 meters from transport vehicle. The dose rate tallies at this distance are well converged in all regions. For comparison, all tallied surfaces are plotted together in Figure 3 for Co-60 and Figure 4 for Cs-137. The peak for the Cs-137 case is much more sensitive to the lead streaming, because of the lower energy gamma. The two endpoints of the cask surface tally cover a large distance (from end of thermal shield to top or bottom of cask), so these represent an average dose rate. That is why it appears the impact limiter dose rate is higher than the cask surface. In reality the cask surface dose rate is greater at the streaming location. This dose point is unimportant, however, since it is not an external surface of the cask.

For both nuclides, the 2 meter dose is well converged and clearly covers the peak side dose rate. As stated before, the 2 meter maximum occurs closer to the upper end due to the sensitivity of low energy gammas to the streaming path.

Figure 1- Upper Impact Limiter Dose Rate Response for Co-60

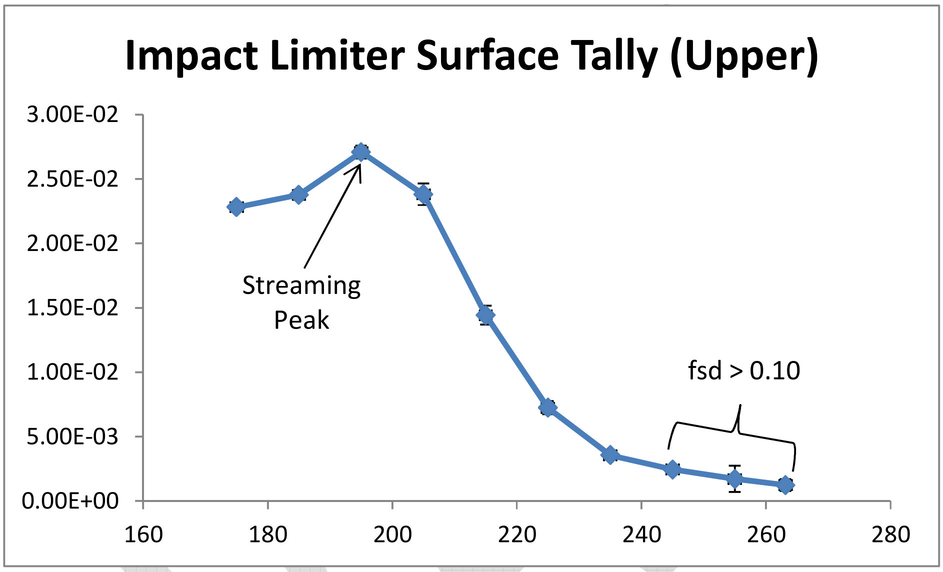
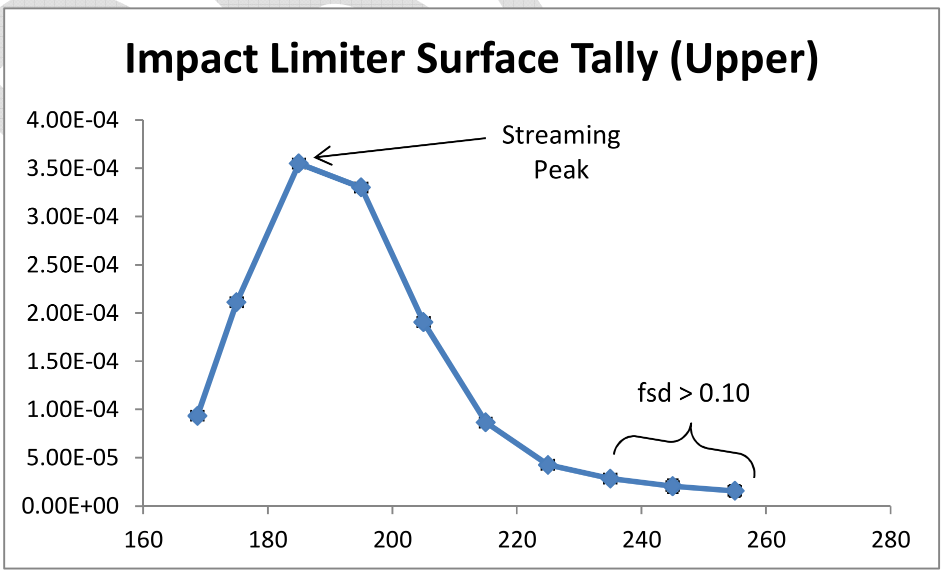


Figure 2- Upper Impact Limiter Dose Rate Response for Cs-137



Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

Figure 3- Total Dose Rate Response for Co-60

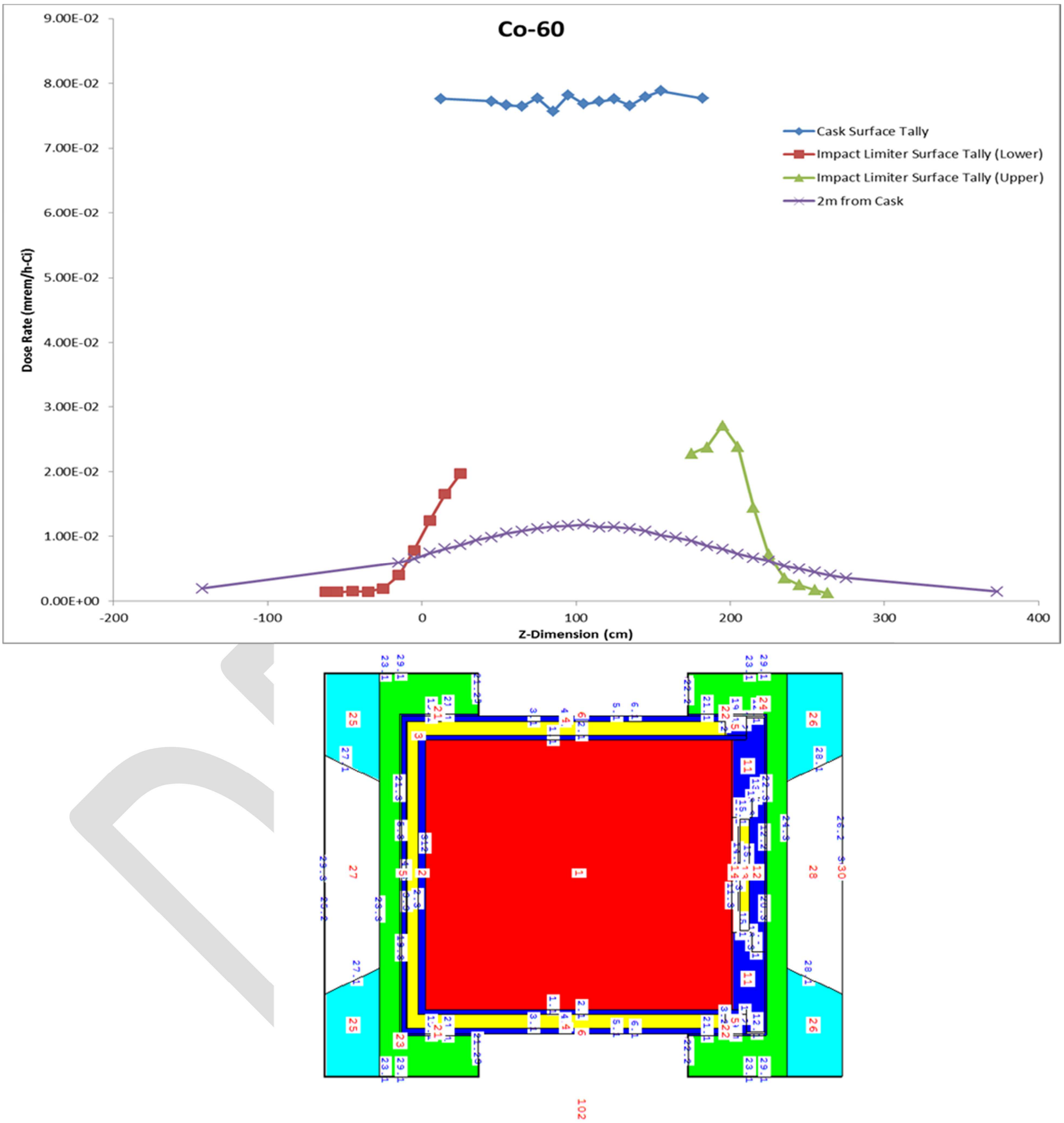
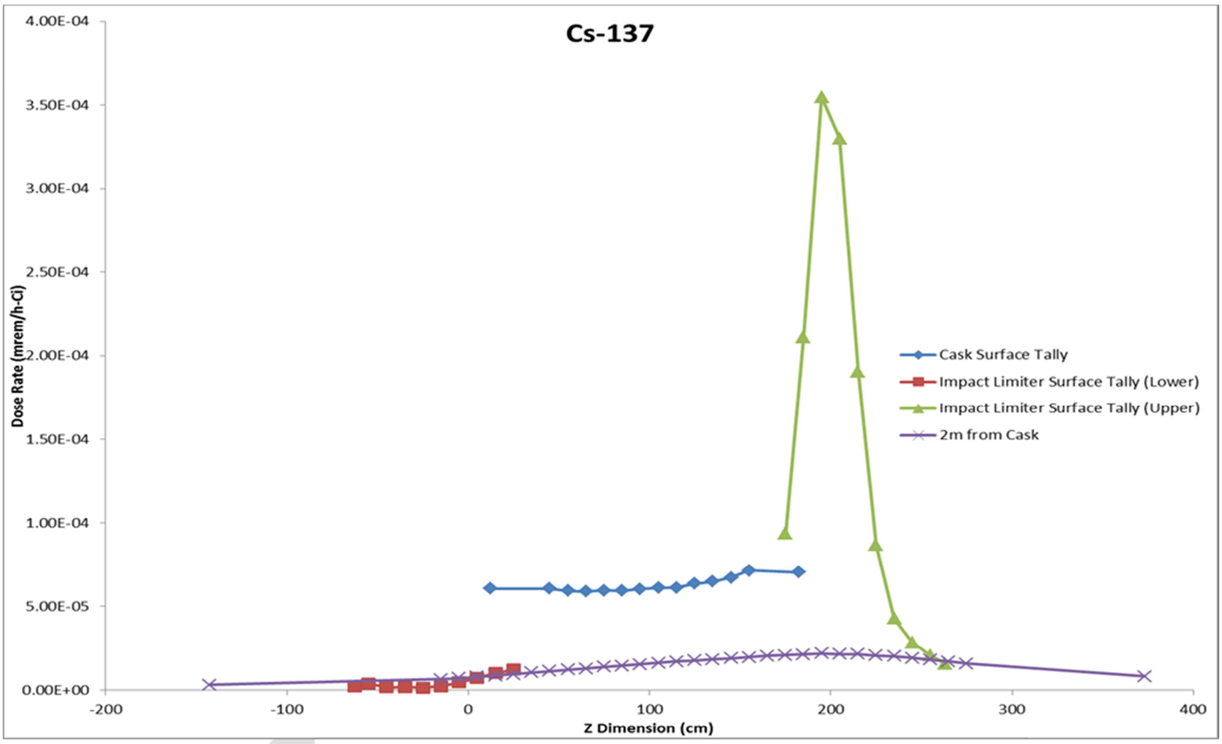
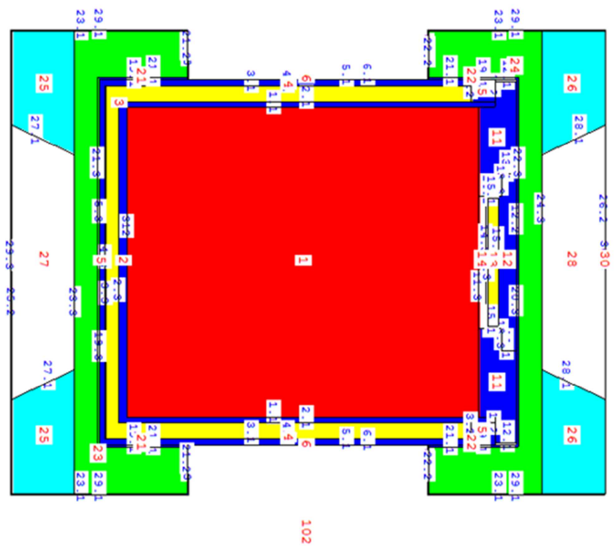


Figure 4- Total Dose Rate Response for Cs-137





To ensure convergence for all regions of the problem, the impact limiter surface dose rate calculations are now run with weight windows optimized for the upper and lower impact limiter surfaces. Additionally, improvements in variance reduction are also included via weight window optimizations to ensure that all reported tally bins are converged (fsd < 0.10).

Due to the nature of these calculations and the extremely long run times that are utilized to obtain fsd values less than 0.10 in all cases, the MCNP statistical checking for the problem as a whole will report some failures of statistical checks such as the variance of variance and factor of merit. This is due to the fact that the problem as a whole becomes so well converged, with fsd values below 0.1% in many cases. At this point, the problem result cannot be further improved through the running of additional histories, and the fact that the VOV and FOM do not decrease proportionally with the number of histories to the extent required by MCNP to report a pass for these tests. If the dose rate calculations were broken into enough different cases with different weight window based variance reductions and each optimized to produce fsd values of around 1%, the cases could all be shown to pass all MCNP statistical checks.

SAR Impact:

Section 5.3.2

Calculation Impact:

Section 7.7.2

RAI 5-5 Question:

Justify the code benchmarking results with respect to:

1. the efficiency and uncertainty of the detector(s) that was used in measuring the package surface dose rates;
2. calibration of the detector for this measurement purpose;
3. the conclusion that the calculated dose rate is greater than the measured ones except one case; and
4. the applicability of benchmark analysis results to other major gamma emitting.

The applicant stated that it used the ^{60}Co gamma scan results of the acceptance test for the first fabricated cask and used the results as a way for code benchmarking. For neutron shielding, the applicant used the well known Ueki experiment. However, it is not clear if the results of these benchmarks are applicable to the RT-100 package.

Typically, code benchmarking requires carefully designed set up of experiments, carefully selected detector, well calibrated detector, accurately measured dimensions of the experiment and the detector positions, and well understood efficiency of the measurements. In order to demonstrate the suitability of these measurement data for code benchmarking for the RT-100 package design, the applicant needs to provide information on: (1) the efficiency and the accuracy of the detector for the measurements; (2) information regarding the calibration of the detector for this measurement purpose; (3) justification of the validity of the benchmark analyses for both gamma and neutron; (4) justification for the conclusion that the calculated dose rate is greater than the measured ones except one case; and (5) the applicability of benchmark analysis results to other major gamma emitting radionuclides (beside ^{60}Co) that have significant presence in the contents to be shipped.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 5-5 response:

MCNP predicted dose rates that were consistent with the measured dose rates for Co-60 gamma scan acceptance testing of the first fabricated RT-100; Robatel agrees that these measurements were not designed to be benchmarks for the shielding calculations. Therefore, all benchmark calculations are removed from the SAR.

There is lack of high-quality shielding experiments available to the end-users for validation of shielding software packages for applications involving combinations of steel and lead shield materials typically found in radioactive material shipping packages such as the RT-100 . Robatel's use of MCNP5 for shielding evaluation of the RT-100 is consistent with Spent Fuel Project Office, Interim Staff Guidance – 21, Use of Computational Modeling Software. ISG 21 references NUREG/CR-6802, "Recommendations for Shielding Evaluations for Transport and Storage Packages". NUREG-6802 states that, "A formal validation of the shielding portion of the SARP submittal is not requested. The use of reasonable procedures and well-established computer codes is expected to produce acceptable results." MCNP5-1.40 Release was used for the RT-100 shielding evaluation. Correct installation of MCNP is verified using a test problem set distributed with MCNP. The installation is documented in accordance with Robatel QA requirements.

SAR Impact:
TBD

Calculation Impact:
TBD

Chapter 6 – Criticality Evaluation:

None

Chapter 7 – Operating Procedures:

RAI 7-1 Question:

Clarify the limitations of Figure 7.5-1 in determining appropriate waste volume and content decay heat.

a) It is expected that Figure 7.5-1 will be used by shippers to determine waste volume and decay heats within the package. Therefore, the limitations associated with the figure should be specified, such as secondary container volume, relative fractions of water in waste volume, ionic resin in waste volume, shipping time limitation, etc. A warning against extrapolating the curve should also be provided. These limitations should be specified in the text and within the figure.

b) Section 7.5 states "If the waste volume and decay heat values for a cask are above the curve illustrated in Figure 7.5-1, the user must perform a more detailed calculation of hydrogen generation for their specific contents and expected shipping time using the information provided in Section 4.4." However, according to Figure 7.5-1, it is "NOT ACCEPTABLE" to ship if waste volume and decay heats are above the curve. Is the need to perform a more detailed calculation dependent on whether the waste volume and decay heat falls <u>outside</u> the range of the curve (e.g., decay heats larger than 13 W or waste volumes greater than 100 ft^3) or <u>above</u> the curve?

c) What does the superscript "1" represent in the Figure 7.5-1 description?

This information is required by the staff to determine compliance with 10 CFR 71.43.

<u>RAI 7-1 response:</u>

a) The loading curve provided in Figure 7.5-1 has been revised to clarify the limitations of its use by a shipper. The shaded area of the curve can be used by shippers to load packages without further analysis, as long as they meet the conditions of Table 2.

Table 2. Conditions and Justifications for using the Loading Curve

Condition for Shipper to use the Loading Curve	Justification
Waste consisting of dewatered resins and filters from commercial power plants	Historically shipments of commercial resins and filters have consisted of approximately 90-100% gamma radiation, as shown in RT100-REF-01-01 *"Historical WCS Cask Summaries by Waste Category"*. To bound these shipments, the calculation assumes a decay energy distribution of 80% gamma and 20% alpha radiation. This results in effective G-Values for resin beads of 0.836 and for water of 0.68 molecules/100eV at 298K. These values are adjusted for maximum NCT temperature of 80 °C, and bound the expected G-Values for resins and filters from commercial reactors.
Maximum 25.75% Free Water by volume of the waste	The loading curve assumes a free water volume of 25.75%. The main effect of free water is to limit the void volume in the cavity, thereby increasing the hydrogen mole fraction. Since the loading curve assumes 25.75% free water for a hydrogen concentration of 5% or less, shippers must ensure that the limit is not exceeded.
No limit on moisture content of resin	The G-values for resins, as noted in Table 5.3 of EPRI NP-5977, are for resins with high moisture contents (i,e, swollen resin).
Use of a liner listed in Table 7.5.1-2 or equivalent	The calculation determines the free volume for waste by subtracting the maximum liner volume (30.1 ft^3) from the cask cavity volume. Equivalent liners may be used provided the volume occupied by the liner material does not exceed 30.1 ft^3. Table 7.5.1-2 consists of liners that meet these volume conditions.
Shipment time not greater than 10 days	Shipment time calculated for 20 days (allowing a shipment within 10 days following regulation).
Loading at temperature not to exceed 38 °C and standard pressure (1 atm)	The maximum ambient NCT temperature is 38 °C per 10 CFR 71.

Packages not meeting these conditions require further analysis. The analysis requires using the gas generation equations developed in Section 4.4, further described in the response to RAI 7-3.

The acceptable range now appears as an area under the curve – therefore, the curve cannot be extrapolated.

b) The curve has been revised to extend all the way to the left, representing a bounding case of 0 ft^3 of waste. On the right, the curve extends to 130 ft^3. A vertical line has been added to right side of curve at this point. Contents are “acceptable” with no further analysis if the waste volume and decay heat of the contents falls within the shaded area. “NOT ACCEPTABLE” has been changed to “DETAILED ANALYSIS REQUIRED”. If the decay heat and waste volume combination fall outside the shaded area, or if the requirements listed in Table 2 are not met, a more detailed analysis shall be performed. This analysis is addressed in response to RAI 7-3.

c) This superscript was intended to have a footnote stating “Shipments within the shaded area have up to 10 days shipment time before flammable gas mixture limit is reached.” As described Table 2, a condition for using the loading curve is that the shipment time be no greater than 10 days. Therefore, the footnote is no longer required.

<u>SAR Impact:</u>

Addition of Section 4.4.4 *“Hydrogen Gas Generation – Simplified Model used to develop Loading Curve”* detailing the process used to develop the loading curve.

Revision of Section 7.5 and Figure 7.5-1. Addition of Table 7.5.1-1 *“Conditions and Justifications for using Package Loading Curve (Excerpt from Table 4.4.4-1)”* and Table 7.5.1-2 *“Secondary Container Volumes (Excerpt from Table 4.4.3-6)”*.

<u>Calculation Impact:</u>

Revision of RTL-001-CALC-SH-0301

<u>RAI 7-2 Question:</u>

Revise the operating procedures to point the users to Section 7.6, “Appendix,” for determining the allowable quantity of the contents.

Section 7.6 of the application provides instructions for determining the allowable quantity of the contents with a specific chemical/physical make-up. However, there is no “pointer” in the step-by-step operating procedures that points the users to Section 7.6.

The applicant needs to revise the Operating Procedures to point the users to Section 7.6, “Appendix,” of the application for determining the allowable quantity of the contents.

This information is required by the staff to determine compliance with 10 CFR 71.111.

<u>RAI 7-2 response:</u>

Section 7.1.2.1 *“Content Loading”* Step 1 was intended to point the reader to Appendix 7.6, but the mandatory nature of the requirement may not have been fully clear. This step is clarified to state the following:

Robatel Technologies Responses to the NRC Second Round of Request for Additional Information for the Model N° RT-100 Package Docket N° 71-9365

1) Prior to loading of the RT-100, the following conditions shall be met:
   a) Package contents meet the requirements of the RT-100 Certificate of Compliance
   b) Package contents meet the requirements of the loading table addressed in Section 7.6
   c) Package contents meet the requirements of the hydrogen generation evaluation described in Section 7.5

Additionally, Figure 7.1.2-1 is revised to include the 3 requirements noted above.

<u>SAR Impact:</u>

Section 7.1.2.1 is updated.
Figure 7.1.2-1 is revised.

<u>Calculation Impact:</u>

No impact to calculation packages.

<u>RAI 7-3 Question:</u>

Incorporate into Chapter 7 the information presented in Section 4.4. of the application

The procedures indicate that Figure 7.5-1 should be used to determine the appropriate contents for loading. However, the figure is valid only for specific conditions. The necessary procedures described in Section 4.4. of the application must be included in Chapter 7 for those conditions in which Figure 7.5-1 is not appropriate.

This information is required by the staff to determine compliance with 10 CFR 71.43 and 71.87.

<u>RAI 7-3 response:</u>

SAR Section 4.4 has been revised to include subsections 4.4.4 "Hydrogen Gas Generation – Simplified Model used to develop Loading Curve" and 4.4.5 "Hydrogen Gas Generation – Analytical Model used for Detailed Analysis". Section 4.4.5 expands upon the previous sections to develop Equations 4.8 and 4.9. These equations are used in place of the Loading Curve if it cannot be used due to the restrictions noted in Table 4.4.4-1.

Equation 4.8

$$t_{max} = \frac{(2.5A_N P_0)(4.6E6 - V_C - 0.8911V_{WASTE})(0.8911V_{WASTE} + V_C)}{(R_g T_0 D_H)[0.6336V_{WASTE}G_{Ti}(\alpha_i - 0.05) + V_C G_{TC}(\alpha_C - 0.05) + 0.2575V_{WASTE}G_{TW}(\alpha_W - 0.05)]}$$

Equation 4.9

$$D_{H,max} = \frac{(2.5A_N P_0)(4.6E6 - V_C - 0.8911V_{WASTE})(0.8911V_{WASTE} + V_C)}{(R_g T_0 t)[0.6336V_{WASTE}G_{Ti}(\alpha_i - 0.05) + V_C G_{TC}(\alpha_C - 0.05) + 0.2575V_{WASTE}G_{TW}(\alpha_W - 0.05)]}$$

where:

t_{max}	=	maximum allowable shipping time to ensure the hydrogen generated during shipment time does not exceed 5% [eV/s]
$D_{H,max}$	=	maximum allowable decay heat to ensure the hydrogen generated during shipment time does not exceed 5% [eV/s]
A_N	=	Avogadro's constant [6.022×10^{23} molecules/gmol]
R_g	=	gas law constant [82.05 $cm^3 \cdot atm/gmol \cdot K$]
P_0	=	pressure when the container is sealed [atm]
T_0	=	temperature when the container is sealed [K]
D_H	=	decay heat of cask contents [eV/s]
t	=	shipment time [s]
V_C	=	secondary container volume [cm^3]
V_{WASTE}	=	waste volume [cm^3]
G_{Ti}	=	total radiolytic G value for the ionic resin [molecules/100eV]
G_{TC}	=	total radiolytic G value for the container [molecules/100eV]
G_{TW}	=	total radiolytic G value for water in waste [molecules/100eV]
α_i	=	fraction of G_{Ti} that is equivalent to G_{FGi}, flammable gas released, for the resin
α_C	=	fraction of G_{TC} that is equivalent to G_{FGC}, flammable gas released, for the container
α_W	=	fraction of G_{TW} that is equivalent to G_{FGW}, flammable gas released, for water in the waste

The user may measure the decay heat of the cask contents ($\boldsymbol{D_H}$) in order to calculate the maximum allowable shipping time ($\boldsymbol{t_{max}}$) using Equation 4.8.

Alternately, the user may know the shipment time ($\boldsymbol{t}$) and calculate the maximum allowable decay heat of the cask contents ($\boldsymbol{D_{H,max}}$) using Equation 4.9.

Initial pressure ($\boldsymbol{P_0}$) and initial temperature ($\boldsymbol{T_0}$) may be measured by the user at the time of loading. The container volume ($\boldsymbol{V_C}$) and waste volume ($\boldsymbol{V_{WASTE}}$) are known.

The use of a different alpha/gamma decay heat distribution than that used in the loading curve must be justified by the user based on waste characterization. Table 4.4.5-1 has been developed to give G-values ($\boldsymbol{G_{Ti}}$, $\boldsymbol{G_{TC}}$, $\boldsymbol{G_{TW}}$) and α fractions ($\boldsymbol{\alpha_i}$, $\boldsymbol{\alpha_C}$, $\boldsymbol{\alpha_W}$) for a range of alpha/gamma decay heat distributions.

Section 7.5 of the SAR has been revised to include the subsections 7.5.1 *"Hydrogen Gas Generation – Simplified Model used to develop Loading Curve"*, 7.5.2 *"Hydrogen Gas Generation – Analytical Model used for Detailed Analysis"*, and 7.5.3 *"Hydrogen Gas Generation – Analytical Model Example"*. These subsections give step-by-step instructions for the user to use the loading curve and the equations developed in Section 4.4.

<u>SAR Impact:</u>

Section 7.5 has been updated to include additional information in Subsections 7.5.2 and 7.5.3 for the user to analyze the hydrogen generation of the contents based on the equations developed in Section 4.4.

Calculation Impact:

None

Chapter 8 – Acceptance Tests and Maintenance Procedures:

RAI 8-1 Question:

Clarify the quick disconnect valve and quick disconnect valve cover plate leakage test procedures.

It is not clear how the quick disconnect valve (Section 8.1.4.3) and cover plate (Section 8.1.4.4) will be helium leak tested. For example, why should the secondary lid not be attached to the primary lid, as indicated in the testing procedure "Note"? It would appear that helium would leak out of the system if the secondary lid was not attached.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 8-1 response:

The quick-disconnect valve and its cover plate can be tested either with the primary lid off or on the cask body. In the first configuration with the primary lid off, a bag containing helium is attached to the lower portion of the primary lid. In the alternate configuration with the primary lid on, the secondary lid is removed, covered with plastic sheet and taped, and the opening is used to inject helium into the cask cavity. The only difference in the configurations is how the helium is injected. The containment boundary and the test method are identical. Sections 8.1.4.3 and 8.1.4.4 have been updated to include figures to show the test configurations. Figures 8.1.4-5 and 8.1.4-6 from the SAR have been provided below for reference.

Figure 8.1.4-5. Test Apparatus for Measuring the Helium Leak Rate through the Quick Disconnect Valve Cover Plate

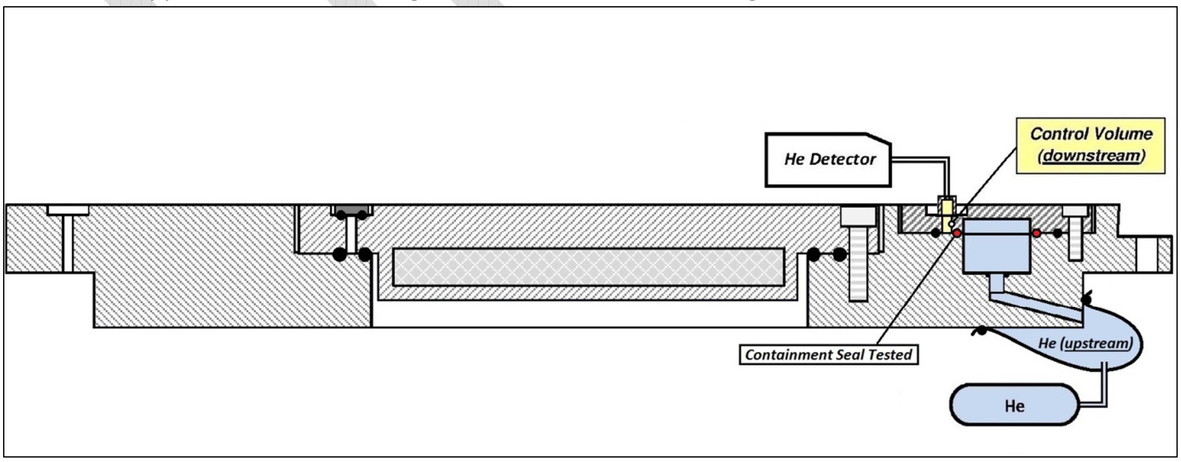
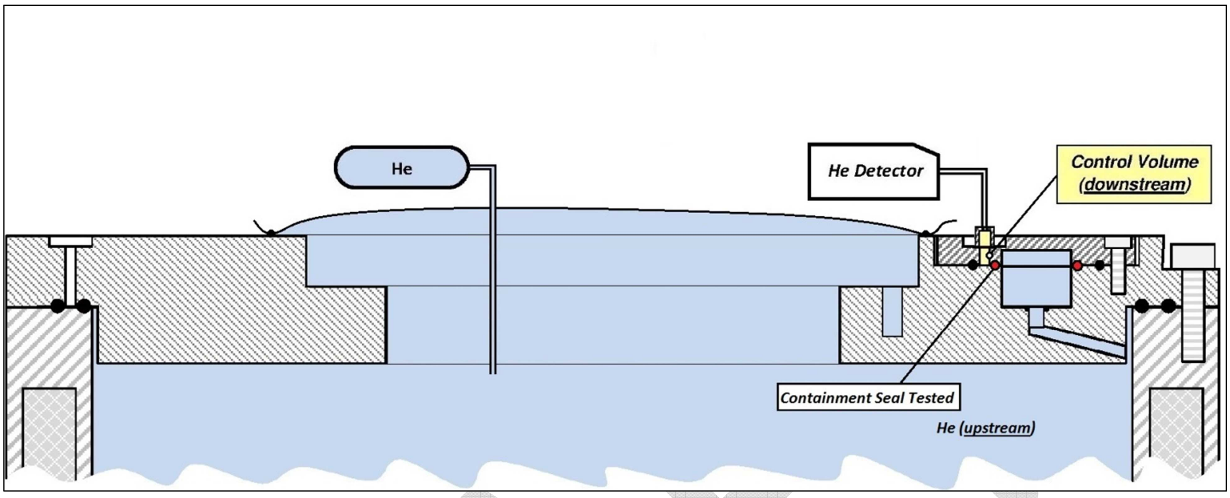


Figure 8.1.4-6. Alternate Test Apparatus for Measuring the Helium Leak Rate through the Quick Disconnect Valve Cover Plate



Additionally, Step 2 of Section 8.1.4.4 incorrectly stated to remove the quick disconnect valve cover plate, when in fact the quick disconnect valve should be removed. This step has been corrected.

<u>SAR Impact:</u>

Section 8.1.4.3 is updated to include Figures 8.1.4-2 and 8.1.4-3. Section 8.1.4.4 is updated to correct step 2 and to include Figures 8.1.4-4 and 8.1.4-5.

<u>Calculation Impact:</u>

No impact to calculation packages.

<u>RAI 8-2 Question:</u>

Provide a note in Section 8.2.2.2 to remind the user to verify if the cover plate and/or the lids were removed or loosened during a preceding shipment of Type A material.

Users of Type B packages should be aware that containment boundary components (e.g., seals and valves) could have been opened during a prior shipment of Type A contents, Low Specific Activity (LSA) material, or Surface Contaminated Objects (SCO), but a pre-shipment leakage rate test might not have been performed. If any containment boundary component is not opened during loading of a Type B package, consideration should be given if the containment boundary component might have been opened during a prior shipment and not have undergone a pre-shipment leakage rate test.

This information is required by the staff to determine compliance with 10 CFR 71.51, and 71.87.

<u>RAI 8-2 response:</u>

The following note was added to the *"Components to be tested"* portion of SAR Section 8.2.2.2:

"<u>Caution:</u> Users of the RT-100 shall be aware that containment boundary components (detailed in Figure 4.1.2-1) could have been opened during a prior shipment of Type A contents, Low Specific Activity (LSA) material, or Surface Contaminated Objects (SCO), but a pre-shipment leakage rate test might not have been performed. The user must verify that an unopened lid has been previously leak tested in accordance with the Certificate of Compliance. If this verification cannot be made, the appropriate containment boundary seal must be leak tested."

<u>SAR Impact:</u>

Section 8.2.2.2 of the SAR is updated to include additional information.

<u>Calculation Impact:</u>

No impact to calculation packages.

<u>RAI 8-3 Question:</u>

Clarify that the primary lid, secondary lid, and cover plate are leakage tested as part of the cask body containment boundary.

Section 8.1.4.1 describes leakage testing for the inner shell, cask bottom, and upper flange as part of the fabrication testing. However, per ANSI N14.5, the primary lid, secondary lid, and cover plate, which form the containment boundary, must also be tested as part of fabrication leakage testing.

This information is required by the staff to determine compliance with 10 CFR 71.43, and 71.51.

<u>RAI 8-3 response:</u>

The leakage tests performed on the cask body containment boundary during fabrication include the primary lid, secondary lid, and cover plate. This information was not included in Section 8.1.4.1 of SAR Revision 2.

Section 8.1.4.1 will be separated into the following subsections:
Section 8.1.4.1.1 "Inner Shell Leak Testing – Prior to Lead Pouring"
Section 8.1.4.1.2 "Primary Lid Assembly Including Secondary Lid and Cover Plate – Prior to Final Assembly"

SAR Impact:

Section 8.1.4.1.2 is added to address these leak tests.

Calculation Impact:

No impact to calculation packages.

RAI 8-4 Question:

Confirm that detailed procedures, that would provide guidance to convert pressure rise test data to leakage rates, are available to package users.

Section 8.2.2.2 does not provide guidance for determining the leakage rate from pressure rise data. It is the leakage rate, however, that must be compared to the acceptance criteria in Table 8.3-1. The equation to determine the leakage rate from pressure rise data should be provided in Chapter 8 or in detailed procedures that are available to package users.

This information is required by the staff to determine compliance with 10 CFR 71.87.

RAI 8-4 response:

The SAR has been revised to give the user guidance to compare the test results to the acceptance criteria. The guidance requires that there be no detectable leak over the calculated test duration for the pressure rise test.

Specifically, Section 8.2.2.2 of the SAR is revised to include additional information under "Acceptance Criteria". ANSI N14.5-1997, Section 8.4 states:

"the preshipment leakage rate test need not be more sensitive than 1x10^{-3} ref-cm^3/s."

This corresponds to a minimum sensitivity, $\boldsymbol{S_{min}}$, under standard conditions of 1.01x10^{-4} Pa-m^3/s. The test is carried out by the pressure rise method. Using formulas B.14 and B.17 given in Annex B of ANSI N14.5-1997, the test duration, ***H***, must be greater than the minimum required test duration, $\boldsymbol{H_{min}}$:

$$H \geq H_{min} = 2 \cdot \frac{V_C \cdot p}{S_{min}} \cdot \frac{T_{std}}{T_{amb}}$$

where: H = actual test duration [s]

H_{min} = minimum required test duration [s]

S_{min} = minimum required sensitivity [1.01x10^{-4} Pa-m^3/s]

p = minimum measurable pressure [Pa] for the test, or gauge resolution

V_C = control volume [m^3]

T_{std} = standard temperature [298 K]

T_{amb} = ambient temperature [K] measured during the test

A detailed procedure provided to the cask user includes the volumes for the interspace between the O-ring seals and the leak test port. The control volume, $\boldsymbol{V_C}$, comprises of this volume along with the volume of the test apparatus.

Over the calculated test duration, there can be no measurable pressure rise. I.e., the pressure rise, ***ΔP***, must be less than or equal to the gauge resolution, ***p***:

$$\Delta P = P_1 - P_2 \leq p$$

where: P_1 = pressure [Pa] at the start of the test, t_1 being the start time [s]
P_2 = pressure [Pa] at the end of the test, t_2 being the end time [s]
ΔP = change in pressure [Pa] during the test
p = gauge resolution [Pa]

Additionally, a more detailed procedure is included in Section 8.2.2.2 of the SAR under "Testing Procedure".

SAR Impact:

Section 8.2.2.2 of the SAR is updated to include additional information.

Calculation Impact:

No impact to calculation packages.

RAI 8-5 Question:

Identify and summarize the differences between COFREND and ASNT-NDT certifications.

The applicant states that personnel shall be either ASNT-NDT or COFREND certified for leak testing but does not identify if and how those certifications are equivalent. The staff understands that each standard is a set of consistent rules and that a line by line comparison may lead to an incorrect conclusion. However, the main differences between ASNT-NDT and COFREND should be identified and summarized.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 8-5 response:

The SAR anticipated that and mentions the use of COFREND certification for Leak testing NDE activities. The equivalence note 102885 EQN 001 rev C approved by the applicant is added to the SAR as a reference to justify the acceptability of use of COFREND for leak testing instead of ASNT 2006 certified personnel.

Section 8.1.4 is revised to state:

“Note: detailed procedures following the instructions below are to be approved by personnel certified in ASNT NDT or COFREND Level III in leak testing. The use of COFREND certified personnel instead of ASNT certified personnel is accepted for leakage testing for the RT-100, based on the equivalence note 102885 EQN 001 rev C.”

SAR Impact:

Addition of note to Section 8.1.4. Addition of Reference 12 to SAR Chapter 8, *102885 EQN 001, Rev C, “Equivalence Table – ANST / COFREND – Qualification and Certification of NDE Personnel”*.

Calculation Impact:

None

RAI 8-6 Question:

Clarify the standards used for the EPDM O-rings.

Page 2-8 of the application mentions that the EPDM O-rings follow ASTM D1418. Page 8-10 does not list this standard.

This information is required by the staff to determine compliance with 10 CFR 71.43.

RAI 8-6 response:

The reference to ASTM D1418 is added to Section 8.1.5.2. The difference between the standards is that ASTM D1418 defines the material and ASTM D2000 defines the critical characteristics.

ASTM D1418 is referenced in Chapter 2 to clearly identify what material the “EPDM” abbreviation is. The definition of the EPDM material per D1418 is:

“Terpolymer of ethylene, propylene, and a diene with the residual unsaturated portion of the diene in the side chain.”

ASTM D1418 and ASTM D2000 are referenced in Chapter 8 to define both the material designation and the critical characteristics of the O-Rings.

SAR Impact:

Section 2.2.1 is revised to clarify that EPDM is an accepted material designation per ASTM D1418.

Section 8.1.5.2 is revised to include the reference to ASTM D1418.

Calculation Impact:

None