NWP
Nuclear Waste Partnership LLC
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October 22, 2015

ATTN: Document Control Desk
Director, Spent Fuel Project Office
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: RESPONSE TO SECOND ROUND REQUEST FOR ADDITIONAL INFORMATION REGARDING REVISION 7 OF THE RH-TRU 72-B SHIPPING PACKAGE APPLICATION, DOCKET NO. 71-9212, TAC NO. L24965

References:

1. Letter from T. E. Sellmer to Document Control Desk, dated November 10, 2014, subject: Revision 7 of the RH-TRU 72-B Shipping Package Application, Docket No. 71-9212
2. Letter from H. Akhavannik (NRC) to T. E. Sellmer, dated December 19, 2014, subject: Application for Revision No. 8 of Certificate of Compliance No. 9212 for the Model No. RH-TRU 72-B Package – Supplemental Information Needed, TAC No. L24965
3. Letter from T. E. Sellmer to Document Control Desk, dated February 18, 2015, subject: Supplemental Information Regarding Revision 7 of the RH-TRU 72-B Shipping Package Application, Docket No. 71-9212
4. Letter from H. Akhavannik (NRC) to T. E. Sellmer, dated May 8, 2015, subject: Request for Additional Information for Review of the Model No. RH-TRU 72-B
5. Letter from T. E. Sellmer to Document Control Desk, dated July 31, 2015, subject: Response to Request for Additional Information Regarding Revision 7 of the RH-TRU 72-B Shipping Package Application, Docket No. 71-9212, TAC No. L24965
6. Letter from H. Akhavannik (NRC) to T. E. Sellmer, dated September 23, 2015, subject: Application for Model No. RH-TRU 72B Transportation Package - Second Round Request for Additional Information

Dear Ms. Akhavannik:

Nuclear Waste Partnership LLC (NWP), on behalf of the U.S. Department of Energy, hereby submits responses to the Second Round Request for Additional Information (RAI) regarding Revision 7 of the RH-TRU 72-B Shipping Package Application, U.S. Nuclear Regulatory Commission (NRC) Docket No. 71-9212 (Reference 6). This information supplements the content of References 1, 3, and 5.

The supplemental information provided consists of the following attachments:

- Attachment A – Responses to Second Round RAIs
- Attachment B – Summary of Revisions
- Attachment C – Revised Documents

Attachment A provides individual responses to the Second Round RAI questions. Attachment B summarizes the changes being made to the SAR in response to the RAIs, and Attachment C provides the revised SAR, RH-TRAMPAC, and RH-TRU Payload Appendices. All SAR page margin redline marks are retained from the original November 2014, Revision 7, submittal and the July 2015 response to the original NRC RAI; new margin redline marks have been added to indicate changes made in response to the second round RAIs. No changes were necessary for the RH-TRAMPAC or RH-TRU Payload Appendices documents as a result of the enclosed RAI responses. The date shown in the header for all documents now reflects a date of October 2015.

If you have any questions regarding this submittal, please contact Mr. S. A. Porter of my staff at (253) 858-6690 or myself at (575) 234-7396.

Sincerely,

Todd Sellmer

T. E. Sellmer, Manager
Packaging and Information Systems

TES:clm

cc: H. Akhavannik, USNRC
J. C. Rhoades, CBFO
J. R. Stroble, CBFO

The following table summarizes the components of this submittal. No deviations occur from the NRC-prescribed PDF formatting for the submitted files. Please contact Ms. C. L. Morrison at (505) 878-1353 or cindy.morrison@wipp.ws to resolve any discrepancies in this submittal.

File Name	File Size (KB)	Sensitivity Level	Submittal Type
001 RH-TRU 72-B R7 RAI-2 Transmittal Letter.pdf	594	Publicly Available	EIE
002 RH-TRU 72-B SAR R7.pdf	31,319	Publicly Available	EIE
003 RH-TRAMPAC R3.pdf	1,755	Publicly Available	EIE
004 RH-TRU Payload Appendices R3.pdf	10,154	Publicly Available	EIE

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Responses to NRC Second Round Request for Additional Information (RAI) for Revision 7 of the RH-TRU 72-B Safety Analysis Report (SAR), Revision 3 of the Remote-Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC), and Revision 3 of the RH-TRU Payload Appendices

5.0 Shielding

5-1 Clarify how source material concentration is prevented for the directly loaded RH-TRU waste canister.

In response to first round RAI 5-3, the applicant made some changes to address source concentration concerns. They added an additional limit that no more than half of the activity for the package may be loaded into a single drum. This is discussed in Section 5.3.1 of the safety analysis report (SAR) and the limit is implemented in step 11 in SAR, Section 5.5.4, in the procedure for determining maximum activity. Both the language in SAR Section 5.3.1 and step 11 state that this is only applicable when there are drums present. Source concentration is also a concern for a directly loaded RH-TRU waste canister with a concentrated source. An example of this situation is described in the SAR Section 5.5.4.1, "Acceptable Activity Examples." The first example, 5.5.4.1.1, "Concentrated ^{60}Co Source in RLC in RH-TRU 72-B," is a "…metal capsule 1 cm in diameter and 3 cm long." Under step 11 of this example it states, "NA" despite the 0.652 sum of fractions in step 10. Based on the logic from Section 5.3.1, this loading should not be allowed. The applicant should address the issues raised in first round RAI 5-3 with respect to concentration of source material when source material is directly loaded into the RH-TRU waste canister (i.e., not in drums).

This information is needed so that the staff can determine compliance with the regulations in 10 CFR 71.47 and 10 CFR 71.51(a)(2).

<u>Response</u>:

Comment incorporated. Any potentially concentrated source (i.e., one not meeting the NUREG-1608[1] definition of "distributed throughout") in a direct loaded canister will be evaluated against the requirement that the combined sum of fractions for the gamma and the neutron source term shall be less than or equal to one-half (1/2) of the total activity limit fraction per canister as established by the concentrated source model. To incorporate and clarify this requirement, appropriate changes have been made to Step 10 of SAR Section 5.5.4, to Step 10 of SAR Section 5.5.4.1.1, and to SAR Table 5.5-8.

5-2 Clarify the criterion for determining if package contents are "distributed" and justify that it is appropriate.

Step 2 of the procedure for determining acceptable activity in SAR Section 5.5.4 states:

> *"Optionally determine if the package contents are eligible to be considered a distributed source as follows:*

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[1] J. Cook, R. Lewis, E. Easton, NRC, R. Boyle, DOT, R. Pope, ORNL, *Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects*, NUREG-1608, RAMREG-003, June 1998.

> *Case A: For drums overpacked in a payload canister, the canister contents may be considered distributed if the combined sum of the sum of fractions for the gamma and the neutron source term (as described in Steps 3 through 9, below) for each drum (using the minimum density value among the drums overpacked in the payload canister) is less than or equal to one-half (1/2) of the total activity limit fraction allowed in the canister."*

The staff finds this criterion to be unclear. The text in Case A directs the user to calculate the sum of fractions using the tables and procedure for a distributed source; however, as the user has yet to determine if the source can qualify as a distributed source, this appears to be circular logic. In addition the staff does not understand how all of the drums being less than or equal to one half the total activity limit qualifies it as a distributed source as this could also be true for drums with concentrated sources. In fact the analytical assumption for the concentrated source configuration assumes the source activity is equally divided into three drums, so under this criterion the concentrated source representation within the SAR would qualify as a distributed source. The applicant needs to clarify the text in Case A of SAR Section 5.5.4 further and justify that it is appropriate for determining if a source is distributed or concentrated.

This information is needed so that the staff can determine compliance with the regulations in 10 CFR 71.47 and 10 CFR 71.51(a)(2).

<u>Response</u>:

Appropriate changes have been made to the text of Steps 2 and 3 of SAR Section 5.5.4 to clarify the criteria for determining if package contents are sufficiently distributed within an RH-TRU waste canister to justify use of results from a distributed source model when determining acceptable activity levels. Justification is different depending on whether the canister is used to overpack drums (Case A) or is direct-loaded (Case B). Justification for each case is provided in the following paragraphs.

Since both the distributed and concentrated source models distribute the total contents of a canister equally into three regions of the canister, both source models are considered to be reasonably representative of a canister containing three drums (i.e., Case A) if each drum contains one-third (1/3) of the total source term and, in the case of a distributed source model, one-third of the total mass of the contents. Further, as shown in SAR Section 5.3, variations between drum sources and masses are also acceptable as long as the contribution from any single drum to the activity limit fraction for the entire canister is limited to no more than one-half (1/2) of the total activity limit fraction allowed for the canister. Of note, with reference to SAR Figure 5.3-1, this worst-case drum limitation is applicable independent of whether results from a distributed or concentrated source model are being used to establish activity limits. Although previously not clearly stated, this has always been the intent as evidenced by the allowable activity example already provided in SAR Section 5.5.4.1.3, where the individual drum limitation in Step 11 is imposed even though the content was conservatively treated as a concentrated source in Step 2.

Relative to Case A, it is also worth noting that differences in distance attenuation effects on dose rate (especially on surface dose rate) for a source that is evenly distributed to and throughout three drums (i.e., per a distributed source model) versus it being evenly distributed to, but centered in the three drums (i.e., per a concentrated source model), are insignificant. Quantitatively, with reference to SAR Table 5.5-3 which corresponds to the only situation that isolates distance attenuation effects,[2] the maximum difference in allowable activity between distributed and concentrated source types at a given energy level is 9.8% at 0.2 MeV. This difference is considered to be acceptable as it falls within the 10% administrative margin adopted in Step 10 of SAR Section 5.5.4.

For Case A, based on a collective consideration of the above discussions and extensive historical data from previously completed RH-TRU 72-B shipments, as provided in prior RSI and RAI responses, use of either a distributed or a concentrated source model is considered reasonable and justified for the case of overpacked drums. For concentrated source modeling, it is very conservatively assumed that there is no significant shielding of the source by itself (i.e., self-shielding) or by any other waste materials in the canister. If such conservatism results in acceptable activity limit fractions when established in accordance with the above discussions, the results from the concentrated source model can be conservatively applied. The distributed source model more realistically assumes both source and non-source materials are intermixed and takes advantage of the shielding effects of the non-source material. Consistent with the final summary paragraph of the response to first-round RAI 5-2, historical data covering hundreds of RH-TRU 72B shipments supports the use of this assumption and, therefore, a distributed source model for all Case A overpacked drum configurations is reasonable and justified, and in fact is generally conservative.[3]

For the Case B direct-load canister, differences in distance attenuation effects on dose rates (in particular, on surface dose rate) for a source that is evenly distributed throughout a canister versus that same source being concentrated in the center of the canister are very significant. For this reason, the definition of "distributed throughout" from NUREG-1608 is imposed and must be satisfied in order to justify use of results from the distributed source model. Furthermore, as discussed in the above response to second-round RAI 5-1, if this definition is not met for the direct-load scenario, it is necessary to limit the combined sum of fractions for the gamma and the neutron source term to no more than one-half of the total activity limit fraction as established by the results of the concentrated source model.

Based on the above discussions, the text for Steps 2 and 3 of SAR Section 5.5.4 has been revised to read as follows:

2. Optionally determine if the package contents are eligible to utilize results obtained from a distributed source model when determining acceptable activity levels as follows:

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[2] As evidenced by the last sentence of the next-to-last paragraph of SAR Section 5.5, Table 5.5-3 presents the only case where the distributed source has an activity allowable that differs from that of the concentrated source due to distance attenuation effects only.

[3] Historical data provided with the response to first-round RAI 5-2 (i.e., Table RAI 5-2.1 therein) utilized results obtained from a distributed source model. As shown there, and as further discussed in the first-round RAI 5-2 response, "…although pre-shipment dose rate surveys, as well as intermediate surveys performed at ports of entry, etc., during transport to the WIPP site, have not identified violations of surface or 2-meter dose rate limits for any of the 230 shipments, the revised methodology would have conservatively precluded eight shipments."

Case A: For drums overpacked in a payload canister, the canister contents may always be considered sufficiently distributed to utilize results obtained from a distributed source model. This is primarily because differences in distance attenuation effects for a source that is evenly distributed to and throughout three drums (i.e., per a distributed source model) versus it being evenly distributed to, but centered in the three drums (i.e., per a concentrated source model), are insignificant. Quantitatively, with reference to SAR Table 5.5-3,[4] the maximum difference in allowable activity between distributed and concentrated source types at a given energy level is 9.8% at 0.2 MeV. This difference is considered to be acceptable as it falls within the 10% administrative margin adopted in Step 10, below.

Case B: For waste direct-loaded into a payload canister, the canister contents may only utilize the results obtained from the distributed source model if the contents of the canister meet the definition of "distributed throughout" from NUREG-1608. This is primarily because differences in distance attenuation effects for a source that is distributed throughout a canister versus it being concentrated in the center of the canister are very significant.

3. If eligible to utilize results obtained from a distributed source model, optionally determine the density (ρ, g/cc) of the contents in the payload canister (utilize the minimum density value in the case of multiple drums overpacked in a payload canister).

7.0 Operating Procedures

7-1 Revise: (a) step 6 of Section 7.4.1.2 and step 3 of Section 7.4.1.3 for pre-shipment leakage rate test; (b) steps 8.1.3.1.1.6, 8.1.3.2.5, and 8.1.3.6.6 for fabrication leakage rate tests; and (c) steps 8.2.2.1.7 and 8.2.2.4.6 for maintenance/periodic leakage rate tests.

(a) Step 6 of Section 7.4.1.2, "Determining the Test Volume and Test Time," and step 3 of Section 7.4.1.3, "Performing the Gas Pressure Rise Leakage Rate Test," state: "Isolate the vacuum pump from the test volume by closing the vacuum pump isolation valve" for pre-shipment leakage rate tests.

(b) Step 8.1.3.1.1.6 of Section 8.1.3.1.1, "Testing the IV Structure Integrity," step 8.1.3.2.5 of Section 8.1.3.2, "Testing the IV Lid Seal Integrity," and step 8.1.3.6.6 of Section 8.1.3.6, "Testing the QC Lid Seal Integrity," state: "Isolate the vacuum pump from the system" for fabrication leakage rate tests.

(c) Step 8.2.2.1.7 of Section 8.2.2.1, "Testing the IV Lid Seal Integrity," and step 8.2.2.4.6 of Section 8.2.2.4, "Testing the QC Lid Seal Integrity," state: "Isolate the vacuum pump from the system" for maintenance/periodic leakage rate tests.

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[4] Table 5.5-3 is considered here because it corresponds to the only case where, as indicated at the end of the next to the last paragraph of SAR Section 5.5, the distributed source has an activity allowable that differs from that of the concentrated source due to distance attenuation effects only.

To assure that the vacuum pump is completely isolated from the test volume/system and the testing results are reliable, the steps mentioned above need to be revised to such as "isolate the vacuum pump from the test volume/system by closing the vacuum pump isolation valve, *shutting off the vacuum pump and venting the suction line to atmosphere*." The revision/addition is used to prevent a leak in a faulty valve.

This information is necessary to determine compliance with 10 CFR 71.51(a)(1).

<u>Response</u>:

(a) The testing process is correct as described in Step 6 of SAR Section 7.4.1.2 and Step 3 of SAR Section 7.4.1.3, as presented herein. The pre-shipment leak test that implements the gas pressure rise method is performed using a specific leak test system. The use of this specific leak test system is mandated in the DOE CH Packaging Operations Manual (DOE/WIPP 02-3284), and delineates the requirements for pre-shipment leak testing. Use of any other leak test system is prohibited. The semi-automatic leak test equipment performs a "self-check" of the system prior to each pre-shipment leak test to confirm that the system (including valves and associated leak test apparatus hardware) is operating properly. During the "self-check" the system looks for any leakage that exceeds an established leak rate for the system. The "self-check" also tests for a decreasing value in the initial pressure after all isolation valves are closed. If the system records a leak rate that exceeds the system's established leak rate (or detects a decreasing value in the initial pressure), the system indicates this as a failure of the system "self-check" and does not allow the leak testing to proceed until the cause of the failed "self-check" is repaired and a successful "self-check" is performed by the leak test system. Implementation of this DOE mandated specific leak test system ensures that closure of the vacuum pump isolation valve effectively isolates the system such that the additional steps outlined in RAI 7-1(a) are not required to ensure an accurate leak test.

When operating high-vacuum systems such as the leak test system used for performing the tests delineated in SAR Sections 7.4.1.2 and 7.4.1.3, it is not desirable to "break open" the vacuum system (defined as altering the original configuration) while performing a test. Such an action may result in an unintended change in one (or more) of the three primary parameters of a pressure change leak test (pressure, volume and/or time). An unintended change in any of these parameters can lead to erroneous "false positive" or "false negative" leak test results.

(b) The testing process is correct as described in Step 8.1.3.1.1.6 of SAR Section 8.1.3.1.1, Step 8.1.3.2.5 of SAR Section 8.1.3.2, and Step 8.1.3.6.6 of SAR Section 8.1.3.6, as clarified in the following paragraphs:

(1) As described in Step 8.1.3.1.1.6 of SAR Section 8.1.3.1.1, the vacuum pump is isolated from the IV gas sampling port after achieving the required level of vacuum. In subsequent Step 8.1.3.1.1.7, the evacuated IV annulus is backfilled with helium gas to establish a positive helium pressure within. Once a positive helium pressure is established, the IV gas sampling closure bolt is completely closed and tightened per Step 8.1.3.1.1.8, and then the auxiliary vacuum pump, helium source, and the IV test port tool are completely removed from the IV gas sampling port per Step 8.1.3.1.1.9. Performing these steps along with verifying that a positive helium atmosphere has been established per Step 8.1.3.1.1.7

prior to installing the OC lid per Step 8.1.3.1.1.10, followed by the helium mass spectrometer leak detector per Step 8.1.3.1.1.11, ensures that a positive helium atmosphere is maintained, and the subsequent leak test is performed in accordance with ANSI N14.5-2014.

(2) As described in Step 8.1.3.2.5 of SAR Section 8.1.3.2, the vacuum pump is isolated from the IV backfill port after achieving the required level of vacuum. In subsequent Step 8.1.3.2.6, the evacuated IV cavity is backfilled with helium gas to establish a positive helium pressure within. Once a positive helium pressure is established, the IV backfill port closure bolt is completely closed and tightened per Step 8.1.3.2.7, and then the auxiliary vacuum pump, helium source, and helium-contaminated test port tool are completely removed from the IV backfill port per Step 8.1.3.2.8. Performing these steps along with verifying that a positive helium atmosphere has been established per Step 8.1.3.2.6 prior to installing a clean (helium-free) test port tool per Step 8.1.3.2.9, followed by the helium mass spectrometer leak detector per Step 8.1.3.2.10, ensures that a positive helium atmosphere is maintained, and the subsequent leak test is performed in accordance with ANSI N14.5-2014.

(3) As described in Step 8.1.3.6.6 of SAR Section 8.1.3.6, the vacuum pump is isolated from the OC gas sampling port after achieving the required level of vacuum. In subsequent Step 8.1.3.6.7, the evacuated OC annulus is backfilled with helium gas to establish a positive helium pressure within. Once a positive helium pressure is established, the OC gas sampling port closure bolt is completely closed and tightened per Step 8.1.3.6.8, and then the auxiliary vacuum pump, helium source, and helium-contaminated test port tool are completely removed from the OC gas sampling port per Step 8.1.3.6.9. Performing these steps along with verifying that a positive helium atmosphere has been established per Step 8.1.3.6.7 prior to installing a clean (helium-free) test port tool per Step 8.1.3.6.10, followed by the helium mass spectrometer leak detector per Step 8.1.3.6.11, ensures that a positive helium atmosphere is maintained, and the subsequent leak test is performed in accordance with ANSI N14.5-2014.

(c) The testing process is correct as described in Step 8.2.2.1.7 of SAR Section 8.2.2.1, and Step 8.2.2.4.6 of SAR Section 8.2.2.4, as explained in the following paragraphs:

(1) As described in Step 8.2.2.1.7 of SAR Section 8.2.2.1, the vacuum pump is isolated from the IV gas sampling port after achieving the required level of vacuum. In subsequent Step 8.2.2.1.8, the evacuated IV annulus is backfilled with helium gas to establish a positive helium pressure within. Once a positive helium pressure is established, the IV gas sampling port closure bolt is completely closed and tightened per Step 8.2.2.1.9, and then the auxiliary vacuum pump, helium source, and helium-contaminated test port tool are completely removed from the IV gas sampling port per Steps 8.2.2.1.10. Performing these steps along with verifying that a positive helium atmosphere has been established per Step 8.2.2.1.8 prior to installing a clean (helium-free) test port tool per Step 8.2.2.1.11, followed by the helium mass spectrometer leak detector per Step 8.2.2.1.12, ensures that a positive helium atmosphere is maintained, and the subsequent leak test is performed in accordance with ANSI N14.5-2014.

(2) As described in Step 8.2.2.4.6 of SAR Section 8.2.2.4, the vacuum pump is isolated from the OC gas sampling port after achieving the required level of vacuum. In subsequent Step 8.2.2.4.7, the evacuated OC annulus is backfilled with helium gas to establish a positive helium pressure within. Once a positive helium pressure is established, the OC gas sampling port closure bolt is completely closed and tightened per Step 8.2.2.4.8, and then the auxiliary vacuum pump, helium source, and helium-contaminated test port tool are completely removed from the OC gas sampling port per Step 8.2.2.4.9. Performing these steps along with verifying that a positive helium atmosphere has been established per Step 8.2.2.4.7 prior to installing the clean (helium-free) test port tool per Step 8.2.2.4.10, following by the helium mass spectrometer leak detector per Step 8.2.2.4.11, ensures that a positive helium atmosphere is maintained and the subsequent leak test is performed in accordance with ANSI N14.5-2014.

7-2 Provide derivation of the equation, used in step 9 of SAR 7.4.1.2, from Equation B14 in Appendix B.12 of ANSI N14.5-2014.

The applicant stated in the first round RAI response that the equation, now used in step 9 of SAR 7.4.1.2 to determine the test period of the pre-shipment leakage rate test, is a derivation from Equation B14 in Appendix B.12 of ANSI N14.5-2014.

However, in the first round RAI response, the applicant did not provide derivation of the equation. The applicant needs to provide derivation step by step in detail, including units. The derivation of the equation is needed for the staff to justify that the time frame of the leakage rate test is appropriate.

This information is necessary to determine compliance with 10 CFR 71.51(a)(1).

Response:

For pressure rise leakage tests, the measured leakage rate, L_m (std-cm^3/s), from Equation B14 in Appendix B.12 of ANSI N14.5-2014 is given as:

$$L_m = \frac{V_t T_s}{3{,}600\,HP_s}\left(\frac{P_2}{T_2} - \frac{P_1}{T_1}\right) \qquad [1]$$

where V_t is the test volume (cm^3), H is the test duration (hours), P_1 is the gas pressure at the start of the test (atmosphere absolute; torr), T_1 is the gas temperature at the start of the test (K), P_2 is the gas pressure at the end of the test (atmosphere absolute; torr), T_2 is the gas temperature at the end of the test (K), T_s is the standard temperature (25 ºC; 298K), and P_s is the standard pressure (1 atmosphere absolute = 760 torr).

For a maximum allowable preshipment leakage rate, $L_m = 1 \times 10^{-3}$ std-cm^3/s, Equation [1] becomes:

$$1 \times 10^{-3}\ \text{std-cm}^3\text{/s} = \frac{(V_t\ \text{cm}^3)(T_s\ \text{K})}{(3{,}600\ \text{s/hour})(H\ \text{hour})(P_s\ \text{torr})}\left(\frac{(P_2\ \text{torr})}{(T_2\ \text{K})} - \frac{(P_1\ \text{torr})}{(T_1\ \text{K})}\right) \qquad [2]$$

Setting the test duration, t, to a time in seconds, Equation [2] becomes:

$$1\times10^{-3}\ \text{cm}^3/\text{s} = \frac{(V_t\ \text{cm}^3)(T_s\ \text{K})}{(t\ \text{s})(P_s\ \text{torr})}\left(\frac{(P_2\ \text{torr})}{(T_2\ \text{K})} - \frac{(P_1\ \text{torr})}{(T_1\ \text{K})}\right) \qquad [3]$$

Given that the test duration is sufficiently short for the starting and ending test temperatures to be the same test temperature, T_t, Equation [3] becomes:

$$1\times10^{-3}\ \text{cm}^3/\text{s} = \frac{(V_t\ \text{cm}^3)(T_s\ \text{K})}{(t\ \text{s})(P_s\ \text{torr})}\left(\frac{(P_2\ \text{torr}) - (P_1\ \text{torr})}{(T_t\ \text{K})}\right) \qquad [4]$$

(Note that Section 7.4.1.3, *Performing the Gas Pressure Rise Leakage Rate Test*, of the SAR has been revised to ensure that the “temperature at the start of the test time” and “temperature at the end of the test time” are monitored and remain the same during the leak test’s duration.)

Setting the starting and ending test pressures to $P_2 - P_1 = \Delta P$, where ΔP is the test equipment’s sensitivity (usually 0.01 torr, or better), and rearranging the equation to be in terms of the test duration, t, Equation [4] becomes:

$$t = \frac{(V_t\ \text{cm}^3)}{(1\times10^{-3}\ \text{cm}^3/\text{s})}\left(\frac{(\Delta P\ \text{torr})}{(P_s\ \text{torr})}\right)\left(\frac{(T_s\ \text{K})}{(T_t\ \text{K})}\right) \qquad [5]$$

Temperature variations can lead to pressure variations in a pressure rise test, but temperature variations that are found to be impactive to the pressures for the pressure rise test method are typically associated with large volume and/or long duration tests. Given the test equipment’s high sensitivity and relatively small test volume, test durations will be relatively short. Furthermore, the applicable Department of Energy operating procedures used in performance of the pre-shipment leak testing that implement the pressure rise technique precludes performing the test in direct sunlight. The OC and IV lids, due to their large monolithic characteristics, are not susceptible to rapid temperature changes. This, in conjunction with the very short test time associated with the small test volume (≈50 cm^3 for the OC lid main O-ring seal test), results in negligible temperature effects. Finally, given that the effect on the test time is based on the ratio of *absolute* temperatures, a small variation in gas temperature from the standard temperature of 25 ºC (298K) will have a negligibly small effect on the calculated test time and justifies the isothermal assumption. Therefore, assuming isothermal conditions and cancelling units, Equation [5] becomes:

$$t = \frac{V_t\ \Delta P}{(1\times10^{-3})P_s} \qquad [6]$$

The required test time, t, is calculated based on recorded actual ambient and test pressure conditions. This results in a more accurate determination of the required test time based on pressure conditions at the time of testing. When the tested pressure conditions differ from the reference pressure conditions identified in Section 6.2 of ANSI N14.5-2014, it is necessary to determine a corresponding acceptance criterion to ensure that the requirements of Section 7.4.1.1, *Gas Pressure Rise Leakage Rate Test Acceptance Criteria*, of the SAR continues to be met. This is accomplished by determining an equivalent value for “L_m” given in Equation B14 from Appendix B.12 of ANSI N14.5-2014 using the methodology presented in the subsequent paragraphs.

Per Equation B.5 in Appendix B.3 of ANSI N14.5-2014, the volumetric leakage rate at the upstream conditions, L_u (cm^3/s), is:

$$L_u = (F_c + F_m)(P_u - P_d)\left(\frac{P_a}{P_u}\right) \qquad [7]$$

where, per Equation B.3 in Appendix B.3 of ANSI N14.5-2014, the coefficient of continuum flow conductance, F_c (cm^3/atm-s), is derived from Poiseuille's Law for laminar flow as:

$$F_c = \frac{(2.49 \times 10^6)D^4}{a\mu} \qquad [8]$$

and, per Equation B.4 in Appendix B.3 of ANSI N14.5-2014, the coefficient of molecular flow conductance, F_m (cm^3/atm-s), is derived from Knudsen's Law as:

$$F_m = \frac{(3.81 \times 10^3)D^3\sqrt{T/M}}{aP_a} \qquad [9]$$

Section 6.2 of ANSI N14.5-2014 specifies determining the leakage rate at reference conditions for air, where the upstream pressure, P_u = 1 atm absolute, the downstream pressure, P_d = 0.01 atm absolute, and the standard temperature, T_s = T = 25 ºC = 298K. The average pressure, P_a = ½(P_u + P_d) = 0.505 atm. From Table B-1 in Appendix B.3 of ANSI N14.5-2014, the molecular weight of air, M = 29 g/mol, and the dynamic viscosity of air, μ = 0.0185 cP.

Assuming a leakage hole length, a = 1 cm, the corresponding leakage hole diameter, D = 0.00192 cm. Applying this leakage hole diameter, D = 0.00192 cm, in Equation [8], the coefficient of continuum flow conductance, F_c (cm^3/atm-s), becomes:

$$F_c = \frac{(2.49 \times 10^6)(0.00192)^4}{(1)(0.0185)} = 1.829 \times 10^{-3} \text{ cm}^3\text{/atm-s} \qquad [10]$$

Again, applying this leakage hole diameter, D = 0.00192 cm, in Equation [9], the coefficient of molecular flow conductance, F_m (cm^3/atm-s), becomes:

$$F_m = \frac{(3.81 \times 10^3)(0.00192)^3\sqrt{298/29}}{(1)(0.505)} = 1.712 \times 10^{-4} \text{ cm}^3\text{/atm-s} \qquad [11]$$

As a check, applying this leakage hole diameter, D = 0.00192 cm, in Equation [7], the volumetric leakage rate, L_u (cm^3/s), is shown to be the requisite 1 × 10^{-3} cm^3/s:

$$L_u = (1.829 \times 10^{-3} + 1.712 \times 10^{-4})(1 - 0.01)\left(\frac{0.505}{1}\right) = 1 \times 10^{-3} \text{ cm}^3\text{/s} \qquad [12]$$

The above evaluation determined the leakage hole diameter for standard conditions. Applying that same leakage hole diameter to a different downstream pressure will allow determination of an equivalent value for "L_m" given in Equation B14 from Appendix B.12 of ANSI N14.5-2014. A change in the downstream pressure does not affect the results of Equation [10], but does affect the result of Equation [11] because the average pressure, P_a, uses the downstream pressure. Assuming an upstream pressure,

$P_{u'}$ = 1 atm, and a bounding downstream pressure, $P_{d'}$ = 0.9 atm, the average pressure, $P_{a'}$ = ½($P_{u'}$ + $P_{d'}$) = ½(1 + 0.9) = 0.95 atm.

Applying the revised average pressure, $P_{a'}$ = 0.95 atm, in Equation [9], the revised coefficient of molecular flow conductance, $F_{m'}$ (cm^3/atm-s), becomes:

$$F_{m'} = \frac{(3.81\times10^3)(0.00192)^3\sqrt{298/29}}{(1)(0.95)} = 9.099\times10^{-5}\ \text{cm}^3/\text{atm-s} \qquad [13]$$

Applying the revised coefficient of molecular flow conductance, $F_{m'}$ = 9.099 × 10^{-5} cm^3/atm-s, and average pressure, $P_{a'}$ = 0.95 atm, in Equation [7], the equivalent volumetric leakage rate, L_{eq} (cm^3/s), becomes:

$$L_{eq} = \left(1.829\times10^{-3} + 9.099\times10^{-5}\right)(1-0.9)\left(\frac{0.95}{1}\right) = 1.824\times10^{-4}\ \text{cm}^3/\text{s} \qquad [14]$$

The ratio of the equivalent volumetric leakage rate from Equation [14] to the volumetric leakage rate for standard conditions from Equation [12] is:

$$\frac{L_{eq}}{L_s} = \frac{1.824\times10^{-4}}{1\times10^{-3}} = 0.1824 \qquad [15]$$

Equation [7] may be applied to Equation [15] to determine the adjustment factor for pressure conditions that differ from standard conditions:

$$\frac{L_{eq}}{L_s} = \frac{\left(F_c + F_{m'}\right)\left(P_{u'} - P_{d'}\right)\left(\frac{P_{a'}}{P_{u'}}\right)}{\left(F_c + F_m\right)\left(P_u - P_d\right)\left(\frac{P_a}{P_u}\right)} \qquad [16]$$

The above evaluations demonstrate that molecular flow has a relatively small effect on the resulting volumetric leakage rates and, therefore, may be ignored. Equation [16] becomes:

$$\frac{F_c\left(P_{u'} - P_{d'}\right)\left(\frac{P_{a'}}{P_{u'}}\right)}{F_c\left(P_u - P_d\right)\left(\frac{P_a}{P_u}\right)} = \frac{\left(P_{u'} - P_{d'}\right)\left(\frac{P_{a'}}{P_{u'}}\right)}{\left(P_u - P_d\right)\left(\frac{P_a}{P_u}\right)} \qquad [17]$$

Given that the denominator of Equation [17] is based on the volumetric leakage rate for standard conditions, the upstream pressure, P_u = 1 atm, and the downstream pressure, P_d = 0.01 atm. Substituting P_u = 1, P_d = 0.01, and P_a = 0.505 into the denominator of Equation [17], and $P_{a'}$ = ½($P_{u'}$ + $P_{d'}$) into the numerator of Equation [17], the equation becomes:

$$\frac{\left(P_{u'} - P_{d'}\right)\left(\frac{\left(P_{u'} + P_{d'}\right)/2}{P_{u'}}\right)}{(1-0.01)\left(\frac{0.505}{1}\right)} = \frac{\left(P_{u'} - P_{d'}\right)\left(\frac{\left(P_{u'} + P_{d'}\right)}{P_{u'}}\right)}{0.9999} \qquad [18]$$

Rounding 0.9999 to unity, Equation [18] then becomes:

$$\left(P_{u'} - P_{d'}\right)\left(\frac{\left(P_{u'} + P_{d'}\right)}{P_{u'}}\right) = \frac{P_{u'}^2 - P_{d'}^2}{P_{u'}} \qquad [19]$$

For convenience and to differentiate from standard test conditions, let the nomenclature for upstream pressure, $P_{u'} = P_{atm}$, and the downstream pressure, $P_{d'} = P_{test}$. Equation [6], when using the results of Equation [19] in the place of the standard pressure, P_s, in the calculation for the test duration, t, becomes what is currently presented in Step 9 of SAR Section 7.4.1.2:

$$t = \frac{V_t\,\Delta P}{(1\times10^{-3})\left(\frac{P_{atm}^2 - P_{test}^2}{P_{atm}}\right)} = \frac{V_t\,\Delta P}{(1\times10^{-3})}\left(\frac{P_{atm}}{P_{atm}^2 - P_{test}^2}\right) \qquad [20]$$

As an example, given a test volume, V_t = 50 cm^3, a test equipment sensitivity, ΔP = 0.01 torr, an atmospheric pressure, P_{atm} = 760 torr, and a test pressure, P_{test} = 676 torr (11% reduction from ambient atmosphere), the test time, t, may be found using the following pressure values in the revised equation from Step 9 of Section 7.4.1.2, and given as Equation [20]:

$$t = \frac{(50\text{ cm}^3)(0.01\text{ torr})}{(1\times10^{-3}\text{ cm}^3/\text{s})}\left(\frac{760\text{ torr}}{(760\text{ torr})^2 - (676\text{ torr})^2}\right) = 3.2\text{ s} \qquad [21]$$

Due to the short-duration test time of approximately three seconds from Equation [21], the effect of temperature change during the test is negligible and further justifies the assumption that the system remains isothermal during the testing sequence. As noted earlier, Section 7.4.1.3, *Performing the Gas Pressure Rise Leakage Rate Test*, of the SAR has been revised to ensure that the “temperature at the start of the test time” and “temperature at the end of the test time” are monitored, and must remain the same during the test duration.

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Section(s)	**Page(s)**	**Change Description**	**Justification**
5.5.1	5.5-5	Corrected the case name for the last case in Table 5.5-3.	The identified change corrects a typo. No impact to safety basis.
5.5.4	5.5-15 through 5.5-16	Revised Steps 2, 3, and 10 in response to RAIs 5-1 and 5-2 to clarify the process and basis for determining source term activity limits both for direct-loaded waste canisters and canisters overpacking drums. Criteria are provided that identify when results from a distributed source model can be utilized.	Revisions are made to Steps 2 and 3 to clarify and justify the criteria previously provided in the first round RAI responses. For Step 10, a conservative treatment of direct-loaded waste canisters not meeting the “distributed throughout” definition of NUREG-1608 is adopted. No impact to safety basis.
5.5.4.1.1	5.5-17	Revised Step 10 and Table 5.5-8 in response to RAI 5-1 to apply the revised criteria for the total activity limit fraction for this example of a direct-loaded waste canister with a concentrated source.	The identified changes are made to implement revisions to Step 10 in Section 5.5.4. No impact to safety basis.

RH-TRAMPAC, Revision 3, October 2015			
Section(s)	**Page(s)**	**Change Description**	**Justification**
General		Revised title page and spine for revision and date.	Administrative change. No impact to safety basis.

RH-TRU Payload Appendices, Revision 3, October 2015			
Section(s)	**Page(s)**	**Change Description**	**Justification**
General		Revised title page and spine for revision and date.	Administrative change. No impact to safety basis.

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- RH-TRAMPAC, Revision 3, October 2015
- RH-TRU Payload Appendices, Revision 3, October 2015