The following draft responses are provided resultant to RH-TRU 72-B SAR Revision 5 application issues identified during the September 27, 2010, teleconference between the NRC, CBFO, and WTS. Additional information was requested to justify the current basis for a) the magnitude of lead slump of the packaging lead shield under HAC, b) the use of the projected surface area of the curved packaging surfaces for application of NCT insolation boundary conditions, and c) the methodology details for use of preshipment dose rate surveys to satisfy NCT dose rate requirements.

Lead Slump

Teleconference Summary:

NRC reviewer raised concerns as to the validity of scale model testing and applicability of the 125-B 1/4-scale test article to conclude that no lead slump would occur in the RH-TRU 72-B package under HAC conditions. Questions were also raised regarding the fact that the RH-TRU 72-B SAR utilized ORNL-NSIC-68, *Cask Designers Guide, A Guide for the Design, Fabrication, and Operation of Shipping Casks for Nuclear Application*, to analytically present a bounding calculation for 0.513 inches of lead slump.

Proposed Response:

Use of the referenced *Cask Designers Guide* (the Guide) formula for lead slump is very conservative for the RH-TRU 72-B package. This is primarily due to the slump formula being based on the drop of a bare, unprotected package, whereas the RH-TRU 72-B design incorporates relatively "soft" end impact limiters. As such, the calculated 0.513 inches of lead slump is a very conservative upper bound under HAC free-drop conditions. A more realistic evaluation based on 1/4-scale testing of the highly similar 125-B package shows lead slump to be negligible for the RH-TRU 72-B. Therefore, additional shielding analyses with 0.513 inches of lead slump are not necessary to confirm the design basis of the RH-TRU 72-B. Details of how the conclusion of no lead slump for the RH-TRU 72-B was reached are as follows:

Use of Scale Models to Establish Structural Response of Packages

One effective means of establishing the structural response of shipping packages to free-drop conditions is to utilize scale models, where a scaling factor, η, is applied to all dimensions of the full-size design, while materials used in the model are kept identical to those of the full-size design. The scale model is then dropped onto an unyielding surface from the same height as would apply to the full-size package (e.g., 30 feet for HAC free-drop conditions). For this situation, applicable scaling laws[1,2,3] are summarized in Table 1. Of particular note, deformations scale directly with the scale factor, impact accelerations scale by the inverse of the scale factor, and resultant stresses in the model are identical to those that would exist in the full-size design.

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[1] William G. Soper, *Dynamic Modeling with Similar Materials*, Colloquium on Use of Models and Scaling in Shock and Vibration, W. E. Baker (ed), ASME Winter Annual Meeting, ASME, New York, November 1963, pp. 51-56.

[2] W. G. Soper and R. C. Dove, *Similitude in Package Cushioning*, Journal of Applied Mechanics, Transactions of the ASME, Series E, Volume 20, June 1962, pp. 263–266.

[3] P. J. Donelan and A. R. Dowling, *The Use of Scale Models in Impact Testing*, The Resistance to Impact of Spent Magnox Fuel Transport Flasks, Mechanical Engineering Publications, London, 1985, pp 23–46.

Table 1 – Scaling Laws

Parameter	Scale Factor, η (Model vs. Prototype)
Applied Force, F	$F_m = (\eta_m)^2 F_p$
Area, A	$A_m = (\eta_m)^2 A_p$
Stress, σ = F/A	$\sigma_m = F_m/A_m = F_p/A_p = \sigma_p$
Mass, m	$m_m = (\eta_m)^3 m_p$
Momentum, M	$M_m = (\eta_m)^3 M_p$
Energy, E	$E_m = (\eta_m)^3 E_p$
Velocity, v	$V_m = V_p$
Acceleration, a	$a_m = (1/\eta_m) a_p$
Duration, t	$t_m = (\eta_m) t_p$
Deformation, δ	$\delta_m = (\eta_m)\ \delta_p$
Natural Frequency, *f*	$f_m = (1/\eta_m)\ f_p$

Use of 1/4-Scale Tests of the 125-B Package to Establish RH-TRU 72-B Structural Responses

Given the Table 1 scaling laws, it can be shown that the 1/4-scale 125-B cask test article, which was physically tested in support of 125-B Type B certification (USA/9200/B(M)F), is also essentially a 38.5%-scale model of the RH-TRU 72-B cask. Per Table 2, the 38.5% scale factor is determined by averaging the five primary scale factors that dictate a cask's structural response in a drop: 1) gross weight, 2) overall length, 3) impact limiter outside diameter, 4) outer cask length, and 5) outer cask outside diameter.

Table 2 – Determining the RH-TRU 72-B Composite Average Scale Factor

Physical Parameter	1/4-Scale 125-B	RH-TRU 72-B	Scale Factor
Gross Weight, lb (η^3)	2,836	45,000	39.8%
Overall Length, in (η)	69.875	187.750	37.2%
Impact Limiter Outside Diameter, in (η)	30.000	76.000	39.5%
Outer Cask Length, in (η)	51.875	141.750	36.6%
Outer Cask Outside Diameter, in (η)	16.375	41.625	39.3%
Composite Average Scale Factor ($\bar{\eta}$)	—	—	38.5%

Based on the above, it is readily concluded that the RH-TRU 72-B and 125-B overall structural responses can be directly established by use of the same scale model, where the model represents a 1/4-scale of the 125-B and a 38.5%-scale of the RH-TRU 72-B.

Lead Slump Response of the RH-TRU 72-B Package

Using the composite average scale factor for the RH-TRU 72-B, $\bar{\eta}$ = 38.5%, it is possible to compare the appropriately scaled RH-TRU 72-B cask's physical parameters of interest with respect to lead slump (i.e., outer cask outer and inner shell thicknesses, lead thickness and lead column height) with those of the 1/4-scale 125-B cask. Table 3 summarizes the comparison of these parameters and reports the percent difference (Δ%).

Table 3 – Comparison of RH-TRU 72-B and 125-B Physical Parameters That Affect Lead Slump

Physical Parameter of Importance to Lead Slump	Full-Size 72-B	38.5%-Scale 72-B	1/4-Scale 125-B	Δ%
Outer Cask Outer Shell Thickness, in	1.500	0.578	0.500	+15.6%
Outer Cask Inner Shell Thickness, in	1.000	0.385	0.250	+54.0%
Outer Cask Lead Thickness, in	1.875	0.722	0.969	-25.5%
Outer Cask Lead Column Height, in	124.250	47.836	44.750	+6.9%

As can be seen in Table 3, when it comes to parameters of importance for lead slump, the 38.5%-scale RH-TRU 72-B outer cask outer and inner steel shells are effectively thicker (by 15.6% and 54%, respectively) and the lead is effectively thinner (by 25.5%) than for the 1/4-scale 125-B, all of which will favorably reduce lead slump. The only parameter of the 38.5%-scale RH-TRU 72-B that is unfavorable when it comes to lead slump is, therefore, the lead column height. However, being only 6.9% greater than for the 1/4-scale 125-B, the increased column height will be more than offset by the significantly increased steel shell thicknesses and the reduced lead thickness. (It should also be noted that cask fabrication methods and lead installation techniques and controls for the RH-TRU 72-B are the same as used for the 125-B, and thus will not affect lead performance in a drop.) Given this comparison, it is concluded that the results for lead slump obtained from 1/4-scale testing of the 125-B can justifiably be used to bound lead slump for the RH-TRU 72-B cask.

Lead slump for the 1/4-scale 125-B test article[4] was measured at Sandia National Laboratories via X-radiography using a 10 MeV Linitron linear accelerator. Comparison of pre- and post-test X-radiographs demonstrated that no measurable lead slump, to a resolution of 0.030 inches for the defined geometry, occurred. Since no measurable lead slump was detected based on 1/4-scale 125-B testing, no measurable lead slump would occur if a 38.5%-scale test of the RH-TRU 72-B cask were to be performed. Zero deformation in a scale model translates directly

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[4] M. M. Warrant and B. J. Joseph, *Test Data Report for Quarter Scale NuPac 125-B Rail Cask Model*, GEND-INF-091, Sandia National Laboratories, Albuquerque, New Mexico, February 1987.

into zero deformation at full scale (see Table 1); thus, no lead slump will occur for a full-size RH-TRU 72-B under NCT or HAC free-drop conditions.

Justification for the Use of Scale Model Tests to Establish Lead Slump

It is readily shown that the *Cask Designers Guide* formula for lead slump scales precisely. With reference to equation 2.16 of the Guide, lead slump, ΔH, is calculated as follows:

$$\Delta H = \frac{RWH}{\pi(R^2 - r^2)(t_s\sigma_s + R\sigma_{Pb})}$$

For a given drop height, H, noting that lead weight, W, is directly proportional to the cube of the scale factor, linear dimensions (R = lead outer radius, r = lead inner radius and t_s = steel shell thickness) are directly proportional to the scale factor, and material properties (σ_s = steel flow stress and σ_{Pb} = lead flow stress) are independent of scale factor, lead slump, ΔH, is seen to be directly proportional to the scale factor. This provides initial validation that lead slump does scale.

In addition, with reference to an article by W. G. Soper, "Experiments show that, in spite of the complexity of the behavior of lead, its performance in shock tests can be accurately predicted from small-scale tests by a very simple scaling law. Thus, it is possible to select the dimensions of full-scale test blocks from trials on blocks of small and convenient size."[5]

Given the above, it is concluded that the use of scale modeling to establish lead slump is justified.

Discussion of Observed "Zero" Lead Slump vs. Cask Designers Guide Formula for Lead Slump

As noted earlier in this response, the *Cask Designers Guide* formula for lead slump is based on the drop of a bare, unprotected package where the presence of the "soft" impact limiters can significantly reduce, if not entirely eliminate, lead slump. Given the concept of a lead flow stress, as used in the slump formula, until the minimum flow stress is reached at the bottom of the lead column, no significant lead flow or slumping would actually be expected. The Guide identifies lead flow stress as generally falling between 5,000 and 10,000 psi. Thus, if 5,000 psi is not reached at the bottom of the lead column, lead slump would be expected to be minimal. Using the 1/4-scale 125-B maximum measured end drop impact acceleration of 200 *g* (see Table 2.10.6.6-5 of the 125-B SAR, which presents the corresponding 50 *g* impact for full scale), lead column height of 44.75 inches, and the density of lead of 0.41 pounds per cubic inch, the stress at the bottom of the lead column is as follows:

$$\sigma = \rho(g)(h) = 0.41(200)(44.75) = 3{,}670 \text{ psi}$$

[5] W. G. Soper, *Dynamic Similitude for Lead*, Journal of Applied Mechanics, Brief Notes, March 1961 Transactions of the ASME, pages 132–133.

Since this is less than the minimum flow stress of 5,000 psi, no slump would actually be expected, which is consistent with that observed in the 1/4-scale 125-B testing.

Thermal Insolation

Teleconference Summary:

NRC reviewer questioned the level of insolation applied under the NCT thermal analyses for the curved RH-TRU 72-B package surfaces when shipped in a horizontal orientation. Instead of applying the 10 CFR §71.71(c)(1) specified 12-hour averaged insolation boundary condition of 400 W/m^2 to the curved surfaces of the package, the thermal analysis used a 12-hour averaged insolation boundary condition of $800/2/\pi = 127.32$ W/m^2 on the horizontal package cylindrical surfaces within a steady-state model. Concerns were raised as to whether this approach provided peak package temperatures consistent with the regulatory requirements stated in 10 CFR §71.71(c)(1).

Proposed Response:

At the time of the original RH-TRU 72-B application submission and consistent with the then recently licensed 125-B Cask, the technique of using the projected area of the upward facing curved surfaces instead of the full area to calculate the total incident insolation on the curved surfaces for a 360° model was an accepted procedure within a steady-state modeling approach. This approach simply combined the effects of a transient "12 hours on/12 hours off" solar incidence with credit for self-shading of packaging surfaces. It is noted that Sections 654.5 and 654.7 of IAEA TS-G-1.1, *Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material*, discuss the use of projected area and taking credit for self-shading when applying the regulatory total insolation boundary conditions.

Instead of explicitly modeling the transient solar incidence and the 3D self-shading, the current SAR modeling combined these effects within the 2D NCT steady-state models through the use of the projected area of curved packaging surfaces. The modeling arrived at the incident solar loading for the horizontal curved surfaces by first adjusting the flat surface insolation value (800 W/m^2) by a factor of 0.5 (i.e., to 400 W/m^2) to yield the same total insolation over a 24-hour period for a steady-state evaluation rather than modeling the 12-hour horizontal flat surface insolation value (800 W/m^2) in a transient "12 hours on/12 hours off" manner as specified by Section 654.2 of IAEA TS-G-1.1. The resulting 400 W/m^2 value was then further reduced by a factor of π to 127.32 W/m^2 to account for the average insolation over a 360° segment of a horizontal cylinder, taking credit for reduced incidence and self-shading (i.e., using the horizontal projection of area as allowed by Section 654.5 of IAEA TS-G-1.1).

Given the above, it is the applicant's position that the results of the current RH-TRU 72-B thermal analyses for the 50-watt payload cases provide valid maximum temperatures for items well removed from the outermost surfaces of the package such as the waste, the shield insert, and the canister shell, and reasonable maximum temperatures for the packaging structural components. However, the current SAR analyses do somewhat under predict the maximum outermost packaging component temperatures.

To confirm the validity of canister, shield insert, and waste centerline temperatures and to quantify any potentially non-conservative effects of using the current steady-state SAR thermal analysis approach, a number of transient sensitivity analyses were performed utilizing modeling assumptions as summarized in Table 4 and further discussed below.

Table 4 – Thermal Sensitivity Analysis Runs

Case	Type	Insolation	Self-shading
NS15 NCT Sensitivity A	2D Transient	400 W/m^2 applied to <u>all</u> curved surfaces; 12 hours on/12 hours off	No
NS15 NCT Sensitivity B	3D Transient	400 W/m^2 applied to <u>upper half</u> of curved surfaces; 12 hours on/12 hours off	Yes
NS30 HAC Sensitivity C	2D Transient	No insolation prior to and during fire event with 400 W/m^2 applied to <u>all</u> curved surfaces after the fire; 12 hours on/12 hours off	No

<u>NS15 NCT Sensitivity A</u>

A "12 hours on/12 hours off" NCT sensitivity analysis was performed for the RH-TRU 72-B with the NS15 payload canister. The NS15 case was chosen since it has the highest waste centerline, shield insert (as applicable), and canister shell temperatures for all 50-watt cases with all other packaging component temperatures within 2 °F of the current NS15 SAR analysis. The transient sensitivity analysis directly applies a 400 W/m^2 insolation boundary condition on all external curved surfaces of the package using a 12-hour on and 12-hour off cycle and makes no adjustment and/or takes no credit for self-shading of the package external surfaces. As shown in Table 5, the sensitivity analysis predicts waste centerline, shield insert, and canister shell temperatures that are higher by 9 °F or less than the current SAR NS15 analysis, which is expected when ignoring the effects of self-shading. Similarly, packaging structural component temperatures are higher by 14 °F or less than the temperatures predicted by the current SAR NS15 analysis. However, all component temperatures remain well within the NCT allowable temperature limits and, even with solar loads applied, the maximum external surface temperatures remain within the regulatory limits for exclusive-use shipments. Additionally, the NS15 shield insert maximum temperature remains less than its 150 °F design basis and all sensitivity analysis temperatures are below the current SAR 300-watt metallic waste case temperatures that are utilized to establish the bounding values for all hot temperature structural component evaluations. Note: Hot foam structural evaluations are performed using a bulk average foam temperature of 140 °F, which remains above the bulk average foam temperature of 133 °F established by the Sensitivity A analysis.

NS15 NCT Sensitivity B

To demonstrate reasonable consistency between the current modeling approach and the requirements stated in 10 CFR §71.71(c)(1), the transient, "12 hours on/12 hours off" NCT sensitivity analysis described above was expanded by separating the models of the cask and payload into two 180° model segments, with one 180° model segment representing the half of the package facing upwards and the other 180° model segment representing the half of the package facing downward. This alternative transient sensitivity analysis directly applies a 400 W/m^2 insolation boundary condition on the external curved surfaces for the upper 180° model segment of the package using a 12-hour on and 12-hour off cycle, and applies a zero insolation load on the lower 180° model segment of the package. As shown in Table 6, the alternative sensitivity analysis predicts waste centerline, shield insert, canister shell, forging, O-ring seal, and lid temperatures that are below the temperatures predicted by the current SAR NS15 analysis. The predicted temperatures for the remaining packaging structural components (i.e., shells and lead shield) are higher by 6 °F or less than the temperatures predicted by the current SAR NS15 analysis. Again, all component temperatures remain well within the NCT allowable temperature limits, all maximum external surface temperatures remain within the regulatory limits for exclusive-use shipments, and all temperatures utilized in hot temperature structural evaluations are below the current SAR 300-watt metallic waste case temperatures.

As demonstrated by the results summarized in Table 5 and Table 6, the current SAR NCT analyses for all 50-watt cases are sufficient for ensuring the NCT safety basis of the package.

NS30 HAC Sensitivity C

The modeling methodology used for insolation has no significant impact on the peak HAC temperatures since, per the regulations, insolation may be ignored prior to and during the HAC fire event. As such, the current SAR analyses accurately predict the peak payload and packaging component temperatures over the entire fire event and the impact of the insolation modeling approach is seen only for the post-fire steady-state HAC condition. Although the post-fire temperatures have no structural implications since the condition does not have an associated structural design criterion, the NS30 case was chosen for performance of an additional sensitivity analysis to quantify the effects. The transient sensitivity analysis directly applies a 400 W/m^2 insolation boundary condition on all external curved surfaces of the package using a 12-hour on and 12-hour off cycle and makes no adjustment and/or takes no credit for self-shading of the package external surfaces. As shown in Table 7, all component temperatures are within the HAC temperature allowable and the magnitude of temperature change seen between the sensitivity analysis and the current SAR evaluation is similar to that seen for the NCT sensitivity case presented for the NS15 in Table 5. As such, it is fully expected that a 3D transient HAC model that credited self-shading would predict insignificant temperature changes similar to those seen for the NCT sensitivity case presented for the NS15 in Table 6.

As discussed above and demonstrated by the results summarized in Table 7, the current SAR HAC analyses for all 50-watt cases are sufficient for ensuring the HAC safety basis of the package.

Resolution

Due to the fact that the 300-watt case temperature results would similarly be somewhat increased by the application of more conservative 12-hour averaged insolation boundary conditions and no credit for self-shading, it is conservatively proposed that the RH-TRAMPAC Section 5.0 be revised to disallow shipments under the 300-watt case. This would ensure that all current structural evaluations are bounded for shipments made under the 50-watt cases by the existing SAR structural evaluation bounding material reference temperatures.

The revision of Section 5.0 of the RH-TRAMPAC is proposed to explicitly state the following: "The design decay heat limit for the RH-TRU 72-B is 50 watts per canister."

Table 5 – NS15 NCT Sensitivity A Thermal Analysis Comparison to Current SAR

Location/Component	Maximum Temperature (ºF)					
	NS15		NS30	50W	300W	Allowable
	Sensitivity A	Current SAR	Current SAR	Current SAR	Current SAR	
Waste Centerline	250	247	234	217	181	①
NS_ _ Shield Insert	149 (142 Avg.)	141	137	N/A	N/A	256
Canister Shell	142	133	132	132	167	2,600②
IV Shell	140	128	128	127	150	800③
IV Void Space Bulk Avg	140	127	127	-	-	N/A
OC Inner Shell	140	126	126	126	143	800③
OC Lead Shield	140	126	126	126	143	620
OC Outer Shell	140	126	126	126	143	800③
OC Thermal Shield	145	125	125	125	142	185④
OC Upper Ring Forging	134	125	125	126	137	800③
IV O-Ring Seal	134	125	126	126	140	225
OC O-Ring Seal	133	125	125	126	137	225
IV Lid	134	125	126	127	141	800③
OC Lid	134	125	125	126	137	800③
Impact Limiter Foam	150 (133 Avg.)	132 (127 Avg.)	132 (127 Avg.)	132	143	300
Impact Limiter Shell	158	133	133	133	142	185④

Notes:

① The temperature limit for the waste material is discussed in Appendix 4.6 of the *RH-TRU Payload Appendices*.

② Temperature limit based on the minimum melting temperature for stainless steel or carbon steel.

③ Temperature limit based on the ASME B&PV Code.

④ Temperature limit based on the maximum accessible surface temperature for exclusive-use shipments per 10 CFR 71.43(g).

Table 6 – NS15 NCT Sensitivity B Thermal Analysis Comparison to Current SAR

	Maximum Temperature (ºF)					
	NS15		NS30	50W	300W	Allowable
Location/Component	Sensitivity B	Current SAR	Current SAR	Current SAR	Current SAR	
Waste Centerline	238	247	234	217	181	①
NS_ _ Shield Insert	136 (128 Avg.)	141	137	N/A	N/A	256
Canister Shell	130	133	132	132	167	2,600②
IV Shell	130	128	128	127	150	800③
IV Void Space Bulk Avg	131	127	127	-	-	N/A
OC Inner Shell	132	126	126	126	143	800③
OC Lead Shield	132	126	126	126	143	620
OC Outer Shell	132	126	126	126	143	800③
OC Thermal Shield	139	125	125	125	142	185④
OC Upper Ring Forging	123	125	125	126	137	800③
IV O-Ring Seal	122	125	126	126	140	225
OC O-Ring Seal	122	125	125	126	137	225
IV Lid	123	125	126	127	141	800③
OC Lid	123	125	125	126	137	800③
Impact Limiter Foam	149 (128 Avg.)	132 (127 Avg.)	132 (127 Avg.)	132	143	300
Impact Limiter Shell	158	133	133	133	142	185④

Notes:

① The temperature limit for the waste material is discussed in Appendix 4.6 of the *RH-TRU Payload Appendices*.

② Temperature limit based on the minimum melting temperature for stainless steel or carbon steel.

③ Temperature limit based on the ASME B&PV Code.

④ Temperature limit based on the maximum accessible surface temperature for exclusive-use shipments per 10 CFR 71.43(g).

Table 7 – NS30 HAC Sensitivity C Thermal Analysis Comparison to Current SAR

	Maximum Post-Fire Steady-State Temperature (ºF)			
	NS30		NS15	Allowable
Location/Component	Sensitivity C	Current SAR	Current SAR	
Waste Centerline	237	232	244	①
NS_ _ Shield Insert	143 (139 Avg.)	135	138	256
Canister Shell	140	129	130	2,600②
IV Shell	139	125	125	800③
IV Void Space Bulk Avg	139	124	124	N/A
OC Inner Shell	139	123	123	800③
OC Lead Shield	139	123	123	620
OC Outer Shell	139	123	123	800③
OC Thermal Shield	145	123	123	2,600②
OC Upper Ring Forging	133	123	123	800③
IV O-Ring Seal	132	123	123	360/225
OC O-Ring Seal	131	123	123	360/225
IV Lid	133	123	123	800③
OC Lid	132	123	123	800③
Impact Limiter Foam	N/A	N/A	N/A	N/A④
Impact Limiter Shell	156	131	131	2,600②

Notes:

① The temperature limit for the waste material is discussed in Appendix 4.6 of the *RH-TRU Payload Appendices*.

② Temperature limit based on the minimum melting temperature for stainless steel or carbon steel.

③ Temperature limit based on the ASME B&PV Code.

④ No temperature limit exists for the impact limiter foam under HAC since failure of the foam via thermal decomposition provides a principle thermal protection mechanism under elevated temperature conditions. Foam at temperatures greater than 670 ºF is assumed to be charred.[6]

[6] Williamson, C., and Iams, Z., *Thermal Assault and Polyurethane Foam - Evaluating Protective Mechanisms*, General Plastics Manufacturing Company, Tacoma, WA, presented at PATRAM International Symposium, Berlin, Germany, 2004.

Dose Rate

Teleconference Summary:

NRC reviewer asked for specific detail as to the comprehensiveness of the existing NCT dose rate surveys to include the survey equipment, survey methodology, and uncertainty in the measurements.

Proposed Response:

It is proposed that Section 3.2.2 of the RH-TRAMPAC be revised as follows to describe the survey methodology implemented for the demonstration of compliance with the radiation dose rate requirements for normal conditions of transport:

> "Radiation dose rates shall be obtained through the implementation of site-specific procedures that direct the measurement of gamma and neutron dose rates for the package at the surface and at 2 meters from the surface. Contact dose rate surveys shall be performed on all exposed external surfaces (full-length circumferential and ends) of the package and the highest value recorded. Two-meter dose rate surveys from the outer lateral surfaces of the package (excluding the top and underside of the package) shall be performed and the highest value recorded. Radiation monitoring instruments shall be maintained and calibrated at least annually in accordance with national standards (e.g., American National Standards Institute [ANSI]-N323A)."

Examples of devices used to perform gamma dose rate measurements include the Eberline RO-20 ion chamber, the Bicron Micro rem survey meter, and the Johnson Extender Model 2000W. Examples of devices used to perform neutron dose rate measurements include the Eberline E600 radiation detector and Eberline ASP-1/NRD survey meter.

Site practices associated with performance of the radiation dose rate surveys for the RH-TRU 72-B are the same as those used to perform radiological surveys for other radioactive U.S. Department of Transportation shipments in accordance with 49 CFR 173 and applicable national standards. For example, ANSI-N323A, *Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments*, provides comprehensive guidance for implementing a portable monitoring instrument calibration program.

Instrument calibrations are normally performed before first use, following any major maintenance or modifications that could affect calibration, and after any failure of a source response test. Daily response checks are performed, for example, to verify compliance with the expiration date on the calibration sticker, to check the physical condition of the instrument, including detector window integrity, to verify the battery voltage is within the manufacturer's specification, and to check the instrument's background reading. The check source when placed in a reproducible position near the detector is required to be within the range specified for a given measurement device (e.g., +/-20% of the reference value).