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Washington TRU Solutions LLC

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February 16, 2011

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 REQUEST FOR SUPPLEMENTAL INFORMATION REGARDING APPLICATION FOR REVISION 5 OF THE RH-TRU 72-B SHIPPING PACKAGE, DOCKET NO. 71-9212, TAC NO. L24419

References:
1. Letter from T. E. Sellmer to Document Control Desk, dated February 12, 2010, subject: Revision 5 of the RH-TRU 72-B Shipping Package Application, Docket No. 71-9212
2. Letter from T. E. Sellmer to Document Control Desk, dated April 19, 2010, subject: Supplemental Information Regarding Application for Revision 5 of the RH-TRU 72-B Shipping Package Application, Docket No. 71-9212
3. Letter from S. I. Soto (NRC) to T.E. Sellmer, dated July 15, 2010, subject: Request for Additional Information for Review of the Model No. RH-TRU 72-B Shipping Package
4. Letter from T. E. Sellmer to Document Control Desk, dated August 30, 2010, subject: Response to Request for Additional Information Regarding Application for Revision 5 of the RH-TRU 72-B Shipping Package, Docket No. 71-9212, TAC No. L24419
5. Letter from R. Johnson to T.E. Sellmer, dated November 22, 2010, subject: Application for Revision to Certificate of Compliance No. 9212 for the Model No. RH-TRU 72-B Packaging, Docket No. 71-9212 – Supplemental Information Needed
6. Memorandum from C. Staab to D. Weaver, dated December 23, 2010, subject: Summary of December 9, 2010, Meeting with the Department of Energy and Washington TRU Solutions

Dear Sir or Madam:

Washington TRU Solutions LLC (WTS), on behalf of the U.S. Department of Energy (DOE), hereby submits an amendment to Revision 5 of the application for a Certificate of Compliance (CoC) for the RH-TRU 72-B Packaging, U.S. Nuclear Regulatory Commission (NRC) Docket No. 71-9212 (Reference 1). The amendment is in response to the Request for Supplemental Information (RSI) (Reference 5) as clarified at the 12/9/10 meeting between the NRC, WTS, and DOE (Reference 6).

NMSS01

The amendment consists of the following documents:

- RH-TRU 72-B Safety Analysis Report (SAR), Revision 5
- Remote-Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC), Revision 1
- RH-TRU Payload Appendices, Revision 1.

This letter includes the following attachments:

- Attachment A – Responses to RSI
- Attachment B – Summary of Revisions
- Attachment C – Revised Documents
- Attachment D – Supplementary References

Individual responses to the RSI are provided in Attachment A. All technical changes necessary to specifically address the RSI are indicated by right-bars in the margin of the documents ("|") and are summarized in Attachment B. Right-bars in the margin of the documents ("|") indicating technical changes made to the documents in the original and subsequent submittals of this application have been retained.

To facilitate implementation, it is requested that the current package CoC be valid for use one year from the date of issuance of the revised CoC.

If you have any questions regarding this submittal, please contact Mr. B. A. Day of my staff at (575) 234-7414.

Sincerely,

Todd Sell

T. E. Sellmer, Manager
Packaging Integration

TES:clm

Enclosures

cc: J.R. Stroble (CBFO)
C. Staab (NRC)

Responses to NRC Request for Supplemental Information (RSI) on Revision 5 of the RH-TRU 72-B Cask Safety Analysis Report (SAR), Revision 1 of the Remote-Handled Transuranic Waste Authorized Methods for Payload Control (RH-TRAMPAC), and Revision 1 of the RH-TRU Payload Appendices

Thermal

RSI-1: Update the NS15 and NS30 thermal analyses presented in the Safety Analysis Report (SAR) to reflect the recently provided NCT and HAC thermal analyses.

The response from the Request for Additional Information (RAI) teleconference (9/27/10) provided three shielded NS15/NS30 thermal analyses that do not use bulk spatial and temporal-averaged insolation boundary conditions. As a result of the analyses, the applicant mentions that the RH-TRU 72-B SAR design decay heat limit will be changed from 300 W to 50 W per canister. In addition, the new modeling methodology and the higher temperatures of the components found as a result of the updated NS15 and NS30 analyses should be incorporated in the appropriate sections of the SAR, such as Appendix 5.1 of the RH-TRU Payload Appendices.

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

Response:

Comment incorporated. New sensitivity analyses that incorporate insolation boundary conditions that take no credit for self shading of the package under a 12-hour on and 12-hour off transient evaluation were performed and incorporated into a revised thermal calculation package for the NS15 and NS30 canisters (see Attachment D). Correspondingly, Appendix 5.1 of the RH-TRU Payload Appendices and Section 3.4.2 and 3.5.6 of the RH-TRU 72-B SAR were revised to incorporate the sensitivity analyses results.

The revised sensitivity analyses demonstrate that a transient application of insolation boundary conditions without credit for self shading result in packaging component and payload canister component temperatures that remain within their allowable temperature limits and associated structural evaluations remain valid for 50 W payloads. 300 W payload analyses are retained in the SAR, but shipment of 300 W payloads is not authorized per revisions to Section 5.0 of the RH-TRAMPAC that prohibit any payloads greater than 50 W.

Shielding

RSI-1: Provide an analysis of the effect of lead slump on the HAC dose rates.

The applicant provided some discussion in response to the shielding RAI #1 on this subject, indicating that slumping will not occur. However, staff does not find the basis for this conclusion to be applicable. Thus, a shielding analysis should be provided for lead slump, as predicted using the method in the "Cask Designers Guide" document. The analysis should also account for any void between the top of the lead shielding and the outer cask top flange resulting from package fabrication. The analysis should account for the assumed 2% of the source escaping the canister's neutron shield insert and lodging as close to the slump area as allowed by the package HAC configuration. The remainder of the source should likewise be positioned as near as possible to the slump zone while remaining within the canister's neutron shield insert. Using analyses for a few radionuclide contents (e.g., Co-60), the applicant may demonstrate that the dose rates for the puncture HAC configuration bound those for the lead slump configuration.

This information is needed to confirm compliance with 10 CFR 71.51 and 71.73.

Response:

Lead slump for the RH-TRU 72-B package is negligible and further shielding analyses are not, therefore, necessary. As demonstrated below, the lack of slump is directly attributable to the presence of relatively "soft" impact limiters at the ends of the RH-TRU 72-B package. Because of these "soft" limiters, the accelerations associated with free end drops of the package are insufficient for the stress in the lead to reach its minimum flow stress magnitude as established in the Cask Designers Guide.[1] As such, prior application of the Cask Designers Guide formula to establish upper bounds for lead slump of 0.008 inches (SAR Section 2.6.7.1(9)) for Normal Conditions of Transport (NCT) and 0.513 inches (SAR Section 2.7.1.1(9)) for Hypothetical Accident Conditions (HAC) was overly conservative. The prior revisions of the RH-TRU 72-B SAR simply stated that the calculated upper bounds for slump were conservative and, with reference to scale testing of the similar 125-B cask, that no lead slump would actually occur. However, within the RH-TRU 72-B SAR, no specific basis was provided for why use of the Cask Designers Guide formula was overly conservative for the case of the RH-TRU 72-B and limited justification was provided to defend use of the 125-B testing to establish that no slump would actually occur for the RH-TRU 72-B. The remainder of this RSI response provides those previously missing bases and justifications. Changes have been made to the RH-TRU 72-B SAR to better and more consistently identify and justify that there will be no lead slump for the RH-TRU 72-B package.

With reference to RH-TRU 72-B SAR Section 8.3.1, it is also noted that lead installation techniques and procedures are such that any axial gaps at the end of the lead column as a result of fabrication processes will be negligible. Per RH-TRU 72-B SAR Section 8.1.5, post-fabrication gamma scans are utilized to demonstrate the lack of such axial gaps as well as generally ensure a void-free lead fill. Key aspects of the lead installation and gamma scanning activities are summarized at the end of the "Lead Slump Response of the RH-TRU 72-B Package" portion of this RSI response.

Given the information provided by this RSI response, which demonstrates there will be no lead slump, the side puncture location remains the worst case for the HAC shielding analysis as previously claimed in the RH-TRU 72-B SAR. Notably, the NS15 and NS30 shielding analyses account for escape of 2% of the source from the canister insert and for the entire source relocating to a worst case position relative to the puncture damage.

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[1] L. B. Shappert, *Cask Designers Guide, A Guide for the Design, Fabrication, and Operation of Shipping Casks for Nuclear Applications,* ORNL-NSIC-68, Oak Ridge National Laboratory, Oak Ridge, Tennessee, February 1970.

Conservatism of Cask Designers Guide Formula for Lead Slump

Use of the Cask Designers 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. Given the concept of a lead flow stress, as used in the lead slump formula, unless and 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 Cask Designers 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, no lead slump would be expected to occur.

For example, using the maximum end drop impact acceleration, g = 89.7, applicable to the RH-TRU 72-B under HAC cold conditions as available from Table 2.10.3-10 of the RH-TRU 72-B SAR, maximum stress at the bottom end of the lead column, σ, can be readily determined from the following formula where ρ = density of lead = 0.41 lb/in^3 (SAR Table 2.3-2 note 6) and h = lead column height = 124.25 inches per the SAR drawings.

$$\sigma = \rho(g)(h) = 0.41(89.7)(124.25) = 4{,}570\ \text{psi}$$

Temperature Effects on Flow Stress, Impact Accelerations and Lead Slump

Although it is not overtly stated in the Cask Designers Guide, it is reasonably assumed that the 5,000 psi minimum lead flow stress value corresponds to room temperature, or 70 °F. It is further assumed that flow stress magnitude will vary with temperature in a manner similar to how lead compressive strength varies with temperature. With reference to RH-TRU 72-B SAR Figure 2.3-6, by linearly extrapolating and interpolating the 100°F and 175 °F curves at 4% strain, it can be shown that at -20 °F, lead strength is approximately 27% greater than at 70 °F and at 160 °F (upper bound NCT temperature for lead per RH-TRU 72-B SAR Section 2.6.1.1), lead strength is approximately 27% less than at 70 °F (see Table 1). Applying these adjustments to the room temperature lead flow stress of 5,000 psi results in flow stresses of 6,350 psi at -20 °F and 3,650 psi at 160 °F. Table 2 establishes NCT and HAC end drop lead stresses at these minimum and maximum temperature extremes. As shown, for all cases, lead stresses remain well below the temperature-adjusted flow stress magnitudes, with the smallest margin of safety being for the HAC, -20 °F condition. Table 2 establishes the primary basis for why lead slump will not occur for the RH-TRU 72-B package.

Table 1 – RH-TRU 72-B SAR Figure 2.3-6 Extrapolation/Interpolation Values

Temperature (°F)	Compressive Stress (psi)	Interpolated/Extrapolated Compressive Stress (psi)	Change (%)
100	1,413	N/A	N/A
175	1,060	N/A	N/A
160	N/A	1,131	-27
70	N/A	1,554	0
-20	N/A	1,978	+27

Table 2 – Temperature-Corrected Margin of Safety Against Lead Slump

Drop Type	Lead Temperature (°F)	Impact Acceleration, g (per RH-TRU 72-B SAR Table 2.10.3-10)	Lead Stress, $\sigma = \rho g h$ (psi)	Minimum Flow Stress (psi)	Margin of Safety
NCT	-20	42.5	2,165	6,350	+1.93
NCT	160①	28.6	1,457	3,650	+1.51
HAC	-20	89.7	4,570	6,350	+0.39
HAC	160①	51.1	2,603	3,650	+0.40

Note:

① The lead is evaluated at a temperature of 160 °F which corresponds to a polyurethane foam temperature of 140 °F, as reported in the RH-TRU 72-B SAR Table 2.10.3-10.

As further validation of the above conclusion of no lead slump, consideration can be given to the results obtained from drop testing of a ¼-scale model of the 125-B cask at cold, -20 °F conditions. As shown below, use of scale model testing to establish lead slump is justifiable and observations of no slump from the 125-B cask testing are directly applicable to the RH-TRU 72-B package.

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[2,3,4] are

[2] 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.

summarized in Table 3. 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.

Table 3 – 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, $\sigma = F/A$	$\sigma_m = F_m/A_m = F_p/A_p = \sigma_p$
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 Cask to Establish RH-TRU 72-B Structural Responses

Given the Table 3 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 package. Per Table 4, 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.

[3] 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.

[4] 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 4 – 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 ( )	—	—	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.

<u>Lead Slump Response of the RH-TRU 72-B Package</u>

Using the composite average scale factor for the RH-TRU 72-B, = 38.5%, it is possible to compare the appropriately scaled RH-TRU 72-B package'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 5 summarizes the comparison of these parameters and reports the percent difference (Δ%).

Table 5 – 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 5, 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 the lead column height. However, being only 6.9% greater than 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. 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 package.

Lead slump for the 1/4-scale 125-B test article[5] was measured at Sandia National Laboratories via X-radiography using a 10 MeV Linitron linear accelerator. Comparison of pre- and post-test X-radiographs (Sections 3.3 and 12.10 of the Sandia report, respectively) demonstrated that no measurable lead slump occurred. As stated in Section 14.8.2 of the Sandia report, "The x-radiography examination of the outer vessel showed no observable changes in the location of the lead shielding, except in the puncture impact area". 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 package were to be performed. Zero deformation in a scale model translates directly into zero deformation at full-scale (see Table 3), thus no lead slump will occur for a full size RH-TRU 72-B under NCT or HAC free drop conditions.

It should also be noted that cask fabrication methods and lead installation techniques and controls for the RH-TRU 72-B, as described in the RH-TRU 72-B SAR, are the same as used for the 125-B, and, thus, will not affect lead performance in a drop. Those controls are briefly summarized as follows.

In accordance with the RH-TRU 72-B SAR Section 8.3.1, lead installation set-up, preheat, pouring and cooldown procedures are carefully prescribed and controlled. The package is inverted for lead fill with the open end of the outer cask facing downward. After controlled preheating, molten lead is introduced at the lower end and the lead cavity filled. The package is then cooled from the lower end up, with additional molten lead being added at the upper end as the lower end lead solidifies and shrinks. The result is a complete fill of the lead cavity and minimal axial gaps at either end of the lead column following cooldown. To confirm a void-free lead fill and the absence of any significant gaps/shine paths at the ends of the lead column, gamma scan acceptance testing per RH-TRU 72-B SAR Section 8.1.5 is required. Starting at the bottom inside of the outer cask, an iridium-192 or cobalt-60 source is raised in increments, while measuring and recording dose rates on the entire exterior surface of the package. All twelve RH-TRU 72-Bs fabricated to date and now in service have successfully passed the required gamma scans.

Additional 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 Cask Designers 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 =

[5] 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.

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."[6]

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

Summary of RH-TRU 72-B SAR Changes

Changes have been made to the RH-TRU 72-B SAR to better and more consistently identify and justify that there will be no lead slump for the RH-TRU 72-B package. These changes focus on the fact that lead stresses under free end drop conditions remain below their temperature adjusted flow stress magnitudes. Most significantly, RH-TRU 72-B SAR Sections 2.6.7.1(9) for NCT and 2.7.1.1(9) for HAC have been revised to replace the prior, overly conservative lead slump calculations with detailed calculations demonstrating that lead flow stress magnitudes are not reached and therefore no lead slump will occur. In those same RH-TRU 72-B SAR sections, the existing reference to 125-B testing is retained, but reworded to indicate that such testing serves to further validate the flow stress based conclusion that there will be no lead slump for the RH-TRU 72-B package. However, since the 125-B testing is being used as a validation of the no slump conclusion from the application of the Cask Designers Guide formula, the detailed comparisons of RH-TRU 72-B to 125-B lead slump responses, as presented above, are not being incorporated into the RH-TRU 72-B SAR at this time.

For consistency with revised RH-TRU 72-B SAR Sections 2.6.7.1(9) and 2.7.1.1(9), a few other changes have also been made to the RH-TRU 72-B SAR. A full listing of the RH-TRU 72-B SAR changes is provided in Attachment B.

Shielding

RSI-2: Provide sufficient detail regarding the pre-shipment dose rate measurements and results of previous measurements to demonstrate the acceptability of this method, for the current amendment only, for use to meet the requirements of 10 CFR 71.35(a) and 71.47.

Per 10 CFR 71.35(a), an application for a Part 71 Certificate of Compliance (CoC) must include a demonstration that the package containing the proposed contents at the proposed quantity limits satisfies, among other things, the requirements in 10 CFR

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

71.47. The current amendment application seeks to use pre-shipment dose rate measurements to meet this requirement. While pre-shipment measurements are normally not accepted as fulfilling this requirement, they may be found acceptable in the current case for only the current amendment only with certain additional conditions and the provision of further information to justify that the package's compliance with 10 CFR 71.47 will be ensured for the proposed contents at the proposed quantities. Package operations descriptions in Chapter 7, "Package Operations," of the SAR should also be modified to incorporate (by reference is acceptable) these conditions.

The applicant has provided some information regarding performance of pre-shipment measurements; however, this information does not completely satisfy the RAI. In addition to the measurement descriptions currently provided by the applicant, descriptions should be included that explicitly state that the neutron and gamma dose rate measurements are performed on the package surface and at 2 meters from the package surface. This ensures clarity as to which surfaces are being referenced. A statement should be added that clearly states that both gamma and neutron dose rate measurements are always performed and that they are done with appropriate instruments of appropriate/adequate dose rate ranges. The descriptions should also include that a grid is established for the entire package surface with squares no larger than a few inches (4 inches for example) on a side, with measurements taken at every grid location. Similarly, a description of how the 2-meter dose rate measurements are/will be comprehensive is also needed.

To justify the use of measurements in this case, the applicant should provide the results of representative cases from the measurements performed on previous shipments under the current CoC. The information should demonstrate the comprehensive nature of the measurements. The applicant should provide the maximum measured surface and 2-meter dose rates for the package radial side and axial end surfaces, the contents descriptions (including Curie quantity(ies) and the form of the contents) for each result case included in the information. Results should be provided that cover the range of contents forms that are (to be) shipped in the RH-TRU 72-B package. Also, if the cases are not for the maximum allowed Curie quantity(ies) of the radionuclides present in the given cases, the applicant should also provide an evaluation of the dose rates for a package containing the maximum allowed quantities. A conservative approach to this task would be to take the highest dose rate contributor (both for gamma sources and neutron sources) present in the particular case and scale up its quantity to the maximum allowed by the CoC. Then, because the NS15 and NS30 differ from the current waste canisters, justification should be provided as to why the supplied results are sufficient to demonstrate that the higher quantities in the NS15 and NS30 canisters will meet 71.47 limits. The justification should be quantitative as well as qualitative, noting effects of geometry and shielding differences between the proposed canisters and the currently approved canisters.

The applicant should modify the application to include the requested information.

This information is needed to confirm compliance with 10 CFR 71.35(a) and 71.47.

Response:

Comment incorporated. Consistent with the Shielding RSI-2 suggestion, Section 3.2 of the RH-TRAMPAC has been revised to provide detail regarding the pre-shipment dose rate measurements used to meet the Normal Conditions of Transport requirements of 10 CFR 71.47.

Section 3.2.1, Requirements, of the RH-TRAMPAC has been revised to specify that the NCT 2-meter dose rate shall be measured "2 meters from the vertical planes projected by the outer edges of the vehicle." For completeness in summarizing the 10 CFR 71.47 requirement, Section 3.2.1 of the RH-TRAMPAC also has been revised to include the following "with respect to any normally occupied space (i.e., the cab of the trailer shipping the RH-TRU 72-B), the radiation dose rate shall be ≤2 mrem/hr or the personnel who are in such an occupied space shall wear radiation dosimetry devices."

Section 3.2.2, Methods of Compliance and Verification, of the RH-TRAMPAC has been revised to detail the conditions under which the NCT dose rate surveys are performed and documented, including the following:

- The description explicitly states that both neutron and gamma dose rate measurements are performed on the package surface and at 2 meters from the vertical planes projected by the outer edges of the vehicle.
- The description clearly states that "Both gamma and neutron dose rate measurements must be performed using instruments appropriately selected and calibrated for the package contents."
- A schematic has been added as Figure 3.2-1 to specify dose rate measurement locations.
- A dose rate survey form has been added as Table 3.2-1 that requires the documentation of highest individual survey results from gamma and neutron dose rate surveys and selection and summing of the highest gamma and highest neutron dose rates for evaluating compliance with the 10 CFR 71.47 dose rate limits. Note: Tables 3.2-1 and 3.2-2 have been renumbered as Tables 3.2-2 and 3.2-3 to accommodate the addition of the new table.

Dose rate measurements must be performed by continuous scan of all external surfaces of the package. As described in the revised text of Section 3.2.2 of the RH-TRAMPAC, scans on the surfaces are performed by slowly moving the probe (1 to 2 inches per second) over the surface of the package. This method of scanning results in a comprehensive set of dose rate measurements.

Chapter 7, Package Operations, of the RH-TRU 72-B SAR has been revised to add a reference to Section 3.2 of the RH-TRAMPAC to specify the required conditions for performance of the NCT dose rate surveys.

To demonstrate the acceptability of pre-shipment dose rate survey for use in meeting the NCT requirements, Table 6 provides a summary of the pre-shipment measured surface and 2-meter dose rates for shipments completed through November 5, 2010, under the current RH-TRU 72-B Certificate of Compliance. Also summarized is the calculation of the "limit fraction" (ratio between the combined gamma plus neutron surface dose rate measurement and the 200 mrem/hr limit, and the ratio between the combined gamma plus neutron 2-meter dose rate measurement and the 10 mrem/hr limit), all of which are less than 0.81 (≤1.0, as required). Table 6 also summarizes the Hypothetical Accident Condition activity limit for each shipment (calculated per the requirements of RH-TRAMPAC Section 3.2.2 for the General Payload Case), which show variable correlation between dose rates and activity. The variable nature of correlation between activity and dose due to self-shielding and distribution effects (as shown in Figure 1) are the reason that pre-shipment surveys, as described by this revised Section 3.2 of the RH-TRAMPAC, are best suited to satisfy NCT dose rate requirements.

Table 6 – Preshipment Dose Rate and HAC Sum of Partial Fraction Data

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
27-Feb-09	ORR090001	100.50	8.10	0.81	0.01
27-Mar-10	ORR10017	85.50	8.10	0.81	0.02
6-Mar-09	ORR090003	50.50	7.10	0.71	0.01
12-Mar-09	ORR090004	51.50	6.70	0.67	0.01
6-Mar-09	ORR090002	66.20	5.10	0.51	0.00
5-Feb-10	ORR10009	30.50	4.10	0.41	0.00
5-Aug-09	SRR09023	12.40	3.40	0.34	0.06
9-Mar-10	ORR10014	10.30	3.10	0.31	0.00
8-Jul-10	INR10019	31.00	3.00	0.30	0.03
18-Sep-10	INR10030	11.00	2.80	0.28	0.09
2-Sep-09	ORR09005	15.20	2.60	0.26	0.00
3-Mar-10	ORR10012	15.20	2.60	0.26	0.00
28-Oct-09	ORR09009	43.00	2.10	0.22	0.00
4-Sep-09	ORR09006	15.60	2.10	0.21	0.00
10-Sep-09	ORR09007	17.70	2.10	0.21	0.00
23-Oct-09	ORR09010	12.40	2.10	0.21	0.00
28-Jan-10	ORR10003	8.20	2.10	0.21	0.00
2-Feb-10	ORR10006	18.10	2.10	0.21	0.01
27-Feb-10	ORR10011	20.40	2.10	0.21	0.00
18-Mar-10	ORR10015	30.50	2.10	0.21	0.00
5-Aug-10	ORR10039	20.50	2.10	0.21	0.04
2-Jul-09	LAR09016	40.25	0.65	0.20	0.49
17-Apr-10	INR10013	36.00	2.00	0.20	0.06
2-Jul-09	LAR09009	35.25	1.25	0.18	0.85
29-Jan-10	ORR10004	22.60	1.60	0.16	0.00
4-Feb-10	ORR10008	8.50	1.60	0.16	0.00
25-Mar-10	INR10008	11.00	1.50	0.15	0.01
17-Jul-10	INR10023	3.50	1.50	0.15	0.08
11-Sep-10	INR10027	8.00	1.50	0.15	0.02
24-Apr-10	ORR10022	15.50	1.40	0.14	0.17
3-Feb-10	ORR10007	8.20	1.35	0.14	0.00
23-Jan-07	IN070040	1.50	1.30	0.13	0.00
27-Jan-07	IN070048	1.30	1.30	0.13	0.01

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
6-Mar-07	INR07007	1.50	1.30	0.13	0.01
10-Mar-07	INR07008	1.30	1.30	0.13	0.00
10-Jul-07	INR07038	3.00	1.30	0.13	0.01
1-Jul-10	INR10017	6.00	1.30	0.13	0.01
6-Feb-07	IN070057	1.20	1.20	0.12	0.00
11-Feb-07	IN070075	1.30	1.20	0.12	0.01
21-Feb-07	IN070093	1.50	1.20	0.12	0.00
17-Mar-07	INR07009	1.30	1.20	0.12	0.00
31-Mar-07	INR07011	1.40	1.20	0.12	0.01
4-Apr-07	INR07012	1.50	1.20	0.12	0.01
14-Apr-07	INR07013	1.50	1.20	0.12	0.00
18-Apr-07	INR07014	1.30	1.20	0.12	0.01
19-May-07	INR07022	1.30	1.20	0.12	0.00
23-May-07	INR07024	1.30	1.20	0.12	0.00
26-Jun-07	INR07035	1.60	1.20	0.12	0.00
13-Jul-07	INR07040	2.00	1.20	0.12	0.01
7-Mar-08	INR08023	1.40	1.20	0.12	0.00
23-Apr-10	INR10015	5.00	1.20	0.12	0.04
10-Jul-10	INR10021	7.00	1.20	0.12	0.03
25-Sep-10	INR10032	5.00	1.20	0.12	0.02
25-May-10	ORR10029	4.60	1.20	0.12	0.05
6-Aug-10	ORR10040	10.00	1.20	0.12	0.33
27-Feb-07	IN070109	2.50	1.10	0.11	0.01
24-Mar-07	INR07010	1.30	1.10	0.11	0.00
21-Apr-07	INR07015	1.20	1.10	0.11	0.01
25-Apr-07	INR07016	1.60	1.10	0.11	0.00
28-Apr-07	INR07017	1.80	1.10	0.11	0.01
6-May-07	INR07018	1.60	1.10	0.11	0.00
9-May-07	INR07019	1.40	1.10	0.11	0.01
11-May-07	INR07020	1.70	1.10	0.11	0.01
15-May-07	INR07021	1.70	1.10	0.11	0.00
19-May-07	INR07023	1.20	1.10	0.11	0.00
1-Jun-07	INR07025	1.20	1.10	0.11	0.00
3-Jun-07	INR07026	4.00	1.10	0.11	0.00
7-Jun-07	INR07027	1.20	1.10	0.11	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
10-Jun-07	INR07028	1.20	1.10	0.11	0.00
13-Jun-07	INR07029	1.60	1.10	0.11	0.01
14-Jun-07	INR07030	1.20	1.10	0.11	0.00
16-Jun-07	INR07031	1.20	1.10	0.11	0.00
21-Jun-07	INR07032	1.20	1.10	0.11	0.00
21-Jun-07	INR07033	1.20	1.10	0.11	0.01
22-Jun-07	INR07034	1.20	1.10	0.11	0.00
29-Jun-07	INR07036	1.20	1.10	0.11	0.00
7-Jul-07	INR07037	1.20	1.10	0.11	0.00
14-Jul-07	INR07039	1.20	1.10	0.11	0.00
17-Jul-07	INR07041	1.20	1.10	0.11	0.00
24-Jul-07	INR07042	1.20	1.10	0.11	0.00
26-Jul-07	INR07043	1.30	1.10	0.11	0.00
1-Aug-07	INR07044	1.20	1.10	0.11	0.01
3-Aug-07	INR07045	1.20	1.10	0.11	0.00
2-Aug-07	INR07046	1.20	1.10	0.11	0.00
28-Aug-07	INR07047	1.20	1.10	0.11	0.00
30-Aug-07	INR07048	1.20	1.10	0.11	0.00
31-Aug-07	INR07049	1.20	1.10	0.11	0.00
6-Sep-07	INR07050	1.20	1.10	0.11	0.00
6-Sep-07	INR07051	1.10	1.10	0.11	0.00
7-Sep-07	INR07052	1.20	1.10	0.11	0.01
12-Sep-07	INR07053	1.20	1.10	0.11	0.00
13-Sep-07	INR07054	1.10	1.10	0.11	0.00
13-Sep-07	INR07055	1.30	1.10	0.11	0.01
14-Sep-07	INR07056	1.10	1.10	0.11	0.00
16-Sep-07	INR07057	1.70	1.10	0.11	0.02
18-Sep-07	INR07058	4.00	1.10	0.11	0.01
22-Sep-07	INR07059	1.20	1.10	0.11	0.01
22-Sep-07	INR07060	1.10	1.10	0.11	0.00
22-Sep-07	INR07061	1.20	1.10	0.11	0.00
26-Sep-07	INR07062	1.30	1.10	0.11	0.01
27-Sep-07	INR07063	7.00	1.10	0.11	0.00
28-Sep-07	INR07064	1.10	1.10	0.11	0.00
28-Sep-07	INR07065	1.10	1.10	0.11	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction[1,3]	HAC Activity Limit - Sum of Partial Fractions[2,3]
3-Oct-07	INR07066	1.10	1.10	0.11	0.00
3-Oct-07	INR07067	1.10	1.10	0.11	0.00
10-Oct-07	INR07068	1.10	1.10	0.11	0.00
5-Oct-07	INR07069	1.20	1.10	0.11	0.00
5-Oct-07	INR07070	1.10	1.10	0.11	0.00
9-Oct-07	INR07071	1.30	1.10	0.11	0.00
12-Oct-07	INR07072	1.10	1.10	0.11	0.00
12-Oct-07	INR07073	1.30	1.10	0.11	0.00
17-Oct-07	INR07074	1.30	1.10	0.11	0.00
17-Oct-07	INR07075	1.30	1.10	0.11	0.00
20-Oct-07	INR07076	1.30	1.10	0.11	0.00
20-Oct-07	INR07077	1.10	1.10	0.11	0.00
24-Oct-07	INR07078	1.30	1.10	0.11	0.00
24-Oct-07	INR07079	1.30	1.10	0.11	0.00
26-Oct-07	INR07080	1.10	1.10	0.11	0.00
26-Oct-07	INR07081	1.10	1.10	0.11	0.00
28-Oct-07	INR07082	1.10	1.10	0.11	0.00
28-Oct-07	INR07083	1.10	1.10	0.11	0.00
31-Oct-07	INR07084	1.10	1.10	0.11	0.00
2-Nov-07	INR07085	1.10	1.10	0.11	0.00
2-Nov-07	INR07086	1.10	1.10	0.11	0.00
3-Nov-07	INR07087	1.10	1.10	0.11	0.00
6-Nov-07	INR07088	1.10	1.10	0.11	0.00
7-Nov-07	INR07089	1.30	1.10	0.11	0.00
14-Nov-07	INR07090	1.10	1.10	0.11	0.00
15-Nov-07	INR07091	1.10	1.10	0.11	0.00
16-Nov-07	INR07092	1.10	1.10	0.11	0.00
30-Nov-07	INR07093	1.10	1.10	0.11	0.00
30-Nov-07	INR07094	1.10	1.10	0.11	0.00
30-Nov-07	INR07095	1.10	1.10	0.11	0.00
14-Dec-07	INR07096	1.10	1.10	0.11	0.00
14-Dec-07	INR07097	1.10	1.10	0.11	0.00
19-Dec-07	INR07098	1.30	1.10	0.11	0.00
19-Dec-07	INR07099	1.30	1.10	0.11	0.00
5-Jan-08	INR07100	1.40	1.10	0.11	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
5-Jan-08	INR08002	1.10	1.10	0.11	0.00
16-Jan-08	INR08003	1.10	1.10	0.11	0.00
16-Jan-08	INR08004	1.10	1.10	0.11	0.01
17-Jan-08	INR08005	1.40	1.10	0.11	0.01
19-Jan-08	INR08006	1.60	1.10	0.11	0.01
25-Jan-08	INR08007	1.50	1.10	0.11	0.01
25-Jan-08	INR08008	1.30	1.10	0.11	0.01
25-Jan-08	INR08009	1.20	1.10	0.11	0.01
25-Jan-08	INR08010	2.00	1.10	0.11	0.02
12-Feb-08	INR08011	1.20	1.10	0.11	0.01
12-Feb-08	INR08012	1.40	1.10	0.11	0.01
14-Feb-08	INR08013	1.30	1.10	0.11	0.01
20-Feb-08	INR08014	1.40	1.10	0.11	0.01
20-Feb-08	INR08015	1.20	1.10	0.11	0.00
20-Feb-08	INR08016	1.10	1.10	0.11	0.00
21-Feb-08	INR08017	1.20	1.10	0.11	0.01
21-Feb-08	INR08018	1.40	1.10	0.11	0.01
27-Feb-08	INR08019	1.10	1.10	0.11	0.00
28-Feb-08	INR08020	3.00	1.10	0.11	0.00
7-Mar-08	INR08021	1.20	1.10	0.11	0.00
7-Mar-08	INR08022	1.20	1.10	0.11	0.00
8-Mar-08	INR08024	1.10	1.10	0.11	0.00
11-Mar-08	INR08025	1.30	1.10	0.11	0.01
15-Mar-08	INR08026	1.20	1.10	0.11	0.01
18-Mar-08	INR08027	1.10	1.10	0.11	0.00
20-Mar-08	INR08028	1.20	1.10	0.11	0.00
26-Mar-08	INR08029	1.20	1.10	0.11	0.00
27-Mar-08	INR08030	1.50	1.10	0.11	0.00
27-Mar-08	INR08031	1.20	1.10	0.11	0.01
28-Mar-08	INR08032	1.40	1.10	0.11	0.01
2-Apr-08	INR08033	1.80	1.10	0.11	0.00
3-Apr-08	INR08034	1.20	1.10	0.11	0.00
4-Apr-08	INR08035	1.20	1.10	0.11	0.00
9-Apr-08	INR08036	1.10	1.10	0.11	0.00
10-Apr-08	INR08037	1.10	1.10	0.11	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction[1,3]	HAC Activity Limit - Sum of Partial Fractions[2,3]
15-Apr-08	INR08038	1.20	1.10	0.11	0.00
17-Apr-08	INR08039	1.20	1.10	0.11	0.00
18-Apr-08	INR08040	1.20	1.10	0.11	0.00
19-Apr-08	INR08041	1.20	1.10	0.11	0.00
22-Apr-08	INR08042	1.10	1.10	0.11	0.00
24-Apr-08	INR08043	1.20	1.10	0.11	0.00
8-May-08	INR08044	1.20	1.10	0.11	0.01
9-May-08	INR08045	1.10	1.10	0.11	0.00
13-May-08	INR08046	1.10	1.10	0.11	0.00
15-May-08	INR08047	1.20	1.10	0.11	0.00
16-May-08	INR08048	1.10	1.10	0.11	0.00
20-May-08	INR08049	1.10	1.10	0.11	0.00
22-May-08	INR08050	1.10	1.10	0.11	0.00
22-May-08	INR08051	1.30	1.10	0.11	0.00
29-May-08	INR08052	1.30	1.10	0.11	0.01
30-May-08	INR08053	1.20	1.10	0.11	0.00
30-May-08	INR08054	1.10	1.10	0.11	0.00
6-Jun-08	INR08055	1.20	1.10	0.11	0.00
6-Jun-08	INR08056	1.10	1.10	0.11	0.00
17-Jun-08	INR08057	1.10	1.10	0.11	0.00
18-Jun-08	INR08058	1.10	1.10	0.11	0.01
28-Jun-08	INR08059	1.30	1.10	0.11	0.00
1-Jul-08	INR08060	1.20	1.10	0.11	0.01
2-Jul-08	INR08061	1.10	1.10	0.11	0.00
9-Jul-08	INR08062	1.10	1.10	0.11	0.01
9-Jul-08	INR08063	1.10	1.10	0.11	0.00
11-Jul-08	INR08064	1.10	1.10	0.11	0.00
16-Jul-08	INR08065	1.10	1.10	0.11	0.00
18-Jul-08	INR08066	1.40	1.10	0.11	0.02
22-Jul-08	INR08067	1.10	1.10	0.11	0.00
13-Sep-08	INR08068	1.10	1.10	0.11	0.01
26-Jul-08	INR08069	1.10	1.10	0.11	0.01
18-Sep-08	INR08070	1.10	1.10	0.11	0.00
19-Sep-08	INR08071	1.10	1.10	0.11	0.00
25-Sep-08	INR08072	1.10	1.10	0.11	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
26-Sep-08	INR08073	1.10	1.10	0.11	0.00
3-Oct-08	INR08074	1.10	1.10	0.11	0.00
3-Oct-08	INR08075	1.10	1.10	0.11	0.00
8-Oct-08	INR08076	1.10	1.10	0.11	0.00
10-Oct-08	INR08077	1.10	1.10	0.11	0.00
11-Oct-08	INR08078	1.10	1.10	0.11	0.00
15-Oct-08	INR08079	1.10	1.10	0.11	0.00
16-Oct-08	INR08080	1.10	1.10	0.11	0.00
18-Oct-08	INR08081	1.10	1.10	0.11	0.00
22-Oct-08	INR08082	1.10	1.10	0.11	0.00
23-Oct-08	INR08083	1.10	1.10	0.11	0.00
25-Oct-08	INR08084	1.10	1.10	0.11	0.00
30-Oct-08	INR08085	1.10	1.10	0.11	0.00
21-Jan-09	INR090001	1.10	1.10	0.11	0.00
29-Mar-09	INR090002	1.10	1.10	0.11	0.00
22-Jan-09	INR090003	1.10	1.10	0.11	0.00
31-Jan-09	INR090004	1.10	1.10	0.11	0.00
1-Feb-09	INR090005	1.10	1.10	0.11	0.00
4-Feb-09	INR090006	1.10	1.10	0.11	0.00
6-Feb-09	INR090007	1.10	1.10	0.11	0.00
4-Mar-09	INR090008	1.60	1.10	0.11	0.00
6-Mar-09	INR090009	1.60	1.10	0.11	0.01
13-Mar-09	INR090010	1.10	1.10	0.11	0.00
14-Mar-09	INR090011	1.10	1.10	0.11	0.00
18-Mar-09	INR090012	1.10	1.10	0.11	0.00
21-Mar-09	INR090013	1.10	1.10	0.11	0.00
26-Mar-09	INR090014	1.10	1.10	0.11	0.00
29-Mar-09	INR090015	1.30	1.10	0.11	0.00
18-Feb-10	INR10001	1.20	1.10	0.11	0.01
21-Feb-10	INR10002	1.10	1.10	0.11	0.01
25-Feb-10	INR10003	1.20	1.10	0.11	0.00
26-Feb-10	INR10004	1.20	1.10	0.11	0.01
12-Mar-10	INR10005	1.40	1.10	0.11	0.00
19-Mar-10	INR10006	1.40	1.10	0.11	0.01
20-Mar-10	INR10007	1.30	1.10	0.11	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction[1,3]	HAC Activity Limit - Sum of Partial Fractions[2,3]
9-Apr-10	INR10009	1.80	1.10	0.11	0.01
10-Apr-10	INR10010	1.50	1.10	0.11	0.01
15-Apr-10	INR10011	1.90	1.10	0.11	0.04
17-Apr-10	INR10012	1.80	1.10	0.11	0.04
22-Apr-10	INR10014	1.10	1.10	0.11	0.00
25-Apr-10	INR10016	2.00	1.10	0.11	0.00
1-Jul-10	INR10018	1.60	1.10	0.11	0.02
22-Jul-10	INR10024	1.10	1.10	0.11	0.00
23-Jul-10	INR10025	1.30	1.10	0.11	0.01
24-Jul-10	INR10026	1.10	1.10	0.11	0.00
11-Sep-10	INR10028	1.10	1.10	0.11	0.00
16-Sep-10	INR10029	1.70	1.10	0.11	0.00
11-Jun-09	LAR09004	1.10	1.10	0.11	0.07
6-Nov-09	ORR09011	22.00	1.10	0.11	0.00
23-Jan-10	ORR10002	12.30	1.10	0.11	0.00
30-Jan-10	ORR10005	6.10	1.10	0.11	0.01
23-Mar-10	ORR10016	18.20	1.10	0.11	0.00
1-May-10	ORR10024	20.10	1.10	0.11	0.02
8-Jul-10	INR10020	1.50	1.05	0.11	0.00
15-Jul-10	INR10022	1.30	1.05	0.11	0.01
23-Sep-10	INR10031	1.30	1.05	0.11	0.00
11-Sep-09	ORR09008	20.30	0.20	0.10	0.00
25-Sep-09	GER09004	14.20	1.00	0.10	0.00
10-Aug-10	ORR10041	17.50	1.00	0.10	0.26
3-Jun-09	SRR09015	3.40	0.90	0.09	0.13
26-Aug-09	SRR09028	3.40	0.90	0.09	0.06
6-Jun-09	SRR09012	2.40	0.80	0.08	0.02
14-May-10	ORR10028	4.00	0.70	0.07	0.03
24-Jun-09	SRR09013	2.90	0.70	0.07	0.01
17-Jun-09	SRR09016	2.90	0.70	0.07	0.13
16-Aug-08	AER08001	2.60	0.60	0.06	0.02
16-Aug-08	AER08002	7.90	0.60	0.06	0.01
29-Aug-08	AER08003	2.20	0.60	0.06	0.00
7-Sep-08	AER08004	0.80	0.60	0.06	0.01
13-Sep-08	AER08005	3.40	0.60	0.06	0.01

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction[1,3]	HAC Activity Limit - Sum of Partial Fractions[2,3]
1-Nov-08	AER08006	4.40	0.60	0.06	0.00
1-Nov-08	AER08007	2.70	0.60	0.06	0.01
8-Nov-08	AER08008	0.90	0.60	0.06	0.02
8-Nov-08	AER08009	1.40	0.60	0.06	0.01
15-Nov-08	AER08010	0.90	0.60	0.06	0.01
15-Nov-08	AER08011	0.60	0.60	0.06	0.01
24-Jul-09	AER09001	2.10	0.60	0.06	0.01
24-Jul-09	AER09002	5.90	0.60	0.06	0.02
28-Jul-09	AER09003	1.10	0.60	0.06	0.01
31-Jul-09	AER09004	0.80	0.60	0.06	0.01
19-Jan-10	ORR10001	6.30	0.60	0.06	0.00
6-Feb-10	ORR10010	5.60	0.60	0.06	0.00
5-Mar-10	ORR10013	10.50	0.60	0.06	0.00
1-Apr-10	ORR10018	5.90	0.60	0.06	0.13
7-Apr-10	ORR10019	2.10	0.60	0.06	0.05
17-Apr-10	ORR10020	3.70	0.60	0.06	0.03
22-Apr-10	ORR10021	5.30	0.60	0.06	0.04
27-Apr-10	ORR10023	1.30	0.60	0.06	0.04
5-May-10	ORR10025	4.50	0.60	0.06	0.13
7-May-10	ORR10026	2.40	0.60	0.06	0.07
11-May-10	ORR10027	1.20	0.60	0.06	0.01
28-May-10	ORR10030	1.60	0.60	0.06	0.04
17-Jul-10	ORR10031	4.30	0.60	0.06	0.02
20-Jul-10	ORR10032	7.60	0.60	0.06	0.07
22-Jul-10	ORR10033	2.60	0.60	0.06	0.04
23-Jul-10	ORR10034	2.20	0.60	0.06	0.03
27-Jul-10	ORR10035	2.70	0.60	0.06	0.02
29-Jul-10	ORR10036	0.70	0.60	0.06	0.02
30-Jul-10	ORR10037	0.70	0.60	0.06	0.02
4-Aug-10	ORR10038	1.20	0.60	0.06	0.03
12-Aug-10	ORR10042	2.90	0.60	0.06	0.07
13-Aug-10	ORR10043	6.50	0.60	0.06	0.33
18-Aug-10	ORR10044	1.20	0.60	0.06	0.01
20-Aug-10	ORR10045	3.20	0.60	0.06	0.03
1-Sep-10	ORR10046	2.20	0.60	0.06	0.03

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
2-Sep-10	ORR10047	2.20	0.60	0.06	0.02
15-Sep-10	ORR10048	1.60	0.60	0.06	0.03
18-Sep-10	ORR10049	1.20	0.60	0.06	0.05
21-Aug-09	SRR09027	1.90	0.60	0.06	0.07
10-Jun-09	LAR09003	0.50	0.50	0.05	0.10
24-Apr-09	SRR09001	0.50	0.50	0.05	0.00
24-Apr-09	SRR09002	0.50	0.50	0.05	0.00
29-Apr-09	SRR09003	0.50	0.50	0.05	0.00
1-May-09	SRR09004	0.50	0.50	0.05	0.00
6-May-09	SRR09005	0.50	0.50	0.05	0.00
8-May-09	SRR09006	0.50	0.50	0.05	0.00
13-May-09	SRR09007	0.50	0.50	0.05	0.01
15-May-09	SRR09008	0.50	0.50	0.05	0.02
22-May-09	SRR09009	0.50	0.50	0.05	0.01
27-May-09	SRR09010	3.40	0.50	0.05	0.01
29-May-09	SRR09011	0.90	0.50	0.05	0.03
8-Jul-09	SRR09014	0.50	0.50	0.05	0.00
10-Jul-09	SRR09017	1.20	0.50	0.05	0.03
15-Jul-09	SRR09018	0.50	0.50	0.05	0.01
17-Jul-09	SRR09019	0.50	0.50	0.05	0.01
22-Jul-09	SRR09020	0.60	0.50	0.05	0.01
29-Jul-09	SRR09021	0.50	0.50	0.05	0.02
1-Aug-09	SRR09022	0.50	0.50	0.05	0.00
7-Aug-09	SRR09024	1.30	0.50	0.05	0.03
14-Aug-09	SRR09025	1.20	0.50	0.05	0.02
19-Aug-09	SRR09026	2.40	0.50	0.05	0.11
8-Oct-10	SRR10001	0.50	0.50	0.05	0.01
14-Oct-10	SRR10002	0.50	0.50	0.05	0.00
16-Oct-10	SRR10003	0.50	0.50	0.05	0.00
19-Oct-10	SRR10004	0.50	0.50	0.05	0.00
21-Oct-10	SRR10005	1.30	0.50	0.05	0.04
27-Oct-10	SRR10006	1.30	0.50	0.05	0.00
30-Oct-10	SRR10007	0.50	0.50	0.05	0.00
2-Nov-10	SRR10008	0.90	0.50	0.05	0.00
5-Nov-10	SRR10009	0.50	0.50	0.05	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction[①③]	HAC Activity Limit - Sum of Partial Fractions[②③]
16-Jun-09	LAR09006	7.25	0.04	0.04	0.12
3-Jun-09	LAR09001	0.35	0.35	0.04	0.03
5-Jun-09	LAR09002	0.35	0.35	0.04	0.07
16-Jun-09	LAR09005	0.35	0.35	0.04	0.11
16-Jun-09	LAR09007	0.95	0.35	0.04	0.17
18-Jun-09	LAR09008	3.80	0.35	0.04	0.16
19-Jun-09	LAR09010	0.35	0.35	0.04	0.01
24-Jun-09	LAR09011	0.35	0.35	0.04	0.00
25-Jun-09	LAR09012	0.35	0.35	0.04	0.00
25-Jun-09	LAR09013	2.95	0.35	0.04	0.02
29-Jun-09	LAR09014	0.75	0.35	0.04	0.11
30-Jun-09	LAR09015	0.95	0.35	0.04	0.08
27-Aug-09	AER09013	5.80	0.08	0.03	0.01
26-Aug-09	AER09012	5.00	0.06	0.03	0.01
8-Aug-09	AER09006	0.50	0.20	0.02	0.02
12-Aug-09	AER09007	1.50	0.20	0.02	0.01
22-Oct-10	AER10026	2.61	0.06	0.01	0.09
22-Oct-10	AER10027	2.00	0.04	0.01	0.07
13-Aug-09	AER09008	1.80	0.00	0.01	0.02
26-May-10	AER10005	1.01	0.01	0.01	0.00
14-Oct-10	AER10022	0.66	0.05	0.00	0.03
15-Oct-10	AER10023	0.71	0.05	0.00	0.02
23-Aug-09	AER09011	0.82	0.00	0.00	0.00
17-Jun-10	AER10013	0.81	0.03	0.00	0.01
21-Oct-10	AER10025	0.71	0.02	0.00	0.00
14-Oct-09	AER09016	0.70	0.04	0.00	0.00
2-Oct-09	GER09007	0.70	0.00	0.00	0.00
27-Sep-09	GER09005	0.60	0.00	0.00	0.00
2-Aug-09	AER09005	0.13	0.03	0.00	0.00
30-Aug-09	AER09014	0.36	0.03	0.00	0.01
7-May-10	AER10001	0.19	0.03	0.00	0.00
12-May-10	AER10002	0.09	0.03	0.00	0.00
23-May-10	AER10004	0.08	0.03	0.00	0.00
27-May-10	AER10006	0.10	0.03	0.00	0.00
3-Jun-10	AER10007	0.09	0.03	0.00	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
9-Jun-10	AER10009	0.09	0.03	0.00	0.00
11-Jun-10	AER10010	0.19	0.03	0.00	0.01
13-Jun-10	AER10011	0.14	0.03	0.00	0.00
16-Oct-10	AER10024	0.03	0.03	0.00	0.01
30-Oct-10	AER10029	0.21	0.03	0.00	0.03
5-Jun-10	AER10008	0.11	0.02	0.00	0.01
20-Jun-10	AER10012	0.11	0.02	0.00	0.00
29-Sep-10	AER10019	0.33	0.02	0.00	0.01
1-Oct-10	AER10020	0.30	0.02	0.00	0.01
8-Oct-10	AER10021	0.05	0.02	0.00	0.00
8-Jan-10	GER10003	0.40	0.00	0.00	0.01
23-Jun-10	AER10015	0.21	0.02	0.00	0.00
25-Jun-10	AER10016	0.04	0.02	0.00	0.00
23-May-10	AER10003	0.07	0.02	0.00	0.00
20-Jun-10	AER10014	0.03	0.02	0.00	0.00
27-Jun-10	AER10017	0.21	0.02	0.00	0.00
25-Sep-10	AER10018	0.30	0.01	0.00	0.01
23-Sep-09	GER09003	0.30	0.00	0.00	0.00
30-Sep-09	GER09006	0.30	0.00	0.00	0.00
3-Oct-09	GER09008	0.30	0.00	0.00	0.00
30-Oct-10	AER10028	0.04	0.01	0.00	0.02
5-Nov-10	AER10030	0.03	0.01	0.00	0.00
5-Nov-10	AER10031	0.02	0.01	0.00	0.01
20-Aug-09	AER09010	0.23	0.01	0.00	0.00
11-Oct-09	AER09015	0.21	0.00	0.00	0.01
16-Aug-09	AER09009	0.20	0.00	0.00	0.01
16-Oct-09	AER09017	0.10	0.01	0.00	0.00
18-Sep-09	GER09001	0.20	0.00	0.00	0.00
20-Sep-09	GER09002	0.20	0.00	0.00	0.00
10-Oct-09	GER09012	0.20	0.00	0.00	0.01
18-Oct-09	GER09014	0.20	0.00	0.00	0.01
25-Oct-09	GER09015	0.20	0.00	0.00	0.00
28-Oct-09	GER09016	0.20	0.00	0.00	0.01
31-Oct-09	GER09017	0.20	0.00	0.00	0.00
4-Nov-09	GER09018	0.20	0.00	0.00	0.00

Receipt Date	Shipment No.	Dose Rate @surface (mrem/hr)	Dose Rate @2 meter (mrem/hr)	Dose Rate Measurement - Maximum Limit Fraction①③	HAC Activity Limit - Sum of Partial Fractions②③
11-Nov-09	GER09020	0.20	0.00	0.00	0.00
4-Oct-09	GER09009	0.10	0.00	0.00	0.01
7-Oct-09	GER09010	0.10	0.00	0.00	0.00
8-Oct-09	GER09011	0.10	0.00	0.00	0.00
16-Oct-09	GER09013	0.10	0.00	0.00	0.00
5-Nov-09	GER09019	0.10	0.00	0.00	0.00
13-Nov-09	GER09021	0.10	0.00	0.00	0.00
6-Jan-10	GER10001	0.10	0.00	0.00	0.00
7-Jan-10	GER10002	0.10	0.00	0.00	0.00
9-Jan-10	GER10004	0.10	0.00	0.00	0.00
10-Jan-10	GER10005	0.10	0.00	0.00	0.00
13-Jan-10	GER10006	0.10	0.00	0.00	0.00
14-Jan-10	GER10007	0.10	0.00	0.00	0.00
15-Jan-10	GER10008	0.10	0.00	0.00	0.00
18-Jan-10	GER10009	0.10	0.00	0.00	0.00
28-Jan-10	GER10010	0.10	0.00	0.00	0.00
29-Jan-10	GER10011	0.10	0.00	0.00	0.00

Notes:

① Calculated as maximum of the ratio between the combined gamma plus neutron surface dose rate measurement and the 200 mrem/hr limit and the ratio between the combined gamma plus neutron 2-meter dose rate measurement and the 10 mrem/hr limit.

② Calculated per the requirements of RH-TRAMPAC Section 3.2.2 for the General Payload Case

③ Calculated values rounded to 2 decimal places for display convenience.

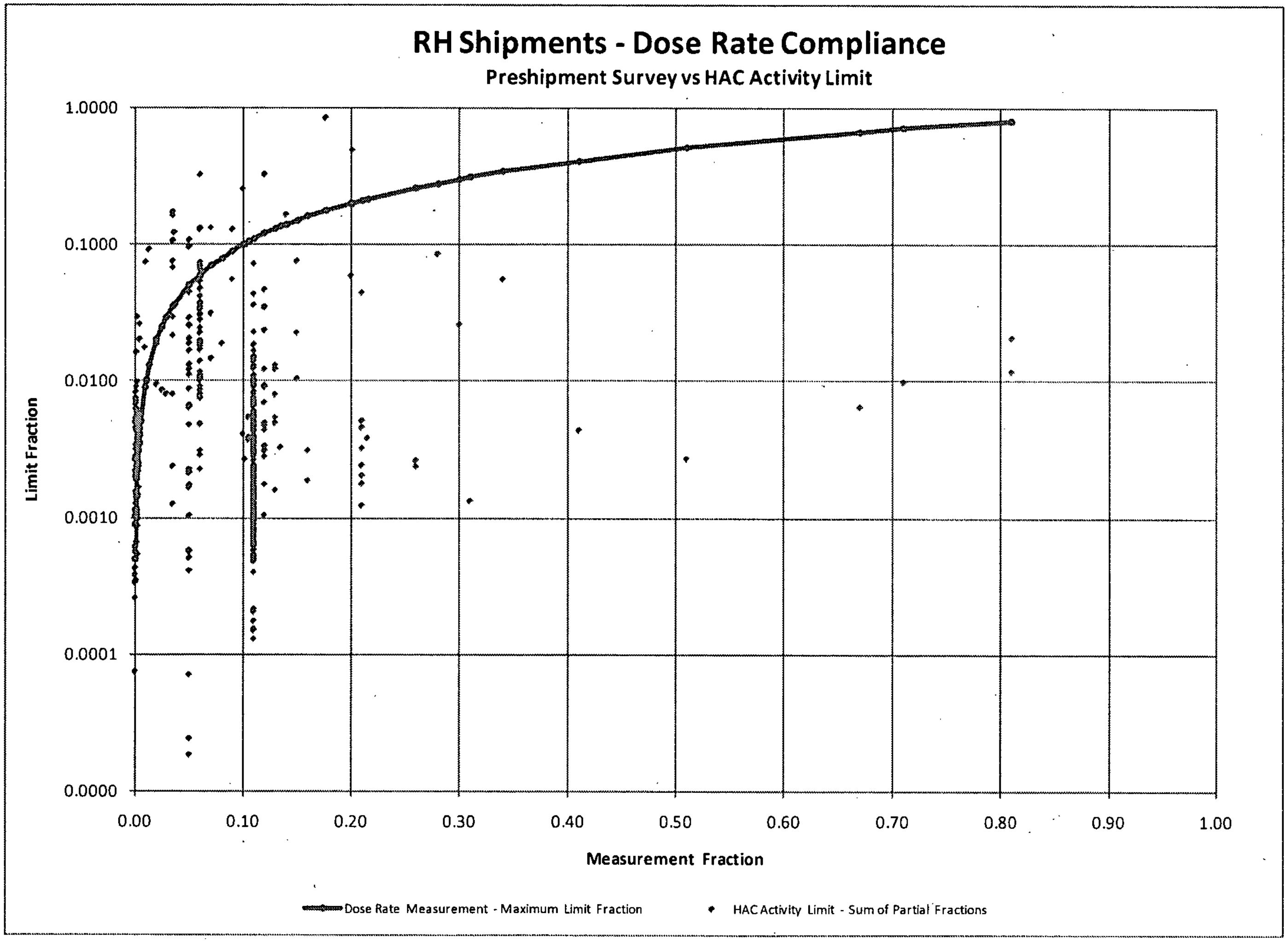

Figure 1 – Preshipment Dose Rate and HAC Sum of Partial Fraction Plot

Summary **Pg.**

RH-TRU 72-B SAR, Revision 5, February 2011			
Section	**Page**	**Change Description**	**Justification**
General		Revised header for date.	Administrative change. No impact to safety basis.
1.2.4.4	1.2-7	Revised 2nd sentence to require dose rate measurements per Section 3.2 of the RH-TRAMPAC and modify descriptions of dose rate measurements for consistency with that reference.	Changes are editorial for consistency with changes to RH-TRAMPAC Section 3.2. No impact to safety basis.
2.1	2.1-2	2nd row in table revised from "Conservatism of the 72-B evaluation approach is demonstrated ..." to "The 72-B evaluation approach used to demonstrate that lead slump will not occur is further validated ...".	Change is editorial for consistency with changes to Sections 2.6.7.1(9) and 2.7.1.1(9). No impact to safety basis.
2.6.7.1(9)	2.6-23, 2.6-24, & 2.6-49	Replaced 1st paragraph with four (4) new paragraphs, revised the last paragraph, and added a new Table 2.6-21 to address NCT lead slump.	Revised to replace the prior, overly conservative lead slump calculations with detailed calculations demonstrating that lead flow stress magnitudes are not reached and therefore no lead slump will occur. No impact to safety basis.
2.7.1.1(9)	2.7-9, 2.7-10, & 2.7-43	Replaced 1st paragraph with four (4) new paragraphs, revised the last paragraph, and added a new Table 2.7-12 to address HAC lead slump.	Revised to replace the prior, overly conservative lead slump calculations with detailed calculations demonstrating that lead flow stress magnitudes are not reached and therefore no lead slump will occur. No impact to safety basis.
2.7.8	2.7-37	Revised 1st and 2nd sentences in 2nd paragraph to address lead slump.	Change is editorial for consistency with changes to Section 2.7.1.1(9). No impact to safety basis.

RH-TRU 72-B SAR, Revision 5, February 2011			
Section	**Page**	**Change Description**	**Justification**
3.4.2	3.4-2 & 3.4-3	Revised to add 3rd, 4th, 5th, and 6th paragraphs to provide additional detail regarding the insolation boundary conditions utilized for the NCT steady-state analysis results presented in Table 3.4-2, to reference and discuss the alternative (no credit for self shading) insolation boundary conditions utilized for the NCT transient analysis results presented in RH-TRU Payload Appendix 5.1, and to conclude that all component temperatures for the 50 W payload remain within their NCT allowable temperature limits.	With all component temperatures remaining within their allowable temperature limits and within the 300 W temperatures presented in Table 3.4-2, there is no impact to the safety basis for 50 W payloads. 300 W payloads are not authorized per RH-TRAMPAC Section 5.0 revisions to authorize only payloads up to 50 W.
3.5.6	3.5-5 & 3.5-6	Added 6th and 7th paragraphs to discuss the alternative (no credit for self shading) insolation boundary conditions utilized for the HAC transient analysis results presented in RH-TRU Payload Appendix 5.1 and to conclude component temperature increases are insignificant in comparison with available thermal margins.	Same as above. No impact to safety basis.
4.3.3	4.3-2	Revised 1st and 2nd sentences in 4th paragraph to address lead slump.	Change is editorial for consistency with changes to Section 2.7.1.1(9). No impact to safety basis.
5.1	5.1-2	Revised "Normal Conditions of Transport:" section for consistency with and added a reference to Section 3.2 of the RH-TRAMPAC.	Changes are editorial for consistency with changes to RH-TRAMPAC Section 3.2. No impact to safety basis.
5.1	5.1-3	Revised 2nd bullet to read, "As demonstrated in Paragraph (9) of Section 2.7.1.1, Flat End Drop, lead slump has been determined to not occur and is, therefore, not modeled."	Change is editorial to reference the Section 2.7.1.1(9) basis for the conclusion that lead slump is not to occur. No impact to safety basis.

RH-TRU 72-B SAR, Revision 5, February 2011			
Section	**Page**	**Change Description**	**Justification**
7.1.2	7.1-4	Revised step 7.1.2.22 to add reference to Section 3.2 of the RH-TRAMPAC for requirements regarding monitoring of radiation levels.	Change is to tie Chapter 7 radiation dose rate measurement requirements to the detailed procedural steps defined in the RH-TRAMPAC. No impact to safety basis.

RH-TRAMPAC, Revision 1, February 2011			
Section	**Page**	**Change Description**	**Justification**
General		Revised header for date.	Administrative change. No impact to safety basis.
3.2.1	3.2-1	Revised 2nd sentence of 1st paragraph to replace "...side of the package..." with "...vertical planes projected by the outer edges of the vehicle...". Added 3rd sentence of 1st paragraph to define the required normally occupied space measurement or requirement for exposed personnel to wear radiation dosimetry devices.	Change is to clarify dose rate compliance consistent with 10CFR71.47(b)(3) and (4). No impact to safety basis.
3.2.2.1	3.2-1 thru 3.2-5	Added 2nd and additional paragraphs in a new section that provides procedural detail regarding the NCT dose rate survey requirements. Table 3.2-1 was added as a form to clarify the measurement documentation requirements and Figure 3.2-1 was added as a schematic to illustrate the measurement locations.	Change is to formalize procedural requirements associated with the preshipment survey in accordance with the Shielding RSI-2 response. No impact to safety basis.
5.0	5.1-1	Revised 2nd paragraph and bulletized list to eliminate the 300 W thermal limit and require all canisters to be shipped at a maximum decay heat of 50 W.	Change is to limit authorized shipments to 50 W decay heat in accordance with the Thermal RSI-1 response. No impact to safety basis.

RH-TRU Payload Appendices, Revision 1, February 2011			
Section	**Page**	**Change Description**	**Justification**
General		Revised header for date.	Administrative change. No impact to safety basis.
4.6.4	4.6-3	Revised and consolidated the 2nd and 3rd sentences in the conclusions paragraph to no longer explicitly reference Table 3.4-2 and Section 3.4.4 of the SAR.	Change is editorial to accommodate the new NS15 and NS30 analysis results summarized in Appendix 5.1 of the RPA. All waste centerline temperatures for 50-watt payloads remain below the 302 °F thermal degradation temperature limit, so there is no impact on the safety basis of the package.
5.1.4	5.1-30	Revised revision level and date for Banken reference.	Change is editorial to incorporate revised thermal analysis calc package. No impact to safety basis.
5.1.4.1	5.1-31 & 5.1-35	Revised 1st paragraph and added 2nd paragraph to incorporate discussion of results for new insolation boundary condition NCT sensitivity analyses for the NS15 and NS30 that take no credit for self shading of the package. Added new Table 5.1-3 to present NCT sensitivity analysis temperature results.	With all component temperatures remaining within their allowable temperature limits there is no impact to the safety basis.
5.1.4.2	5.1-32 & 5.1-38	Added 3rd and 4th paragraphs to incorporate discussion of results for new insolation boundary condition HAC sensitivity analyses for the NS15 and NS30 that take no credit for self shading of the package. Added new Table 5.1-6 to present HAC sensitivity analysis temperature results.	With all component temperatures remaining within their allowable temperature limits there is no impact to the safety basis.

(One Hard Copy and One CD[1] – Document Control Desk)
(Five Hard Copies and One CD[1] – C. Staab)

- RH-TRU 72-B SAR, Revision 5
- RH-TRAMPAC, Revision 1
- RH-TRU Payload Appendices, Revision 1.

[1] CD contains a PDF version of each document listed in Attachments C and D.

(One Hard Copy and One CD[1] – Document Control Desk)
(One Hard Copy and One CD[1] – C. Staab)

- G. J. Banken, *Thermal Analysis of RH Shielded Canisters in RH-TRU 72B Cask*, 01937.01.M0005.01-04, Rev. 2, AREVA Federal Services LLC, Tacoma, WA, February 2011.

AREVA	AREVA Federal Services LLC	
	CALCULATION	

Document No: 01937.01.M0005.01-04	**Rev. No:** 2	**Page 1 of 62**
Project No: 01937.01.M005.01.00001.100	**Project Name:** RH Technical Support	

Title: Thermal Analysis of RH Shielded Canisters in RH-TRU 72-B Cask

Summary:

The purpose of this calculation is to document the thermal performance of the NS15 and NS30 shielded RH waste canisters in the RH-TRU 72-B packaging. The calculation demonstrates compliance with the applicable regulatory requirements as specified in 10 CFR 71 for Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC).

Documentum No.: CALC-3002278-002

Software Utilized:	Version:	Storage Media Attached:
Thermal Desktop® & SINDA/FLUINT	5.1 & 5.3	1 CD

REV.	ORIGINATOR Typed / Signature / Date	CHECKED Typed / Signature / Date	APPROVED Typed / Signature / Date
0	GJ Banken 1/29/2010	MC Lobo 1/29/2010	GL Clark 2/1/2010
1	GJ Banken 8/19/2010	MJ Byeman 8/20/2010	GL Clark 8/20/2010
2	GJ Banken 2/9/11	MJ Byeman 02/09/11	GL Clark Gary L. Clark 2/10/11

REVISION HISTORY

REV.	CHANGES
0	Original Issue
1	Incorporate NRC comment responses.
2	Add sensitivity analysis for alternative insolation modeling

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1.0 Introduction

The Remote-Handled Transuranic Waste Shipping Cask (Model No. RH-TRU 72-B) is designed for the safe transport of remote-handled transuranic (RH-TRU) wastes from various sites around the United States. The purpose of this calculation is to document the thermal performance of the alternative NS15 and NS30 shielded RH waste canisters under NCT and HAC conditions when transported within the RH-TRU 72-B packaging. The NS15 and NS30 neutron shield inserts are supplemental internal additions to the RH-TRU waste canister assembly (removable lid design) and provide dose rate attenuation for neutron-emitting RH waste.

This calculation documents the thermal safety basis for adding the NS15 and NS30 neutron shield inserts to the RH-TRU Waste Canister Assembly as an alternative payload configuration for the RH-TRU 72-B packaging. The analysis confirms that the package design complies with all thermal acceptance criteria specified in 10 CFR 71[1].

1.1 Objective

The objectives of this calculation are:

- develop a thermal model of the waste canister assembly with the NS15 and NS30 neutron shield inserts within the existing and approved thermal model of the RH-TRU 72-B packaging,
- determine the combined thermal performance of the shielded canisters and the RH-TRU 72-B packaging under NCT and HAC conditions of transportation and for a variation in the decay heat distribution within the containers,
- ensure that the RH-TRU 72-B packaging temperatures remain bounded by the previous safety evaluations for NCT and HAC conditions, and
- document sensitivity of results to an alternative methodology for modeling insolation loading.

1.2 Purpose

The purpose of this calculation is to demonstrate compliance with the applicable regulatory requirements for the NS15 and NS30 shielded canisters as an alternative payload configuration for the RH-TRU 72-B packaging. The applicable regulatory requirements are specified in 10 CFR 71 [1] for Normal Conditions of Transport (NCT) and for Hypothetical Accident Conditions (HAC). Further guidance for the calculation is taken from NUREG-1609 [3] and Regulatory Guide 7.8 [4].

1.3 Scope

The scope of this calculation is limited to the transportation of the NS15 and NS30 shielded canisters, as defined by drawing X-106-503-SNP [5], within the RH-TRU 72-B packaging with a payload decay heat of fifty (50) watts or less.

2.0 Description of Thermal Design

The Remote-Handled Transuranic Waste Shipping Cask (Model No. RH-TRU 72-B) is an existing Type B packaging designed for the safe transport of remote-handled transuranic (RH-TRU) wastes from various sites around the United States. This section presents a description of the RH-TRU 72-B packaging and the payload canisters, their design features, the payload configurations, and the thermal load conditions evaluated.

2.1 Geometry

Design drawings of the RH-TRU 72-B packaging and the standard waste canisters are presented in the RH-TRU 72-B SAR [2]. Design information for the NS15 and NS30 neutron shield inserts is provided by design drawing X-106-503-SNP [5].

2.2 Principal Design Features

2.2.1 RH-TRU 72-B Packaging

The RH-TRU 72-B packaging is composed of an inner vessel which optionally provides an inner containment boundary, an outer cask which provides an outer containment boundary and acts as an environmental barrier, and energy absorbing impact limiters at each end of the outer cask. Polyurethane foam filled energy absorbers (impact limiters) are attached to each end of the outer cask to provide impact and thermal protection under normal and accident conditions of transport. The empty cask weighs approximately 37,000 lbs. Figure 2-1 illustrates an overview of the RH-TRU 72-B package.

The RH-TRU 72-B Cask is designed with a totally passive thermal system. The principal design features of this system consists of an external thermal fire shield surrounding a 4.375-in. cask wall and polyurethane foam impact limiters protecting the ends of the cask body. The fire shield consists of a 10 gauge stainless steel sheet (0.135-in. thick) offset from the outer cask body by a 12 gauge stainless steel wire wrap (0.105-in. diameter) on a 3-in. pitch. The cylindrical outer cask consists of a 1.50-in. thick, 41.13-in. O.D. stainless steel outer shell, a 1.875-in. thick lead shield, and a 1-in. thick, 32.375-in. I.D. stainless steel inner shell. The outer cask bottom end plate is 5-in. thick stainless steel, while the outer cask lid is 6-in. thick stainless steel. The 32-in. O.D. inner vessel of the cask is constructed of 0.375-in. thick stainless steel with a 1.50-in. thick stainless steel bottom end plate and a 6.50-in. thick stainless steel lid. Butyl rubber containment O-ring seals are used on the inner and outer containment boundaries. Impact protection is provided by polyurethane foam impact limiters covering each end of the outer cask. The polyurethane impact limiters also provide thermal protection during the hypothetical accident condition (HAC) fire.

2.2.2 Waste Canisters

The payload of the RH-TRU 72-B cask will consist of one RH waste canister, either a standard or shielded configuration. This calculation addresses only the NS15 and NS30 shielded waste canister configurations. All RH-TRU waste will be loaded directly into the payload canister or into inner containers which are then overpacked within the payload canister. The standard payload canister uses a 26-in. outside diameter 1/4-in. thin-wall cylinder fabricated of carbon or stainless steel as the outer shell. Including a lift pintle at the top of the payload canister, the overall length is 120½ inches. The payload canister is basically a one- or two-piece construction unit (fixed or removable lid versions, respectively, either of which may be configured with a through-pintle fill port and plug) capable of transporting RH-TRU waste.

This calculation addresses the addition of the NS15 and NS30 neutron shield inserts for the RH waste canister as an authorized payload configuration for shipment in the RH-TRU 72-B packaging. The NS15 and NS30 neutron shielded canisters contain supplemental internal neutron shielding components added to the RH-TRU waste canister assembly (removable lid design) and provide dose rate attenuation for neutron-emitting RH waste. The nominal dimensions for the NS30 and NS15 neutron shielded canisters are provided in drawing X-106-503-SNP [5].

The neutron shielding for the NS15 and NS30 neutron shield inserts is fabricated from pipe-grade extra-high molecular weight (EHMW), high density polyethylene (HDPE) plastic with a cell classification of 345444C or greater per ASTM D3350 [18]. The NS15 shield insert body pipe has a nominal wall thickness of 3.387-in. (3.288-in. minimum) and the NS30 shield insert body pipe has a nominal wall thickness of 1.454-in. (1.412-in. minimum). Both the NS15 and NS30 shield insert body pipes have a 24-in. outside diameter and the shield insert end caps have a nominal wall thickness of 5-in. Figure 2-2 illustrates an overview of the NS15 shielded waste canister. The overview of the NS30 shielded canister is similar except for the wall thickness of the shield insert.

2.3 Methodology

The methodology used to conduct the analysis was as follows:

1. The existing thermal models of the RH-TRU 72-B packaging for the transport of paper and metallic wastes under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) were extracted from Reference [2] safety analysis report. Since these thermal models were developed under an earlier version of SINDA/FLUINT, the models were re-run and the results compared to the original results to ensure that the current version of the code produces similar results.
2. A 'solids' based thermal model of the 72-B canisters with the NS15 and NS30 neutron shield inserts was developed using the Thermal Desktop® computer program. The thermal model simulates the entire canister and included representation of the paper and metallic waste configurations, as appropriate, plus the waste containers that hold the waste.
3. A 'cask and impact limiter only' thermal model for NCT and HAC were created from the existing non-graphical, text based thermal models obtained from the Reference [2] safety analysis report by deleting the thermal definitions for the canister and payload contained within each thermal model.
4. A representation of the interior surfaces for the inner vessel (IV) of the 72-B cask was added to the 'solids' modeling of the NS15 and NS30 shielded canisters. This thermal representation of the IV surfaces is used to generate the radiation and conductance tie-ins between the shielded canisters and the cask and impact limiter portions of the RH-TRU 72-B packaging.
5. The combined thermal models of the shielded canisters and the 72-B packaging are then exercised using the SINDA/FLUINT computer program to predict the thermal performance of the shielded canisters within the 72-B packaging.

2.4 Design Basis Thermal Load Conditions

The shielded waste canister and RH-TRU 72-B package combinations are evaluated in accordance with 10 CFR 71 [1] and Regulatory Guide 7.8 [4] for the applicable NCT thermal loads. The load conditions are defined as follows:

- *NCT Hot*: An ambient temperature of 100 °F is used to evaluate the maximum temperatures within the cask with maximum decay heat and 10 CFR §71.71(c)(1) prescribed insolation (see Table 2-1).
- *NCT Hot, No Solar*: Same as NCT Hot, but without insolation. This case serves as the basis for evaluation of the maximum temperature at the accessible surfaces of the package in accordance with 10 CFR §71.43(g). 10 CFR §71.43(g) stipulates that for exclusive use packages, the maximum accessible surface temperature must be less than 185 °F for this condition.
- *HAC Hot:* Thermal conditions prior to the event are conservatively taken from the *NCT Hot* condition, followed by a thirty-minute transient with an ambient temperature of 1,475 °F with maximum decay heat, and then back to a steady-state ambient temperature of 100 °F with maximum decay heat and insolation per 10CFR71.71(c)(1). This load case evaluates the peak temperature achieved for the various cask components under the HAC fire event and the associated thermal stresses.

Cold environment conditions are not addressed by this evaluation since the minimum temperatures expected within the packaging and payload are bounded by -20 °F and -40 °F uniform temperature conditions established in the RH-TRU 72-B SAR [2].

2.5 Design Basis Thermal Loads

2.5.1 Insolation Loads

Maximum package temperatures with insolation are determined using two alternative methodologies. The first method applies the insolation values delineated in 10 CFR §71.71(c)(1), averaged over 12 hours, in a steady-state model. This action is intended to conservatively bound the transient thermal response that the payload and internal package components have to a diurnal (i.e., cyclic) solar load. The relatively large thermal mass and the polyurethane foam impact limiters will effectively isolate (i.e., decouple) the thermal response of the internal components from the cyclic variation in insolation heating applied to the outside of the package. To account for self-shading provided by the package surfaces in the horizontal orientation, the projected area of the package curved surfaces is used instead of their full area when calculating the total insolation incident on the package. The full surface area is used for all non-curved package surfaces.

To establish the sensitivity of self-shading by the cask on the predicted temperatures, an alternative insolation modeling methodology is also evaluated within this calculation. The alternative methodology consists of applying the 10 CFR §71.71(c)(1) specified 12-hour average insolation boundary condition of 122.92 Btu/hr-ft^2 (i.e., 400 g-cal/cm^2/12 hours) for curved surfaces and 61.46 Btu/hr-ft^2 (i.e., 200 g-cal/cm^2/12 hours) for the vertical surfaces in a transient "12 hours on/12 hours off" model. Instead of projected area, the transient modeling uses the full area of all of the package's exposed surfaces, thus ignoring any credit for self shading on the surfaces of the lower half of the horizontal cask.

A solar absorptivity of 0.52 is assumed for the stainless steel surfaces under NCT conditions. The solar absorptivity is increased to 0.8 after the HAC fire event to account for potential soot accumulation on the package surfaces.

2.5.2 Payload Decay Heat

The package payload is assumed to consist of a paper based waste stream with an assumed maximum decay heat loading of 50 watts. The decay heat is assumed to be equally distributed within the waste volume on a volumetric basis. Approximately the same total volume of waste can be accommodated by either canister design/payload definition. The thermal properties of the paper based waste stream are the same as presented in the RH-TRU 72-B SAR [2].

Table 2-1 - Insolation Data per 10CFR71.71(c)(1)

Form and Location of Surface	Total Insolation for a 12-hour Period (g-cal/cm^2)$^{(1)}$
Flat surfaces transported horizontally; base surface	None
Flat surfaces transported horizontally; all other surfaces	800
Flat surfaces not transported horizontally	200
Curved surfaces	400

Notes:

(1) The 12 hour period covers the daylight hours. Insolation for the remaining 12 hours (nights) is zero. The total insolation values are converted to equivalent hourly average insolation heat flux values by dividing by 12 for evaluation of package temperatures.

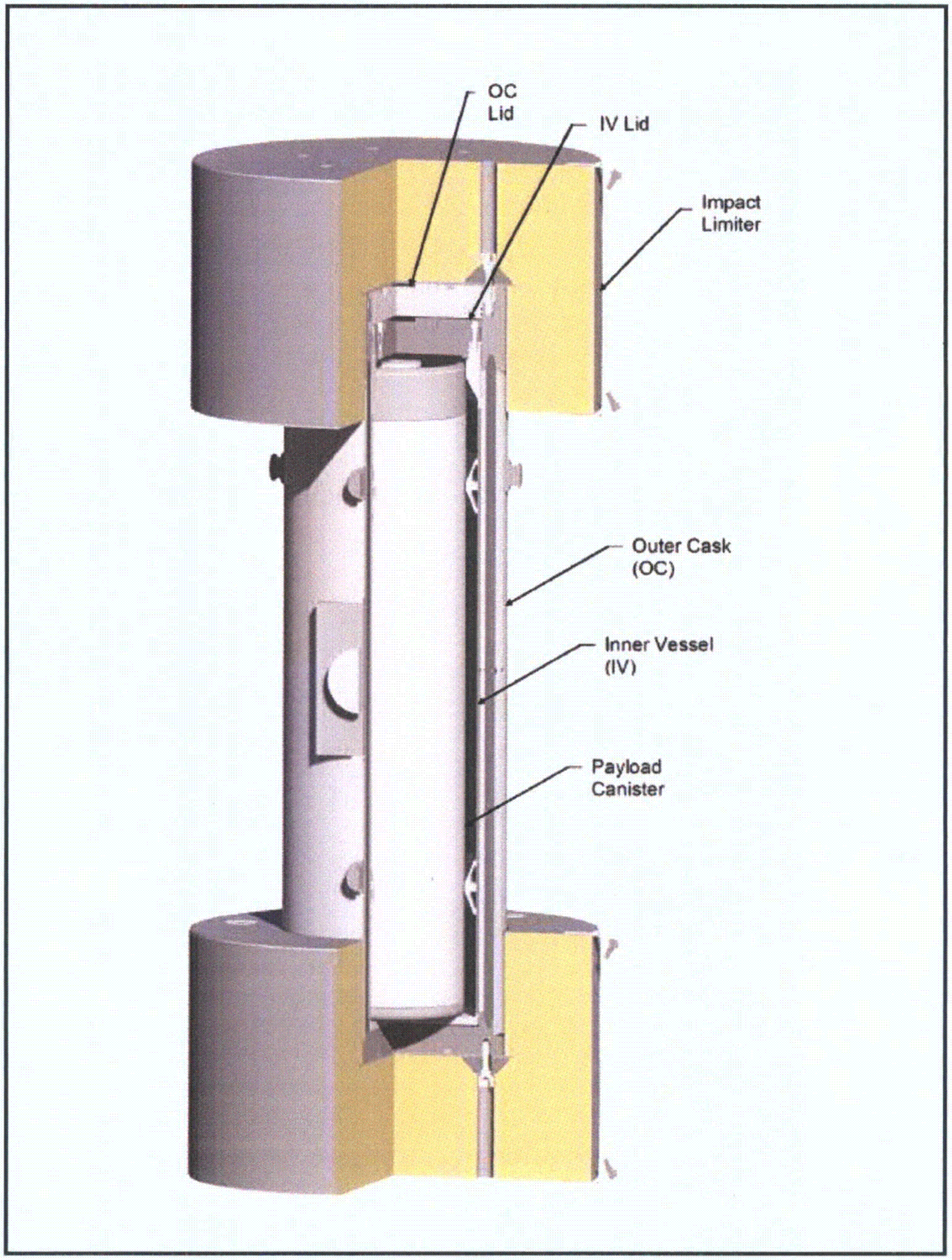

Figure 2-1 - Overview of RH-TRU 72-B Package

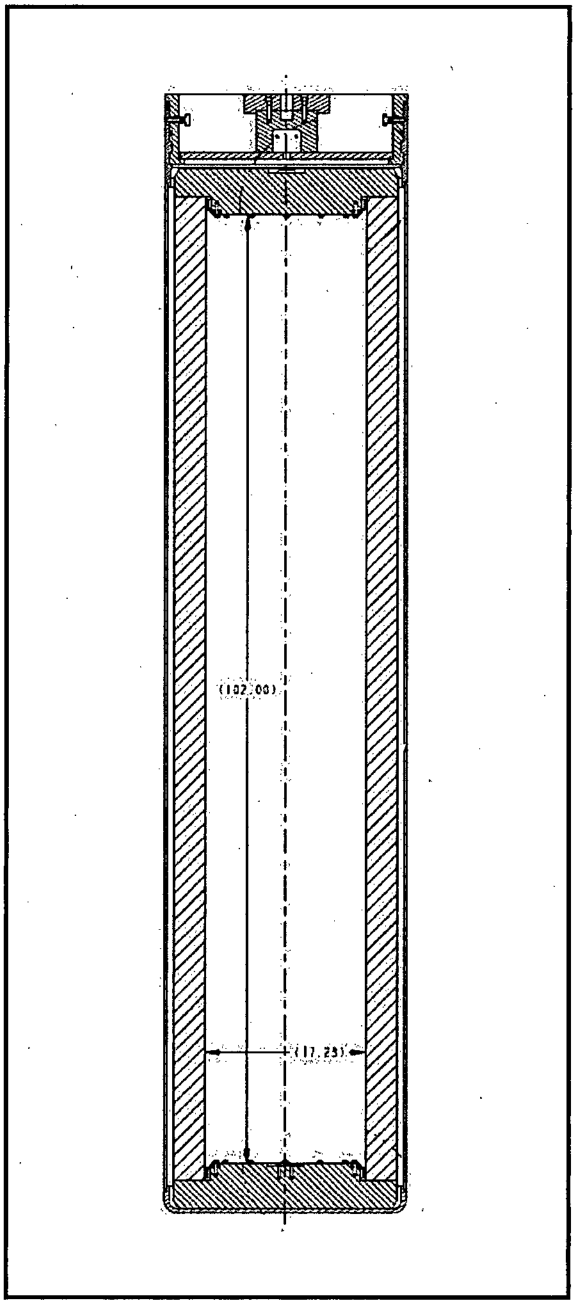

Figure 2-2 - Overview of NS15 Shielded Waste Canister

3.0 Material Specifications

This section presents the thermal properties used in the thermal model of the NS15 and NS30 shielded waste canisters within the RH-TRU 72-B packaging. The RH-TRU 72-B package is fabricated primarily of Type 304 stainless steel, lead, and polyurethane foam. The void spaces within the package are assumed to be filled with air at one atmosphere. Air also fills the gap between the outer cask (OC) outer shell and the thermal shield. The various waste containers to be transported will be constructed of carbon or stainless steel.

The shielded canister shell may be fabricated from carbon or stainless steel. For the purposes of this analysis the shell material is assumed to be ASTM A516 carbon steel since both the higher thermal conductivity and emissivity of carbon steel will bound the canister temperatures achieved under HAC conditions with stainless steel. The shield inserts are fabricated of high density polyethylene (HDPE) material. The void spaces within the waste canisters are assumed to be filled with air at one atmosphere.

3.1 Summary of Thermal Properties

The thermal properties for the RH-TRU 72-B packaging components are documented in the RH-TRU 72-B SAR [2].

The thermal properties of A516 carbon steel assumed for the fabrication of the waste canisters presented in Table 3-1 are taken from Table TCD, material group B, of the ASME Boiler and Pressure Vessel Code [7]. The density of A516 carbon steel is taken from an on-line database [8].

The thermal properties of the HDPE shielding material used for the NS15 and NS30 shield inserts is based on DriscoPlex® pipe material [6] (see product data sheet in Appendix 7.6). The thermal properties of the material presented in Table 3-2 are taken from [9], while its density is obtained from the product datasheet. A single, non-temperature dependent point is used since over the typical working temperature range the thermal conductivity is essentially constant with temperature [9].

The thermal properties for air presented in Table 3-3 are derived from curve fits provided in [10]. Because the thermal conductivity of air varies significantly with temperature, the computer model calculates the thermal conductivity across the various air spaces as a function of the mean film temperature.

The payload within the shielded canisters is conservatively assumed to be paper and to exhibit the thermal conductivity of air in order to bound the potential temperature rise and temperature limit within the payload. This modeling assumption is consistent with the treatment established in the RH-TRU 72-B SAR [2] for paper based payloads.

3.2 Emissivity, Absorption, & Transmittance Data

Table 3-4 presents the surface emissivity assumed for the various surfaces in the shielded canister thermal model. The optical properties are based on the information contained in [11]. The emissivity and solar absorptivity for the RH-TRU 72-B packaging materials are documented in the safety analysis report [2].

3.3 Technical Specification of Components

The materials used in the RH-TRU 72-B package that are considered to be temperature sensitive are the butyl used for the O-ring seals and the polyurethane foam used in the impact limiters.

The RH-TRU 72-B SAR [2] presents the basis for the temperature limitations of the butyl rubber O-ring seals and the polyurethane foam. Per the RH-TRU 72-B SAR, the butyl rubber O-ring seals have an allowable temperature range of -40 °F to 225 °F and a short duration (8 hours) upper temperature limit of 360 °F. The allowable temperature range for the polyurethane foam during impact loadings is -20 °F to 300 °F. Temperature excursions between -40 °F and 300 °F will not permanently degrade the properties of the foam. No temperature limit exists for the polyurethane foam under the hypothetical accident condition (HAC) since the failure of the foam via thermal decomposition provides a principle thermal protection mechanism under elevated temperature conditions. Foam performance under hypothetical accident condition (HAC) transient conditions is discussed in Section 3.5 of the RH-TRU 72-B SAR [2].

Other package materials are stainless steel and lead. The melting points for these materials are 2,600 °F and 620 °F, respectively. The carbon steel, which may be used in the waste containers and the payload canister, has a melting temperature of approximately 2,750 °F. In compliance with the ASME B&PV Code [19], the allowable temperature for stainless steel under NCT conditions is limited to 800 °F if the component serves a structural purpose (e.g., the IV shell, the OC inner and outer shell, lid, and trunnions). While a higher, short-term temperature is permissible under HAC conditions, the NCT limit of 800 °F is conservatively applied for the HAC condition as well.

The design temperature limit for the HDPE used for the shielded inserts is assumed to be the vicat softening temperature. Per data sheet in Appendix 7.6, the vicat softening temperature for the pipe-grade HDPE considered for this evaluation is 256 °F.

No specific temperature limit exists for the waste payload. Instead, the temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].

Table 3-1 - Thermal Properties of ASTM A516 Carbon Steel

Temperature (°F)	Density (lb_m/in^3)	Thermal Conductivity (Btu/hr-ft-°F)	Specific Heat (Btu/lb_m-°F)
70	0.284	23.6	0.106
100		23.9	0.110
150		24.2	0.114
200		24.4	0.118
250		24.4	0.121
300		24.4	0.123
400		24.2	0.128

Table 3-2 - Thermal Properties of HDPE

Temperature (°F)	Density (lb_m/in^3)	Thermal Conductivity (Btu/hr-ft-°F)	Specific Heat (Btu/lb_m-°F)
-	0.035	0.25	0.46

Table 3-3 - Thermal Properties of Air

Temperature (°F)	Density lb_m/in^3)	Specific Heat (Btu/lb_m-°F)	Dynamic Viscosity (lb_m /ft-hr)	Thermal Conductivity (Btu/hr-ft-°F)	Prandtl No.	Coef. Of Thermal Exp. (°R^{-1})
-40	Use Ideal Gas Law w/ Molecular wt = 28.966 g/mole	0.240	0.03673	0.0121	Compute as $Pr = c_p\mu / k$	Compute as $\beta = 1/(°F+459.67)$
0		0.240	0.03953	0.0131		
50		0.240	0.04288	0.0143		
100		0.241	0.04607	0.0155		
200		0.242	0.05207	0.0178		
300		0.243	0.05764	0.0199		
400		0.245	0.06286	0.0220		

Table 3-4 - Surface Emissivity

Material	Assumed Conditions	Assumed Emissivity (ε)
Canister Shell (Carbon Steel)	Painted	0.8
HDPE Surfaces	Black	0.85
Inner Waste Containers Shell (Carbon Steel)	Oxidized or painted	0.8

4.0 Thermal Evaluation under Normal Conditions of Transport

This section presents the thermal analysis methodology and the evaluation of the thermal performance for the NS15 and NS30 shielded canisters and the RH-TRU 72-B packaging combination under NCT conditions to demonstrate compliance with the requirements of 10 CFR §71.43(g) and §71.71. The thermal evaluations are performed using conservative analytical techniques to assure that all materials are maintained within their applicable minimum and maximum allowable temperature during all modes of operation.

4.1 Thermal Model for NCT

The analytical thermal model of the shielded canisters within the RH-TRU 72-B packaging are developed for use with the Thermal Desktop® [12] and SINDA/FLUINT [13] computer programs. These programs work together to provide the functions needed to build, exercise, and post-process a thermal model. The SINDA/FLUINT and Thermal Desktop® computer programs have been validated for safety basis calculations for nuclear related projects [14].

The analytical thermal model of the RH-TRU 72-B packaging developed for the RH-TRU 72-B SAR [2] is re-used for the purposes of this calculation. The thermal model is set up as an axisymmetric, lumped-parameter, finite-difference 360° model. Complete details of the cask and impact limiter modeling are provided in the RH-TRU 72-B SAR. A summary description is also provided in Appendix 7.4.1. The NCT thermal evaluations assumed that the package is in its normal horizontal orientation for transportation.

The thermal modeling of the NS15 and NS30 shielded canister payloads are developed using the Thermal Desktop® computer program based on drawing X-106-503-SNP [5]. With the exception of the payload definition and the thickness of the high density polyethylene (HDPE) used for shielding, identical modeling approaches are used for the thermal models for the two canister designs. Approximately 1,270 thermal nodes are used to define and simulate the NS15 canister design and its enclosed payload, while approximately 1,385 thermal nodes are used for the NS30 canister design.

Waste will not be directly loaded into the NS15 shielded canister. Instead, the wasted is assumed to be contained within three (3) approximately 15-gallon waste containers which are then overpacked by the NS15 canister. Three alternative arrangements of the containers within the NS15 canister were examined to determine the sensitivity of the results to the use and placement of dunnage. While the results indicate a general insensitivity to container placement within the canister, the stacking of the three waste containers against the base of the canister was shown to yield a slightly higher (i.e., ≈2°F) payload temperature than the other placement assumptions.

The heat transfer between the various components within the shielded canisters is via radiation and conduction. All void spaces within the canister and cask cavity are assumed to be filled with air at atmospheric pressure.

A similar modeling approach is used for the payload definition for the NS30 canister, except that the waste is assumed to be contained within six (6) approximately 8-gallon containers that, in turn, are housed within three (3) approximately 30-gallon waste containers.

A paper based waste stream is assumed for the payload with a maximum decay heat loading of 50 watts for either canister configuration. The decay heat is assumed to be equally distributed within the waste volume on a volumetric basis. This is the same modeling approach used in the RH-TRU 72-B SAR [2].

Details of the thermal modeling used for the NS15 and NS30 shielded canister configurations are provided in Appendix 7.4.2.

4.2 Heat and Cold

4.2.1 Maximum Temperatures for NCT Conditions

Two ambient conditions are evaluated for NCT conditions: NCT Hot (i.e., 100 °F with regulatory solar averaged over 12 hours) and NCT Hot, No Solar (i.e., 100 °F with no insolation loading). See Section 2.4 for a description of each ambient condition. Table 4-1 presents the resulting package temperatures for the transportation of the NS15 shielded canister, while Table 4-2 presents the same type of results for the NS30 shielded canister. The maximum temperatures seen for the NS15 and NS30 neutron shield inserts are 141 °F and 137 °F, respectively. The temperature levels achieved under NCT conditions demonstrate that all component temperatures for the NS15 and NS30 canister configurations are within their respective limits.

Figure 4-1 illustrates the temperature distribution within the NS15 shielded canister and payload under the NCT Hot condition. The temperature distribution on the left side of the figure includes the waste drums and waste payload, while the illustration on the right side of the figure presents the temperature distribution within the canister shell and the NS15 shield insert only. Figure 4-2 illustrates similar temperature distributions for the NS30 shielded canister.

Since no specific dunnage is defined for the NS15 and NS30 shielded canisters, the sensitivity of the results to the placement of the waste containers within the shielded canisters was evaluated. The evaluation was conducted for the NS15 canister by considering two alternative placements besides the stacking of the three waste containers against the base of the canister. These alternative placements were 1) the stacking of the three waste containers against the lid of the canister (i.e., the 'top position'), and 2) the centering of the three waste containers within the canister (i.e.,, the 'middle position'). The evaluation showed that the temperature results are essentially insensitive to the stacking arrangement with the middle positioning yielding the lowest peak payload temperature and the bottom positioning the highest. However, the difference in the peak payload temperature between these two positions is only 2°F (see Figure 4-1 and Figure 4-3).

To assess the effect of eccentric placement within the horizontal cask, another sensitivity evaluation was conducted using the 'bottom position' waste container arrangement as described above. The changes to the thermal modeling for the eccentric placement consisted of reducing the mean gap between the lower half of the horizontally oriented drums, HDPE poly insert, and canister and their adjacent component to approximately one half of the gap assumed for the concentric placement of the components. The corresponding mean gap between the upper half of these same components was increased by approximately 50% over that assumed for the concentric placement of the components. The thermal conductance due to the line contact between the components is conservatively ignored. All other aspects of the thermal model remained the same as discussed above. The net thermal impact was a very slight (i.e., ≤ 0.2°F) decrease in the peak payload and HDPE temperatures. The results demonstrate that, given the low decay heat considered for the shielded canisters, the reduction in thermal resistance over the bottom half of the payload and HDPE insert offset the increased thermal resistance over the upper half.

It should be noted that the cask design includes a support structure to limit the eccentric offset of the canister when the cask is in the horizontal position such that a minimum radial gap of 2.375-inches would exist. This gap is only 0.25-inch smaller than that existing for the concentric placement of a canister with the nominal diameter.

4.2.2 Maximum Temperatures for NCT Conditions with Alternative Insolation Modeling

The sensitivity of the predicted package temperatures to the assumed level self-shading contained within the insolation modeling approach used for the Section 4.2.1 steady-state evaluations was established for the NCT Hot condition using an alternative insolation modeling methodology. This alternative methodology consists of applying the 10 CFR §71.71(c)(1) specified 12-hour average insolation boundary condition of 122.92 Btu/hr-ft^2 for the curved surfaces and 61.46 Btu/hr-ft^2 for the vertical surfaces in a transient "12 hours on/12 hours off" model. Unlike the steady-state modeling approached used in the Section 4.2.1 evaluations, no credit is taken for self shading of the surfaces on the lower half of the horizontal cask. Table 4-3 presents a summary comparison of the results for this alternative insolation modeling methodology versus those obtained using the Section 4.2.1 steady-state modeling approach. As expected, without credit for self shading, the 2-D axisymmetric model of the cask yields higher peak cask component temperatures. However, the 9 to 16°F increase in the cask structural component temperatures is insignificant in comparison with the available thermal margin for each component. The associated increase in the shielded canister insert and waste centerline temperatures is between 5 to 9°F. All package component temperatures remain within the NCT allowable temperature limits under either insolation modeling approach.

Figure 4-4 and Figure 4-5 illustrate the temperature response of selected cask and NS15 shielded canister components to the transient "12 hours on/12 hours off" modeling of the insolation loading starting with the initial temperatures at the steady-state condition with no insolation. The figures demonstrate that several days of exposure to the NCT Hot condition are required for the cask and shielded canister components to approach their peak temperature points. The peak waste centerline temperature will not be achieved for nearly a month. Figure 4-6 illustrates a similar transient response for the NS30 shielded canister payload.

4.2.3 Minimum Temperatures for NCT Conditions

Cold environment conditions are not addressed by this evaluation since, given sufficient time, the minimum temperatures expected within the packaging and payload are bounded by -20 °F and -40 °F uniform temperature conditions established in the RH-TRU 72-B SAR [2]. These minimum temperature levels are within the allowable temperature limits for all components of the NS15 and NS30 shielded canisters.

4.3 Maximum Normal Operating Pressure

The RH-TRU 72-B package has a design pressure of 150 psig. The major factors affecting the pressure within the sealed IV are:

- Radiolytic gas generation (or consumption),
- Temperature-related pressure change,
- Barometric pressure change,

- Chemical reactions,
- Biological gas generation, and/or
- Thermal decomposition.

The determination of the maximum normal operating pressure (MNOP) is not within the scope of this calculation.

4.4 Evaluation of Package Performance for Normal Conditions of Transport

The combined thermal performance of the NS15 and NS30 shielded RH waste canisters in the RH-TRU 72-B packaging has been evaluated for the applicable NCT conditions of transportation and for a maximum decay heat loading of 50 W within the canisters. The evaluations found that the resulting component temperatures remained within their specified allowable limits for all cases. Further, the computed temperatures for the RH-TRU 72-B packaging components were essentially the same as those predicted in the RH-TRU 72-B SAR [2] for similar ambient conditions. Thus the NS15 and NS30 shielded RH waste canisters will not impact the safety basis of the RH-TRU 72-B packaging.

Alternative methodologies for applying the specified 10 CFR §71.71(c)(1) insolation boundary condition were evaluated. In addition to using a steady-state model with credit for self shading of the surfaces on the lower half of the horizontal cask as used for the RH-72B SAR [2] evaluations, this calculation also evaluated the impact of applying the insolation loads in a transient "12 hours on/12 hours off" method without credit for self shading. As expected, without credit for self shading, the 2-D axisymmetric model of the cask yields peak cask component temperatures that are 9 to 16°F higher than those seen with the steady-state SAR insolation modeling approach. This level of temperature increase is insignificant in comparison with the available thermal margin for each component and all component temperatures remain within their respective NCT allowable temperature limits. The associated increase in the shielded canister insert and waste centerline temperatures is 5 to 9°F. Given that the canister and cask geometries are the same and the decay heat distribution is similar, a similar change in the peak component temperatures would occur for the existing RH-72B SAR evaluations. As such, there is no impact on the thermal safety basis of the RH-TRU 72-B packaging if the alternative insolation modeling method without credit for cask self shading is used.

Table 4-1 - Maximum NCT Temperatures for NS15 Shielded Canister

Location / Component	Temperature (°F) [1]		
	NCT With Insolation	NCT Without Insolation	Allowable Temperature
Waste Centerline	247	225	N/A [2]
NS15 Shield Insert	141	119	256
Canister Shell	133	111	2,600
IV Shell	128	105	800
IV Void Space Bulk Avg	127	104	N/A
OC Inner Shell	126	103	800
OC Lead Shield	126	103	620
OC Outer Shell	126	103	800
OC Thermal Shield	125	103	185
OC Upper Ring Forging	125	102	800
IV O-Ring Seal	125	103	225
OC O-Ring Seal	125	102	225
IV Lid	125	103	800
OC Lid	125	103	800
Impact Limiter Foam	132	104	300
Impact Limiter Shell	133	105	185

Table Note: 1) Temperatures assume a total payload decay heat loading of 50 W.

2) The temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].

Table 4-2 - Maximum NCT Temperatures for NS30 Shielded Canister

Location / Component	Temperature (°F) [1]		
	NCT With Insolation	NCT Without Insolation	Allowable Temperature
Waste Centerline	234	214	N/A[2]
NS30 Shield Insert	137	115	256
Canister Shell	132	110	2,600
IV Shell	128	105	800
IV Void Space Bulk Avg	127	104	N/A
OC Inner Shell	126	103	800
OC Lead Shield	126	103	620
OC Outer Shell	126	103	800
OC Thermal Shield	125	103	185
OC Upper Ring Forging	125	103	800
IV O-Ring Seal	126	103	225
OC O-Ring Seal	125	103	225
IV Lid	126	103	800
OC Lid	125	103	800
Impact Limiter Foam	132	104	300
Impact Limiter Shell	133	105	185

Table Note: 1) Temperatures assume a total payload decay heat loading of 50 W.

2) The temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].

Table 4-3 - NCT Thermal Sensitivity to Insolation Modeling Methodology

Location / Component	Temperature (°F) [1]				
	NS15		NS30		Allowable Temperature
	NCT With 12 Hr Averaged Insolation [2]	12 Hr On/Off Transient Cycle [3]	NCT With 12 Hr Averaged Insolation [2]	12 Hr On/Off Transient Cycle [3]	
Waste Centerline	247	252	234	241	N/A [4]
NSXX Shield Insert	141	149 Max 143 Avg.	137	146 Max 142 Avg.	256
Canister Shell	133	143 Max 140 Avg. [5]	132	143 Max 140 Avg. [5]	2,600
IV Shell	128	141 Max 135 Avg. [5]	128	141 Max 135 Avg. [5]	800
IV Void Space Bulk Avg	127	142	127	142	N/A
OC Inner Shell	126	142	126	142	800
OC Lead Shield	126	142	126	142	620
OC Outer Shell	126	142 Max 132 Avg. [5]	126	142 Max 132 Avg. [5]	800
OC Thermal Shield	125	146	125	146	2,600 [6]
OC Upper Ring Forging	125	135	125	135	800
IV O-Ring Seal	125	134	126	134	225
OC O-Ring Seal	125	134	125	134	225
IV Lid	125	135	126	135	800
OC Lid	125	134	125	134	800
Impact Limiter Foam	132	150 Max 133 Avg.	132	150 Max 133 Avg.	300
Impact Limiter Shell	133	158	133	158	2,600 [6]

Table Note: 1) Temperatures assume a total payload decay heat loading of 50 W.
2) Steady-state modeling that includes credit for self-shading of lower half of horizontal cask.
3) Modeling ignores self-shading of lower half of horizontal cask. Insolation applied equally around entire circumference of cask body.
4) The temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].
5) Average of maximum temperatures over a 24 hour period.
6) 185°F temperature limit applies only for no solar condition.

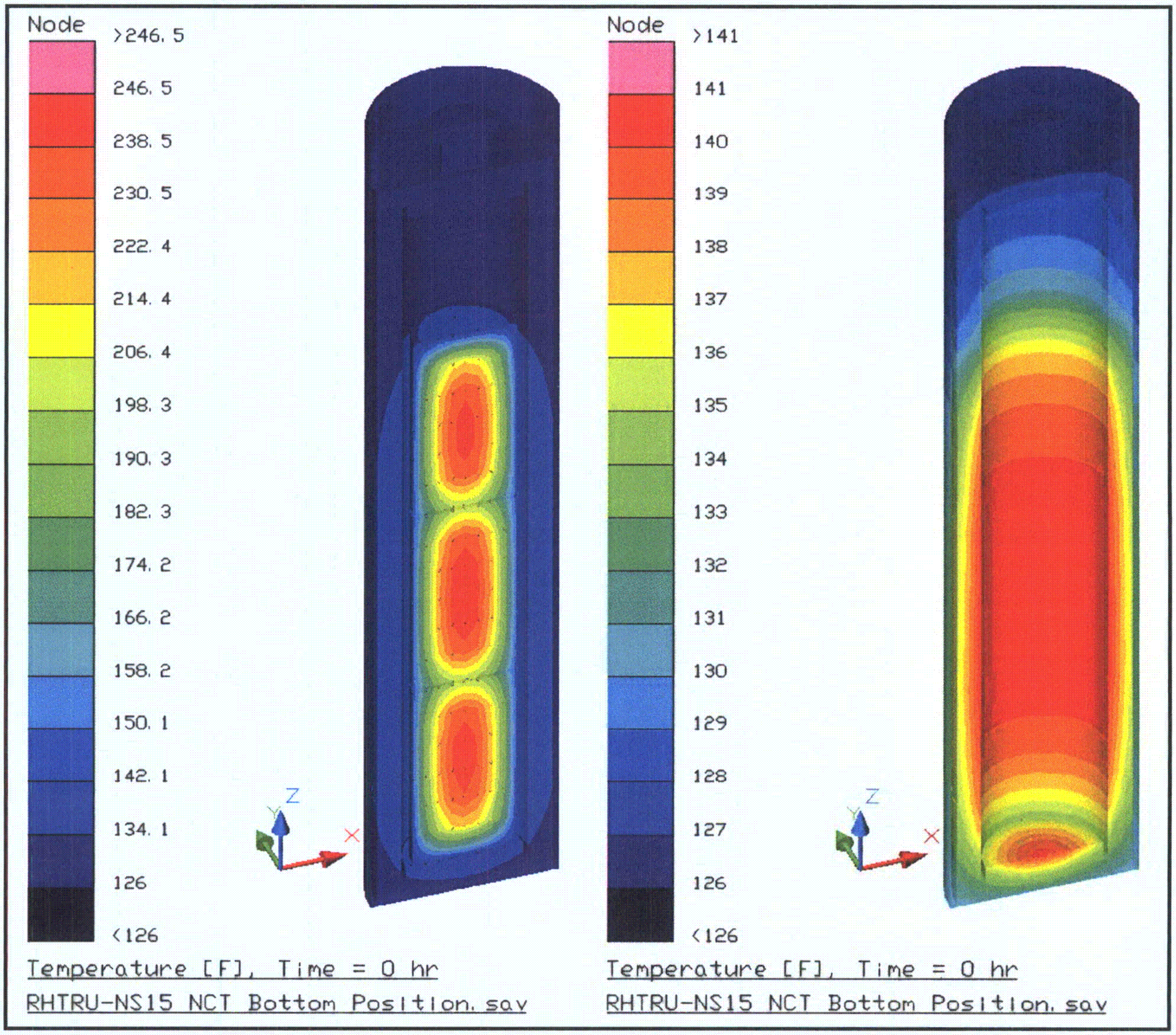

Figure 4-1 - NCT Temperature Distribution within NS15 Shielded Canister

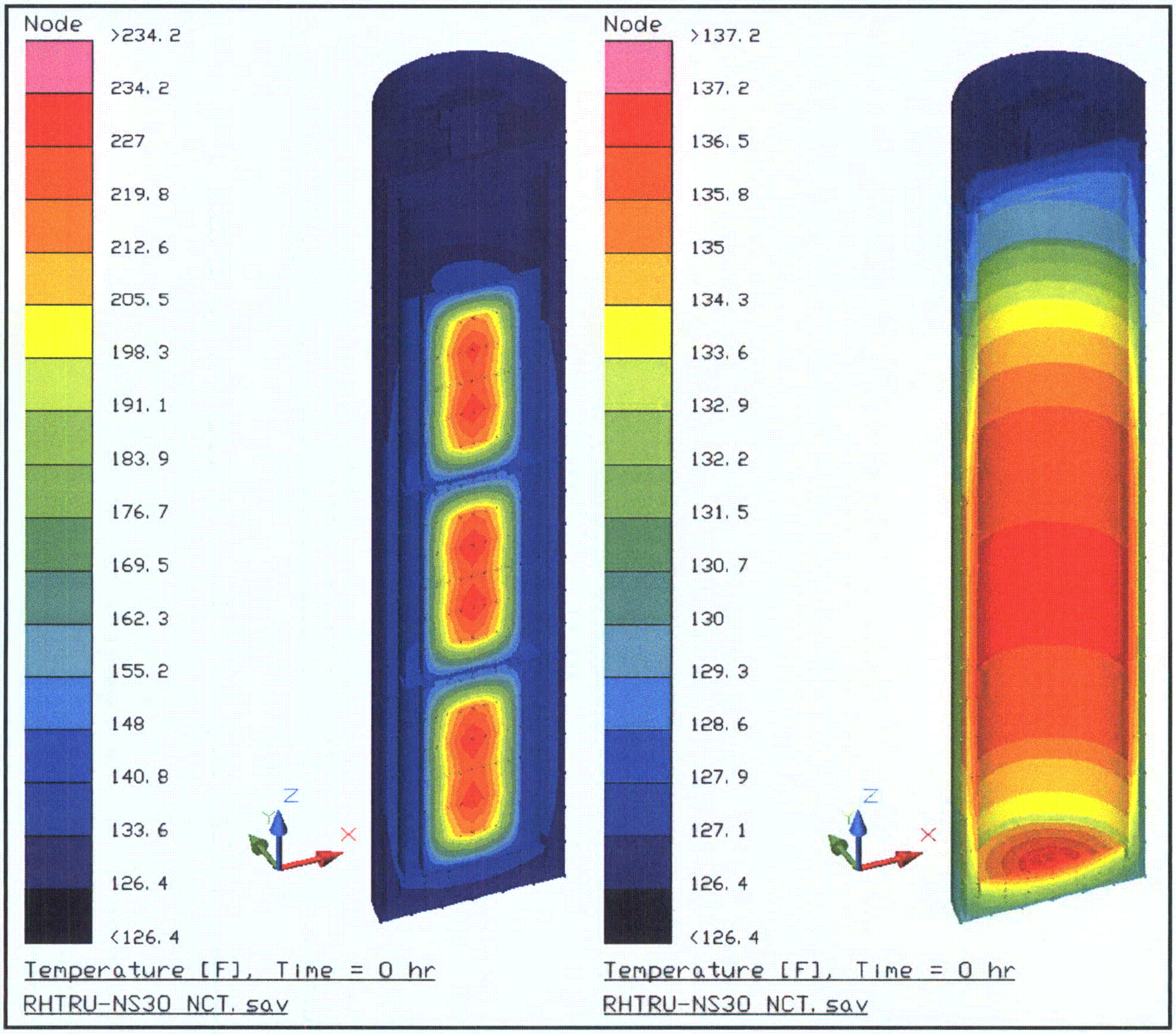

Figure 4-2 - NCT Temperature Distribution within NS30 Shielded Canister

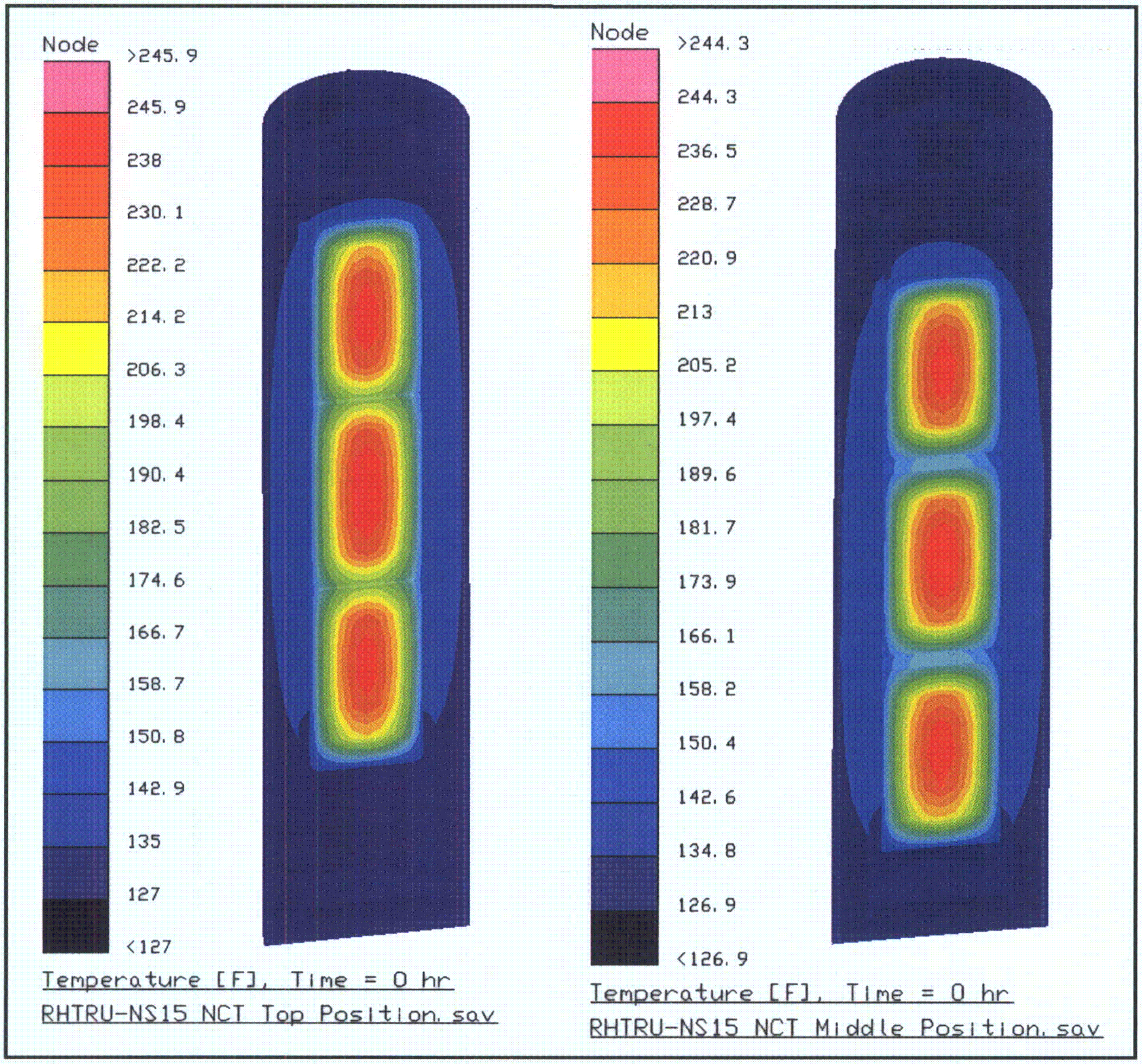

Figure 4-3 - NCT Temperature Distribution for Alternative NS15 Shielded Canister Waste Positioning

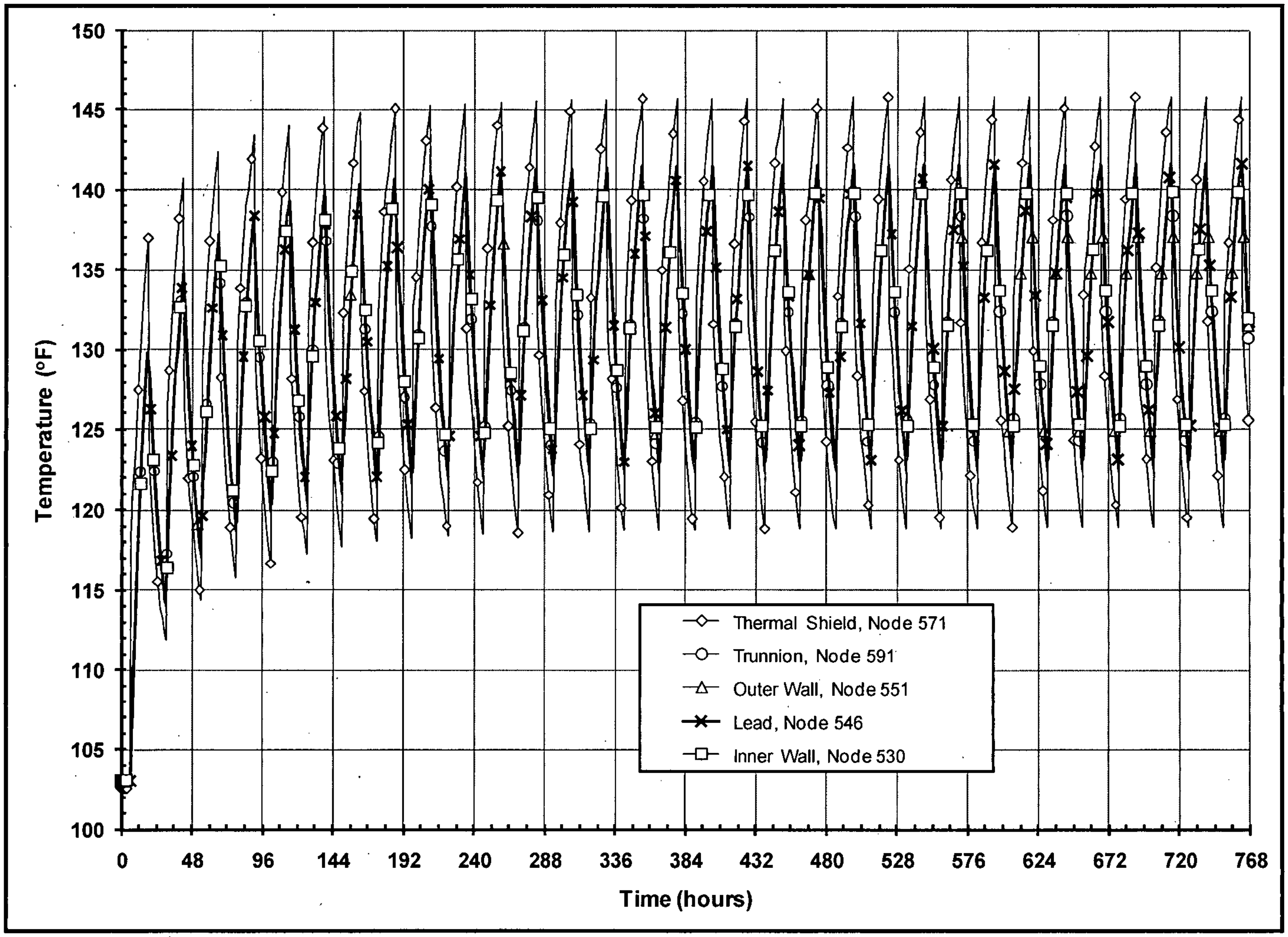

Figure 4-4 - Cask NCT Temperature Response for Transient Insolation Modeling

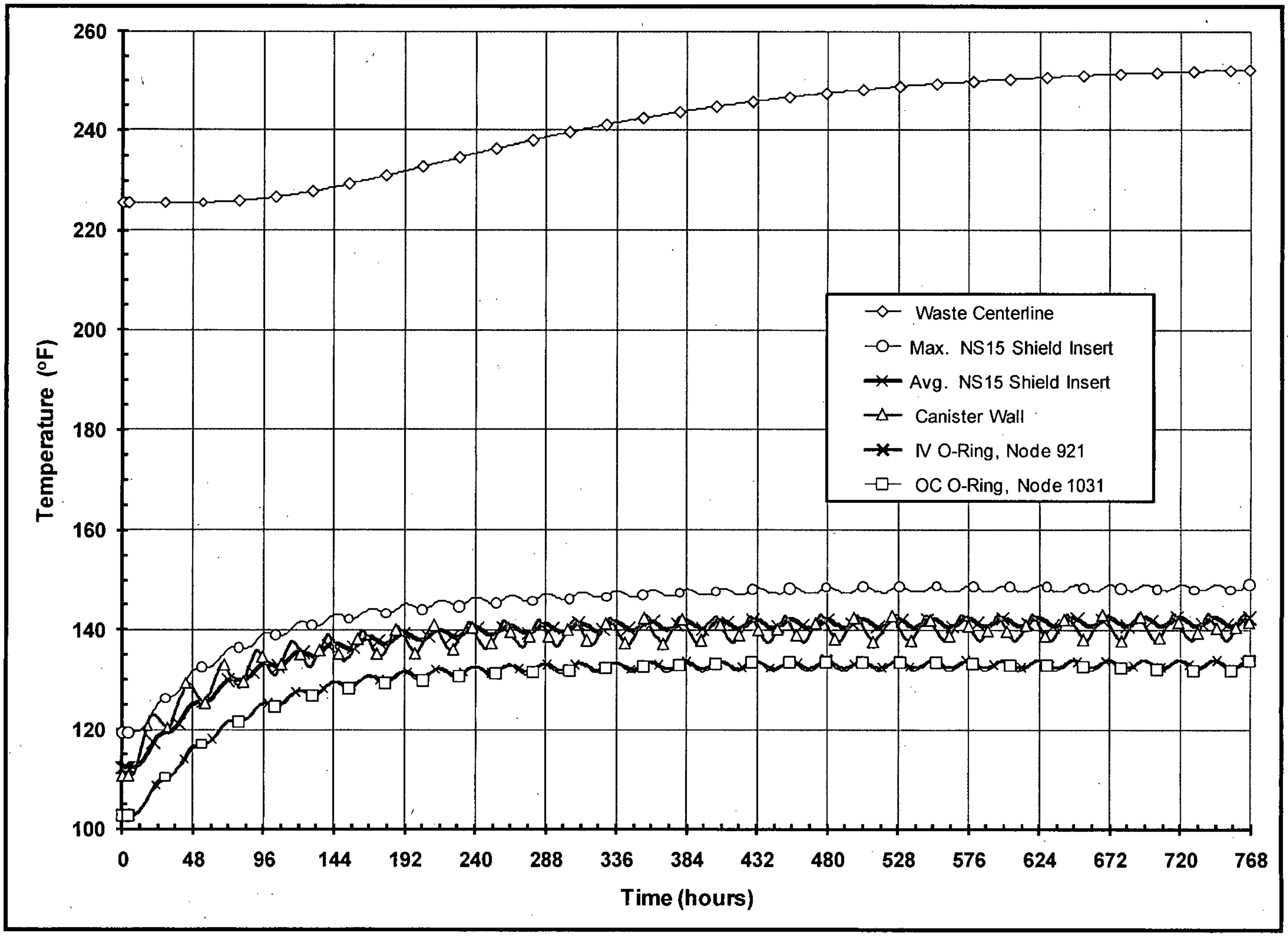

Figure 4-5 - NS15 Shielded Canister Temperature Response for Transient Insolation Modeling

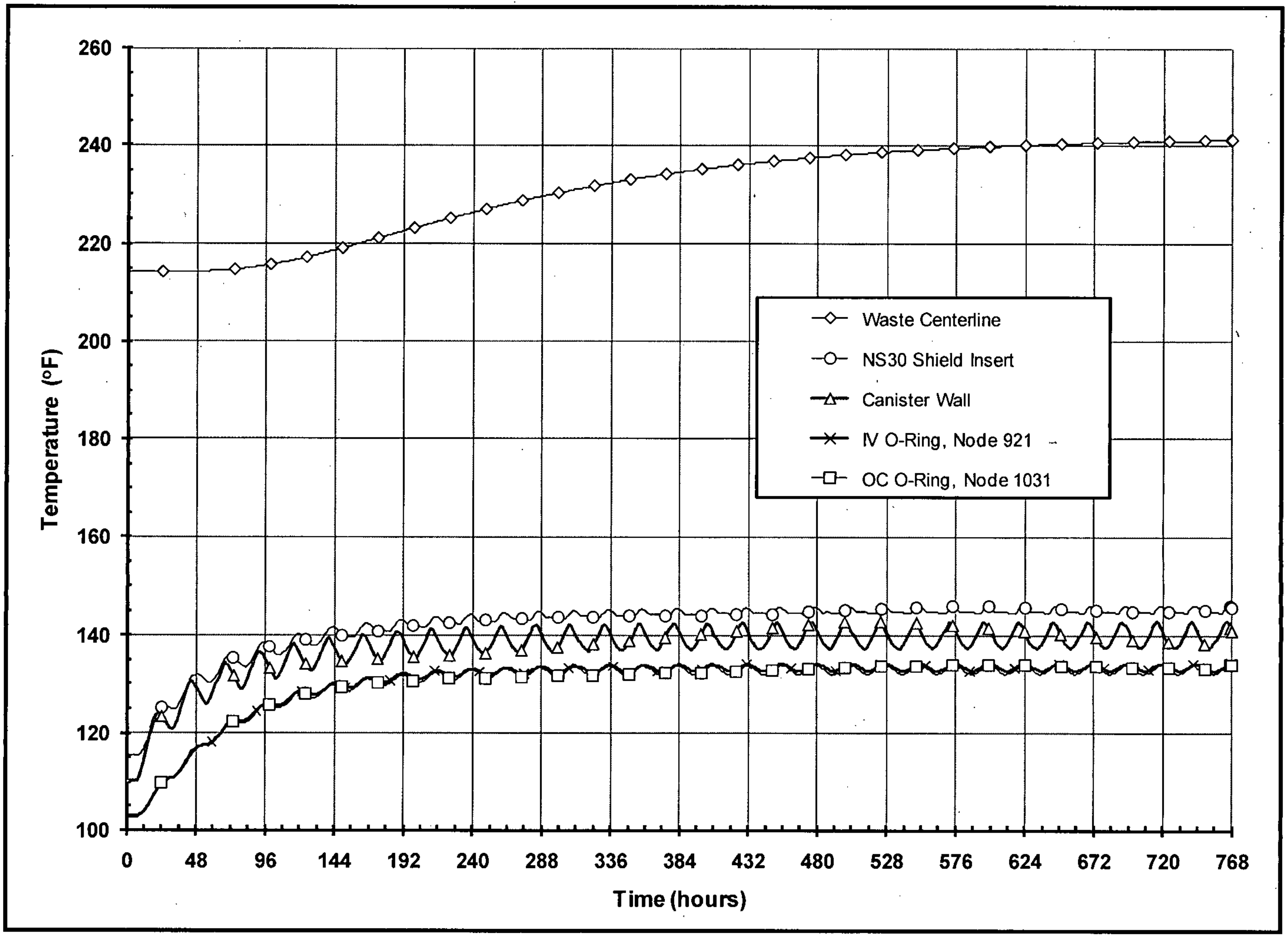

Figure 4-6 - NS30 Shielded Canister Temperature Response for Transient Insolation Modeling

5.0 Thermal Evaluation under Hypothetical Accident Conditions

This section presents the thermal analysis methodology and the evaluation of the thermal performance for the NS15 and NS30 shielded canisters and the RH-TRU 72-B packaging combination under the hypothetical accident condition (HAC) specified in 10 CFR §71.73(c)(4).

5.1 Initial Conditions

The initial conditions assumed for the package prior to the HAC event are described in the RH-TRU 72-B SAR [2]. A summary of the modifications made to the NCT thermal model of the packaging to simulate the assumed package conditions prior to and during the HAC event are as follows:

- The simulated worst-case damage arising from the postulated HAC free and puncture drops were made to the impact limiters. This included reducing the foam thickness to bound the amount of foam lost due to thermal decomposition during the fire event,
- No significant thermal damage is predicted for the RH-TRU 72-B cask body as a result of the free drop events,
- Included credit for the thermal conductance through the wire wrap supporting the thermal shield to maximize the heat flow into the package. This conductance was conservatively ignored for NCT,
- Increased the emissivity of all external surfaces to 0.8 and the solar absorptivity to account for possible oxidation and/or soot accumulation on the surfaces,
- Assumed an initial temperature distribution within the package equivalent to the steady-state conditions with a 100 °F ambient and no insolation.

The RH-TRU 72-B SAR [2] describes the initial conditions and the expected level of damage sustained by the RH-TRU 72-B package from the 10 CFR 71.73 prescribed free and puncture drops. The total gross weight of the loaded NS15 or NS30 shielded canisters is 3,100 lb, or a factor of approximately 2.6 less than the 8,000 lb gross weight for the removable or fixed lid standard payload canisters. As such, the expected level of package damage would be less with an NS15 or NS30 shielded canister payload. Free drop testing of an NS30 shielded canister, which structurally bounds the NS15 shielded canister, in a RH-TRU 72-B surrogate test fixture demonstrated that no significant damage is sustained by the shield insert as a result of the free drop [17]. Therefore, the analytical models of the shielded canisters for NCT condition described in Appendix 7.4.2 are also valid for the HAC evaluation.

5.2 Fire Test Conditions

The fire test conditions analyzed to address the 10 CFR §71.73(c) requirements are as follows:

- The initial ambient conditions are assumed to be 100 °F ambient with no insolation,
- At time = 0, a fully engulfing fire environment consisting of a 1,475 °F ambient with an effective emissivity of 0.9 is used to simulate the average flame temperature of the hydrocarbon fuel/air fire event.

- The convection heat transfer coefficients between the package and the ambient during the 30-minute fire event are based on an average gas velocity of 9 m/sec. Following the 30-minute fire event the convection coefficients are based on still air,
- The ambient condition of 100 °F with insolation is assumed following the 30-minute fire event. A solar absorptivity of 0.8 is assumed for the exterior surfaces to account for potential soot accumulation on the package surfaces.

The transient analysis is continued for 11.5 hours after the end of the 30-minute fire to capture the peak package temperatures. The peak O-ring seal temperatures were determined by extending the transient time period to 24 hours.

5.3 Maximum Temperatures and Pressure

Table 5-1 and Table 5-2 present the predicted maximum temperatures for NS15 and NS30 shielded canister configurations, respectively, under HAC conditions. The results show that all component temperatures remain with allowable limits. The peak temperature of the HDPE shield inserts is seen to remain below the design limit of 256 °F for both configurations. Further, the fact that the canister shell also remains below this temperature level demonstrates that the HDPE temperature limit would not have been exceeded even if direct contact existed between the components. The logic behind this conclusion is as follows: The alternative arrangement of assuming a tight contact between the bases of the insert and canister shell will yield lower transient peak temperatures under HAC conditions for the base of the canister shell since the thermal mass of the HDPE insert would be closely coupled to the canister base and thus help absorb the transient heat flux during the fire event yielding a lower peak canister base temperature than would be achieved with no contact. Therefore, the peak canister temperature achieved under HAC conditions without contact with the HDPE insert will bound that achieved with contact and will also bound the peak HDPE insert temperature achieved with and without contact.

Figure 5-1 illustrates the temperature response of the RH-TRU 72-B packaging with the NS15 canister payload. A similar response is seen with the NS30 canister. The illustrated temperature response is essentially the same as presented in the RH-TRU 72-B SAR [2]. Figure 5-2 and Figure 5-3 illustrate the temperature response of the NS15 and NS30 canister payloads, respectively.

Similar to the NCT evaluation, the HAC evaluations were repeated to establish the sensitivity to the level of self-shading assumed by the insolation modeling approach used for the RH-72B SAR [2] evaluations (see the discussion in Section 4.2.2). The change in insolation modeling methodology has no effect on the pre-fire and end of fire peak temperatures since the effects of insolation are ignored prior to and during the 30-minute fire event (per [3]). Table 5-3 presents a summary comparison of the post-fire peak temperature results obtained using a transient "12 hours on/12 hours off" model without credit for self shading versus those obtained using a steady-state modeling approach with 12 hour averaged insolation levels and credit for self shading. With the exception of the waste centerline temperature, the peak component temperature achieved during the HAC event remain unchanged from those presented in Table 5-1 and Table 5-2.

As seen with the NCT evaluations, the 2-D axisymmetric model of the cask yields higher predicted peak post-fire component temperatures when no credit is taken for self shading. The level of difference yielded by the two insolation modeling methodologies is similar to those seen for the NCT evaluations, with a 9 to 18°F increase in the cask structural component temperatures resulting if no credit for self shading is taken. Again, this level of temperature increase is insignificant in comparison with the available thermal margin for each component. The associated increase in the shielded canister insert and waste centerline temperatures is between 5 to 9°F. All package component temperatures remain within their HAC allowable temperature limits.

5.4 Maximum Thermal Stresses

The temperature levels and transient response seen for the NS15 and NS30 canisters under HAC conditions are similar to that seen for the base payload for the RH-TRU 72-B packaging. As such, the thermal stresses presented in the RH-TRU 72-B SAR [2] are also applicable to the NS15 and NS30 canisters.

5.5 Evaluation of Package Performance for Hypothetical Accident Conditions of Transport

The combined thermal performance of the NS15 and NS30 shielded RH waste canisters in the RH-TRU 72-B packaging has been evaluated for the applicable HAC conditions of transportation and for a maximum decay heat loading of 50 W within the canisters. The evaluations found that the resulting component temperatures remained within their specified allowable limits for all cases. Further, the computed temperatures for the RH-TRU 72-B packaging components were essentially the same as those predicted in the RH-TRU 72-B SAR [2] for accident conditions. Thus the NS15 and NS30 shielded RH waste canisters will not impact the safety basis of the RH-TRU 72-B packaging.

Evaluation of the post-fire temperatures when no credit is taken for self shading showed that the increase in component temperatures would be relatively minor and that all component temperatures would remain within their respective long-term allowable temperature limits. The noted 9 to 18°F increase in the cask's structural component post-fire, steady-state temperatures that would arise if self shading by the cask is ignored would affect the temperature predictions for the existing RH-72B SAR [2] evaluations in a similar manner. The peak package component temperatures achieved under HAC conditions remain the same regardless of the method used to model the insolation loading. As such, no impact on the thermal safety basis of the RH-TRU 72-B packaging will occur for any of the package's authorized payloads if cask self shading is ignored.

Table 5-1 - HAC Temperatures for NS15 Shielded Canister

Location / Component	Temperature (°F) [1]			
	End of Fire	Peak	Post-fire Steady-State	Allowable Temperature
Waste Centerline	225	244	244	N/A[2]
NS15 Shield Insert	119	189	138	256
Canister Shell	113	229	130	2,600
IV Shell	151	323	125	800
IV Void Space Bulk Avg	284	406	124	N/A
OC Inner Shell	416	488	123	800
OC Lead Shield	527	544	123	620
OC Outer Shell	605	606	123	800
OC Thermal Shield	1,231	1,231	123	2,600
OC Upper Ring Forging	105	159	123	800
IV O-Ring Seal	103	142	123	360/225[3]
OC O-Ring Seal	107	145	123	360/225[3]
IV Lid	105	159	123	800
OC Lid	106	150	123	800
Impact Limiter Foam	N/A	N/A	N/A	N/A
Impact Limiter Shell	1,427	1,427	131	2,600

Table Note: 1) Temperatures assume a total payload decay heat loading of 50 W.

2) The temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].

3) 360°F is the transient limit during the HAC transient and 225°F is a steady-state limit for post-fire conditions

Table 5-2 - HAC Temperatures for NS30 Shielded Canister

Location / Component	Temperature (°F) [1]			
	End of Fire	Peak	Post-fire Steady-State	Allowable Temperature
Waste Centerline	214	232	232	N/A[2]
NS30 Shield Insert	115	206	135	256
Canister Shell	113	232	129	2,600
IV Shell	151	323	125	800
IV Void Space Bulk Avg	284	406	124	N/A
OC Inner Shell	416	488	123	800
OC Lead Shield	527	544	123	620
OC Outer Shell	605	606	123	800
OC Thermal Shield	1,231	1,231	123	2,600
OC Upper Ring Forging	105	160	123	800
IV O-Ring Seal	107	149	123	360/225[3]
OC O-Ring Seal	104	149	123	360/225[3]
IV Lid	109	160	123	800
OC Lid	107	151	123	800
Impact Limiter Foam	N/A	N/A	N/A	N/A
Impact Limiter Shell	1,427	1,427	131	2,600

Table Note: 1) Temperatures assume a total payload decay heat loading of 50 W.
2) The temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].
3) 360°F is the transient limit during the HAC transient and 225°F is a steady-state limit for post-fire conditions

Table 5-3 - HAC Post-fire Thermal Sensitivity Analysis Comparison with Insolation Modeling Methodology

Location / Component	Post-Fire Peak Temperature (°F) [1]				
	NS15		NS30		Allowable Temperature
	HAC With 12 Hr Averaged Insolation [2]	12 Hr On/Off Transient Cycle [3]	HAC With 12 Hr Averaged Insolation [2]	12 Hr On/Off Transient Cycle [3]	
Waste Centerline	244	249	232	238	N/A[4]
NSXX Shield Insert	138	146 Max 140 Avg.	135	144 Max 139 Avg.	256
Canister Shell	130	141 Max 138 Avg. [5]	129	141 Max 137 Avg. [5]	2,600
IV Shell	125	140 Max 131 Avg. [5]	125	140 Max 131 Avg. [5]	800
IV Void Space Bulk Avg	124	141	124	141	N/A
OC Inner Shell	123	141	123	141	800
OC Lead Shield	123	141	123	141	620
OC Outer Shell	123	141 Max 129 Avg. [5]	123	141 Max 129 Avg. [5]	800
OC Thermal Shield	123	146	123	146	2,600
OC Upper Ring Forging	123	133	123	133	800
IV O-Ring Seal	123	132	123	132	225
OC O-Ring Seal	123	131	123	132	225
IV Lid	123	133	123	133	800
OC Lid	123	132	123	132	800
Impact Limiter Foam	N/A	N/A	N/A	N/A	N/A
Impact Limiter Shell	131	156	131	156	2,600

Table Note: 1) Temperatures assume a total payload decay heat loading of 50 W.

2) Steady-state modeling that includes credit for self-shading of lower half of horizontal cask.

3) Modeling ignores self-shading of lower half of horizontal cask. Insolation applied equally around entire circumference of cask body.

4) The temperature limit for the waste material is discussed in Appendix 4.6 of the RH-TRU Payload Appendices [2].

5) Average of maximum temperatures over a 24 hour period.

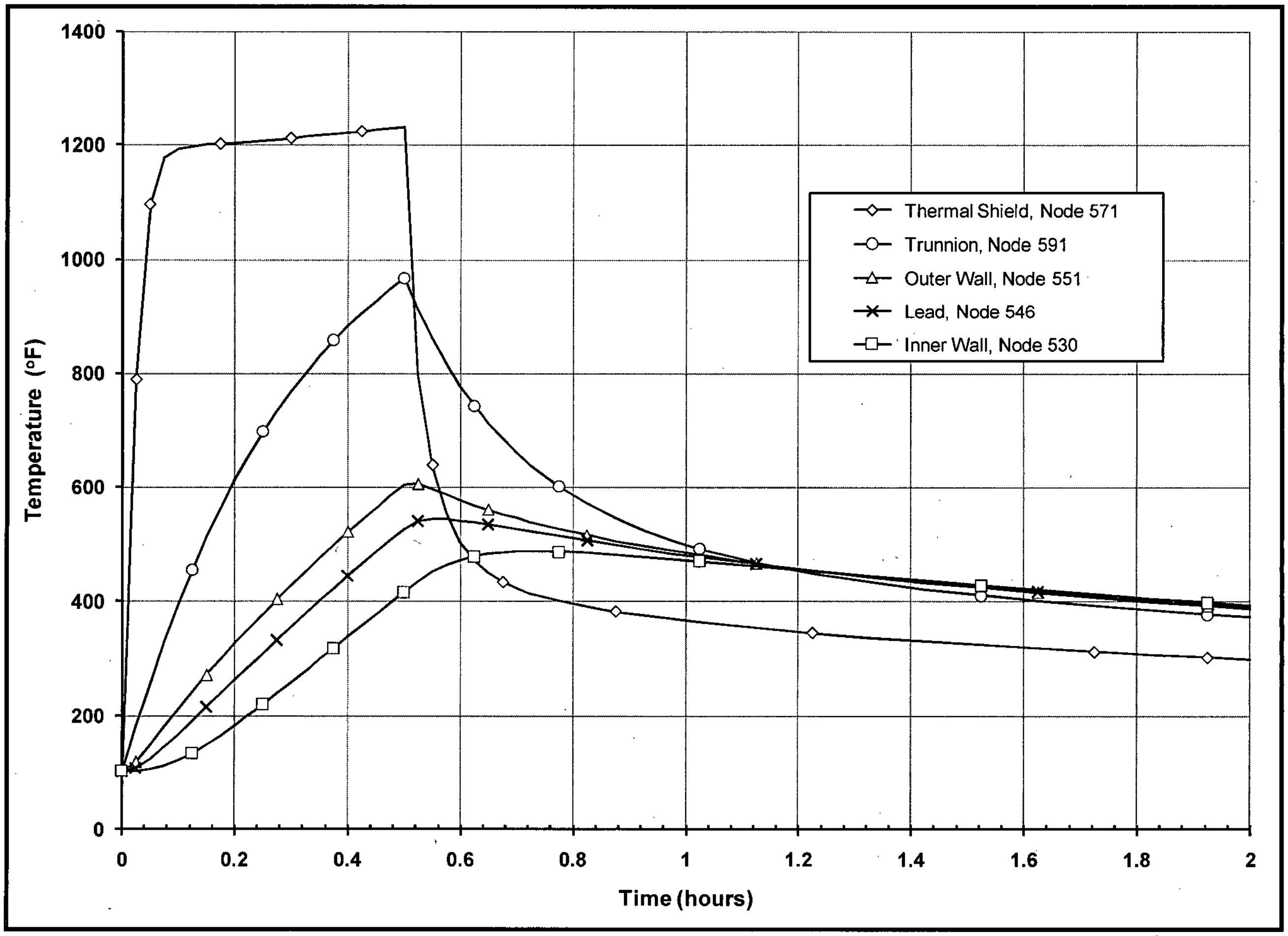

Figure 5-1 - HAC Temperature Response for RH-TRU 72-B Package with NS15 Shielded Canister Payload

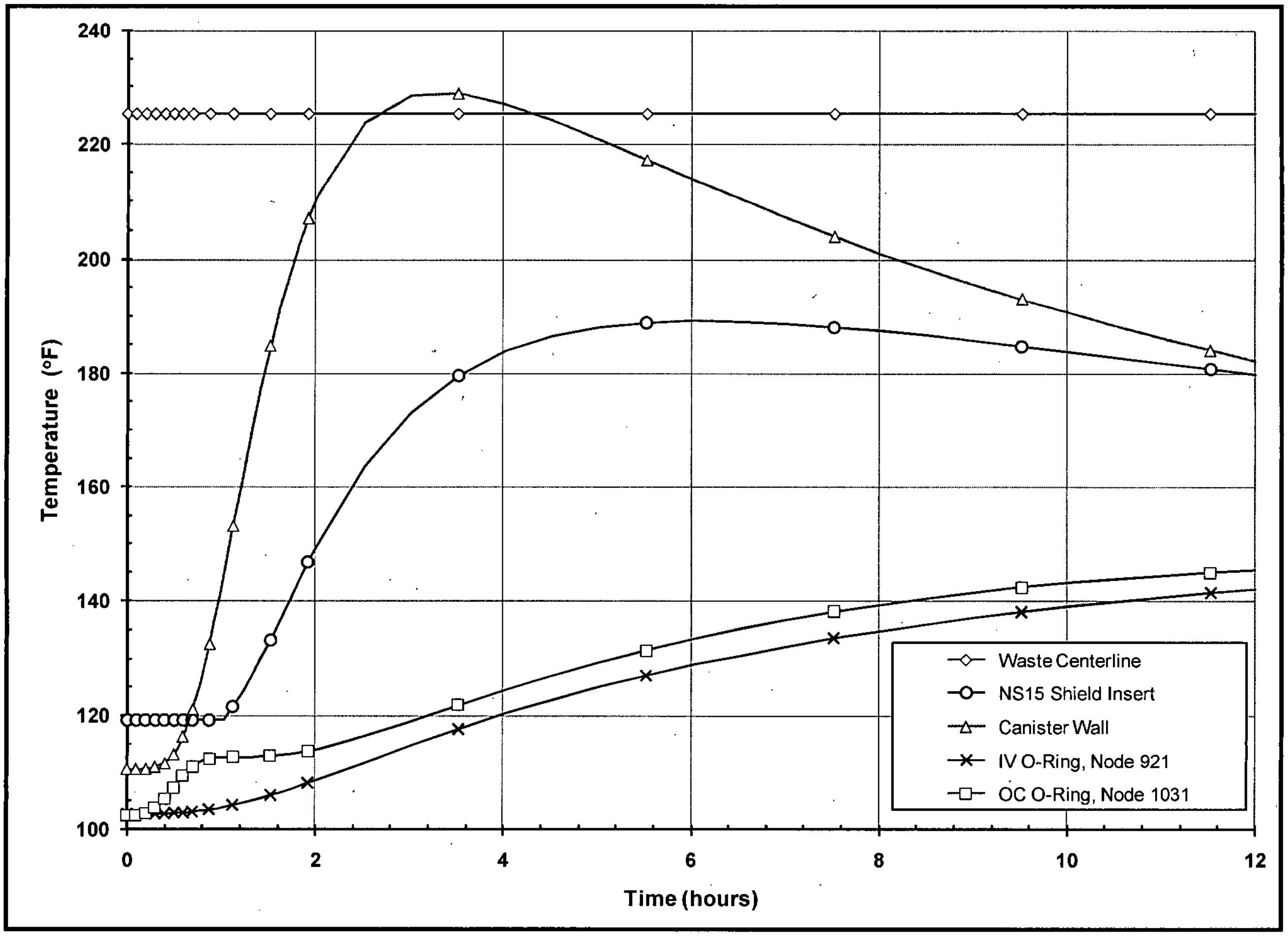

Figure 5-2 - HAC Temperature Response for NS15 Shielded Canister Payload

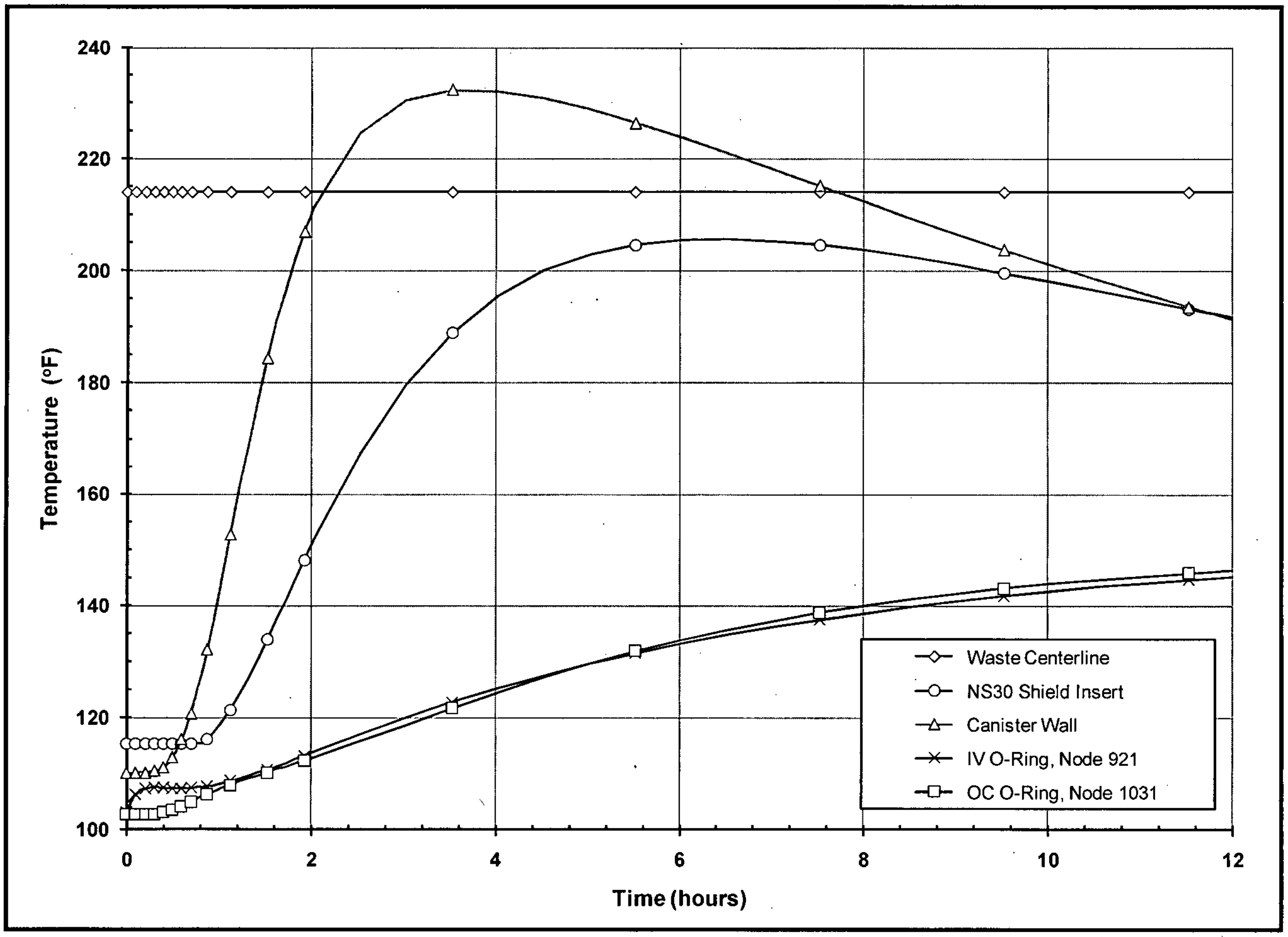

Figure 5-3 - HAC Temperature Response for NS30 Shielded Canister Payload

6.0 Conclusion

The thermal evaluations presented in this calculation demonstrate that both the NS15 and NS30 shielded RH waste canisters with a maximum payload decay heat loading of 50 watts comply with all the thermal acceptance criteria specified in 10 CFR 71[1]. The evaluations were conducted using conservative assumptions and methods. The evaluations included sensitivity analyses for assumed placement of the waste payload within the canister and for centered or eccentric location of the cylindrical shells within one another. The thermal response seen for the RH-TRU 72-B packaging components are seen as being essentially the same as those predicted in the RH-TRU 72-B SAR [2] under both NCT and HAC conditions. As such, the addition of the NS15 and NS30 shielded RH waste canisters as alternative payloads will not impact the safety basis of the RH-TRU 72-B packaging.

This calculation also evaluated the effects of an alternative methodology for applying the specified 10 CFR §71.71(c)(1) insolation boundary condition wherein the steady-state model with credit for self shading of the surfaces on the lower half of the horizontal cask used for the RH-72B SAR [2] evaluations was replaced by a transient "12 hours on/12 hours off" method that takes no credit for cask self shading. The resulting 9 to 16°F increase in cask structural component NCT temperatures and the 5 to 9°F increase in the shielded canister insert and waste centerline temperatures that arises with this alternative insolation modeling method is insignificant in comparison with the available thermal margin for each component. With the exception of the waste centerline temperature, the peak package component temperatures achieved under HAC conditions remain the same regardless of the method used to model the insolation loading. The peak waste centerline temperature would rise by 6°F or less under the alternative insolation modeling methodology. All component temperatures remain within their respective NCT and HAC allowable temperature limits under either insolation modeling method.

A similar change in the peak component temperatures would occur for the existing RH-72B SAR evaluations under the same change in insolation modeling since the canister and cask geometries are the same and the level and distribution of the decay heat loading assumed by this calculation is similar to those assumed in the existing RH-72B SAR evaluations. Given the existing thermal margins, this modeling change would still result in all component temperatures remaining within their respective NCT and HAC allowable temperature limits and, thus, no impact on the thermal safety basis of the RH-TRU 72-B packaging.

7.0 Appendices

7.1 References

1. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Materials*, United States Nuclear Regulatory Commission (USNRC), 01-01-02 Edition.
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18. ASTM D 3350, *Standard Specification for Polyethylene Plastics Pipe and Fittings Materials*, ASTM International, West Conshohocken, PA, 2003, DOI: 10.1520/C0033-03, www.astm.org.
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7.2 Sample Input File

The input files are too large for inclusion directly into this calculation. Instead, the input and output files are provided on a CDROM.

7.3 Computer Run Record

	COMPUTER RUN RECORD		
Computer Run Identification	**Verification of Existing RH-TRU 72-B Thermal Models**		
Software Verification	Verified under AFS-EN-PRC-013, Rev. 01		
Analysis Software	Thermal Desktop™ & SINDA/FLUINT™, Version 5.1		
Hardware Description	Pentium M, Windows XP operating system for computer DLT6000		
Disk Storage Description	All files stored on CD-ROM in folder named: **RH-TRU 72-B Verification**		
Disk File Storage	File Description	File Name	Creator
	ASCII Input	RH-TRU_50Watt_NCT.inp RH-TRU_50Watt_HAC.inp RH-TRU_300Watt_NCT.inp RH-TRU_300Watt_HAC.inp frcvv-sqft.f	G Banken
	Binary Database	-none-	G Banken
	ASCII Output	RH-TRU_NCT_50W.out RH-TRU_50W_HAC.out RH-TRU_NCT_300W.out RH-TRU_300Watt_HAC.out	G Banken
	Binary Output	-none-	G Banken
	Spreadsheets	none	
Printed Attachments	Description		

AREVA	COMPUTER RUN RECORD		
Computer Run Identification	**NS15 Shielded Canister**		
Software Verification	Verified under AFS-EN-PRC-013, Rev. 01		
Analysis Software	Thermal Desktop™ & SINDA/FLUINT™, Version 5.1		
Hardware Description	Pentium M, Windows XP operating system for computer DLT6000		
Disk Storage Description	All files stored on CD-ROM in folder named: **NS15 Safety Evaluation**		
Disk File Storage	File Description	File Name	Creator
	ASCII **Input**	RHTRU-NS15_NCT_Bottom_Position.inp/cc RHTRU-NS15_NCT_Middle_Position.inp/cc RHTRU-NS15_NCT_Top_Position.inp/cc RHTRU-NS15_NCT_Eccentric.inp/cc RHTRU-NS15_NCT_NoSolar.inp RHTRU-NS15_HAC.inp RHTRU-NS15_HAC_PostSS.inp RHTRU-NS15_NCT_Bottom_Position.rad RHTRU-NS15_NCT_Middle_Position.rad RHTRU-NS15_NCT_Top_Position.rad RH-TRU Optical Properties.rco RH-TRU Material Properties.tdp RH-TRU_Cask_NCT.dat / RH-TRU_Cask_HAC.dat frcvv-sqft.f	G Banken
	Binary Database	RHTRU-NS15_NCT_Bottom_Position.dwg RHTRU-NS15_NCT_Middle_Position.dwg RHTRU-NS15_NCT_Top_Position.dwg RHTRU-NS15_NCT_Eccentric.dwg	G Banken
	ASCII Output	RHTRU-NS15_NCT_Bottom_Position.out/usr1 RHTRU-NS15_NCT_Middle_Position.out/usr1 RHTRU-NS15_NCT_Top_Position.out/usr1 RHTRU-NS15_NCT_Eccentric.out/usr1 RHTRU-NS15_NCT_NoSolar.out/usr1 RHTRU-NS15_HAC.out/usr1 RHTRU-NS15_HAC_PostSS.out/usr1	G Banken
	Binary Output	RHTRU-NS15_NCT_Bottom_Position.sav RHTRU-NS15_NCT_Middle_Position.sav RHTRU-NS15_NCT_Top_Position.sav RHTRU-NS15_NCT_Eccentric.sav RHTRU-NS15_NCT_NoSolar.sav RHTRU-NS15_HAC.sav RHTRU-NS15_HAC_PostSS.sav	G Banken
	Spreadsheets	RHTRU-72B Shielded Canister Results.xls	

AREVA	COMPUTER RUN RECORD		
Computer Run Identification	**NS30 Shielded Canister**		
Software Verification	Verified under AFS-EN-PRC-013, Rev. 01		
Analysis Software	Thermal Desktop™ & SINDA/FLUINT™, Version 5.1		
Hardware Description	Pentium M, Windows XP operating system for computer DLT6000		
Disk Storage Description	All files stored on CD-ROM in folder named: **NS30 Safety Evaluation**		
Disk File Storage	File Description	File Name	Creator
	ASCII **Input**	RHTRU-NS30_NCT.inp RHTRU-NS30_NCT_NoSolar.inp RHTRU-NS30_HAC.inp RHTRU-NS30_HAC_PostSS.inp RHTRU-NS30.cc RHTRU-NS30.rad RH-TRU Optical Properties.rco RH-TRU Material Properties.tdp RH-TRU_Cask_NCT.dat RH-TRU_Cask_HAC.dat frcvv-sqft.f	G Banken
	Binary Database	RH-TRU NS30 Canister.dwg	G Banken
	ASCII Output	RHTRU-NS30_NCT.out/usr1 RHTRU-NS30_NCT_NoSolar.out/usr1 RHTRU-NS30_HAC.out/usr1 RHTRU-NS30_HAC_PostSS.out/usr1	G Banken
	Binary Output	RHTRU-NS30_NCT.sav RHTRU-NS30_NCT_NoSolar.sav RHTRU-NS30_HAC.sav RHTRU-NS30_HAC_PostSS.sav	G Banken
	Spreadsheets	RHTRU-72B Shielded Canister Results.xls	

AREVA	COMPUTER RUN RECORD		
Computer Run Identification	**NS15 Shielded Canister**		
Software Verification	Verified under AFS-EN-PRC-013, Rev. 01		
Analysis Software	Thermal Desktop™ & SINDA/FLUINT™, Version 5.3		
Hardware Description	Xeon PC, Windows VISTA operating system		
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Disk File Storage	File Description	File Name	Creator
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	Binary Database	RHTRU-NS15_NCT_Bottom_Position.dwg	G Banken
	ASCII Output	RHTRU-NS15_NCT_12Hr-SolarCycle.out RHTRU-NS15_NCT_12Hr-SolarCycle.usr1 RHTRU-NS15_HAC_PostSS_12Hr-SolarCycle.out RHTRU-NS15_HAC_PostSS_12Hr-SolarCycle.usr1	G Banken
	Binary Output	RHTRU-NS15_NCT_12Hr-SolarCycle.sav RHTRU-NS15_HAC_PostSS_12Hr-SolarCycle.sav	G Banken
	Spreadsheets	RHTRU-72B NS15 NCT 12Hr Solar Cycling.xls RHTRU-72B NS15 HAC 12Hr Solar Cycling.xls	G Banken

COMPUTER RUN RECORD

AREVA	COMPUTER RUN RECORD		
Computer Run Identification	**NS30 Shielded Canister**		
Software Verification	Verified under AFS-EN-PRC-013, Rev. 01		
Analysis Software	Thermal Desktop™ & SINDA/FLUINT™, Version 5.3		
Hardware Description	Xeon PC, Windows VISTA operating system		
Disk Storage Description	All files stored on CD-ROM in folder named: **NS30 Safety Evaluation w/ Alternative Insolation**		
Disk File Storage	File Description	File Name	Creator
	ASCII Input	RHTRU-NS30.cc RHTRU-NS30_NCT_12Hr-SolarCycle.inp RHTRU-NS30_HAC_PostSS_12Hr-SolarCycle.inp RHTRU-NS30.rad RH-TRU Optical Properties.rco RH-TRU Material Properties.tdp RH-TRU_Cask_NCT_12Hr-SolarCycle.dat RH-TRU_Cask_HAC_12Hr-SolarCycle.dat frcvv-sqft.f	G Banken
	Binary Database	RH-TRU NS30 Canister.dwg	G Banken
	ASCII Output	RHTRU-NS30_NCT_12Hr-SolarCycle.out RHTRU-NS30_NCT_12Hr-SolarCycle.usr1 RHTRU-NS30_HAC_PostSS_12Hr-SolarCycle.out RHTRU-NS30_HAC_PostSS_12Hr-SolarCycle.usr1	G Banken
	Binary Output	RHTRU-NS30_NCT_12Hr-SolarCycle.sav RHTRU-NS30_HAC_PostSS_12Hr-SolarCycle.sav	G Banken
	Spreadsheets	RHTRU-72B NS30 NCT 12Hr Solar Cycling.xls RHTRU-72B NS30 HAC 12Hr Solar Cycling.xls	G Banken

7.4 Thermal Model Details

This section presents details of the thermal modeling used to simulate the NS15 and NS30 shielded canisters within the RH-TRU 72-B packaging. The analytical thermal model of the shielded canisters within the RH-TRU 72-B packaging is developed for use with the Thermal Desktop® [12] and SINDA/FLUINT [13] computer programs. These programs work together to provide the functions needed to build, exercise, and post-process a thermal model. The Thermal Desktop® computer program provides graphical input and output display functions, as well as computing the thermal mass, conduction, and radiation exchange conductors for the defined geometry and thermal/optical properties. Thermal Desktop® is designed to run as an application module within the AutoCAD™ design software. As such, all of the CAD tools available for generating geometry within AutoCAD™ can be used for generating a thermal model. In addition, the use of the AutoCAD™ layers tool presents a convenient means of segregating the thermal model into its various elements.

The SINDA/FLUINT computer program is a general purpose code that handles problems defined in finite difference (i.e., lumped parameter) and/or finite element terms and can be used to compute the steady-state and transient behavior of the modeled system. Although the code can be used to solve any physical problem governed by diffusion-type equations, specialized functions used to address the physics of heat transfer and fluid flow make the code primarily a thermal code. The SINDA '85 computer program used to produce the thermal results presented in the RH-TRU 72-B [2] safety analysis report is an early predecessor to Version 5.1 of the SINDA/FLUINT software used for this evaluation.

Together, the Thermal Desktop® and SINDA/FLUINT codes provide the capability to simulate steady-state and transient temperatures using temperature dependent material properties and heat transfer via conduction, convection, and radiation. While complex algorithms may also be programmed into the solution process to, for example, compute heat transfer coefficients as a function of the local conditions, this capability of the code has not been utilized for this evaluation.

The SINDA/FLUINT and Thermal Desktop® computer programs have been validated for safety basis calculations for nuclear related projects [14].

7.4.1 Thermal Model for RH-TRU 72-B Packaging

The analytical thermal model of the RH-TRU 72-B packaging developed for the RH-TRU 72-B SAR [2] is re-used for the purposes of this calculation. The thermal model for NCT provides an axisymmetric, 360° representation of the RH-TRU 72-B cask body and impact limiters, as illustrated in Figure 7-1 to Figure 7-4. The modeling is defined via non-graphical, textual modeling language that defines a lumped-parameter, finite-difference representation of the package. Similar modeling is used for HAC conditions, except for the simulation of the non- axisymmetric effect of the trunnions and the side drop and puncture pin damage. To address these HAC related aspects of the thermal modeling, the thermal modeling for the lead shield, outer vessel, thermal shield, and the impact limiters are extended to three dimensions. Figure 7-5 illustrates the revised thermal modeling for the impact limiters to capture the pre-fire drop damage. Full details of the modeling and the assumptions used in its development are provided in the RH-TRU 72-B SAR. The following bullet items identify the basis of this thermal modeling:

- The thermal analyses are based on coding for the SINDA '85/FLUINT finite difference code

- All internal voids are assumed to be filled with air at one (1) atmosphere
- Solar heat input is based on projected surface area of the package and a solar absorptivity of $\alpha = 0.52$ for NCT and $\alpha = 0.8$ for HAC
- Convective heat transfer from the exterior of the package is based on natural convection for NCT and post-fire HAC conditions and on forced convection during the 30-minute HAC fire. These convection coefficients are determined from the local Nusselt number based on local air temperature (average of the local external surface temperature and the ambient temperature) and the surface area. The Nusselt number is calculated as a function of the Grashof and Prandtl numbers
- External radiation from packaging and impact limiter surfaces is calculated assuming a surface emissivity of $\varepsilon = 0.3$ for NCT and $\varepsilon = 0.8$ for HAC

7.4.2 Thermal Model for NS15 and NS30 Shielded Canisters

The thermal modeling of the NS15 and NS30 shielded canisters and waste payload are developed using the Thermal Desktop® computer program [12] based on the geometry provided by drawing X-106-503-SNP [5]. With the exception of the payload definition and the thickness of the high density polyethylene (HDPE) used for shielding, identical modeling approaches are used for the thermal models for the NS15 and NS30 canister designs. Approximately 1,270 thermal nodes are used to define the NS15 canister design and its enclosed payload, while approximately 1,385 thermal nodes are used for the NS30 canister design. The interface of the graphics based modeling of the NS15 and NS30 shielded canisters with the textual based thermal modeling of the RH-TRU 72-B cask body is provided via a series of shell surfaces illustrated in Figure 7-6 whose location and surface area match precisely the nodal distribution in the text based modeling of the RH-TRU 72-B cask body.

The shell for both shielded payload canister configurations is identical to the unshielded configuration with a 26-in. outside diameter and a ¼-in. thick wall fabricated of painted ASTM A516 carbon steel. Including the lifting pintle at the top of the payload canister, the overall length of the modeled canister is 120½ inches. Given the combination of the relative thinness of the shell, the conductivity of carbon steel, and the relatively low heat flux associated with a 50 W decay heat payload, the shell of the canister is modeled with a single thermal node in the radial direction. Axial thermal resolution is provided with thermal nodes spaced approximately every 5 inches along the shell's length. The lid and base of the canister shell as modeled with one node for the ¼-in. thickness and 5 nodes in the radial direction. The lifting pintle is modeled with solid elements using 30 thermal nodes. The heat transfer between the waste canister shell and the RH-TRU 72-B cask body is modeled as conduction and radiation across the nominal 2.625-in. gap in the same fashion as the thermal modeling defined in the RH-TRU 72-B SAR [2]. The radial gap between the canister and the RH-TRU 72-B inner vessel is mechanically maintained within ½-in. of nominal spacing by the use of spacer rings and support rails. Figure 7-7 illustrates the thermal interface between the waste canister and the inner surfaces of the cask cavity. Heat transfer between the base and lid ends of the canister and the cask inner surfaces is modeled as conduction and radiation across 0.125-in. and 0.5-in. gaps, respectively. The relatively void space associated with the region around the lifting pintle on the canister effectively isolates the top of the canister from the underside of the cask lid.

The HDPE neutron shielding material for the NS15 canister is modeled with a nominal thickness of 3.387-in. and an outer diameter of 24 inches. The top and bottom end caps have a 5-in. thickness. The neutron shielding material for the NS30 canister is modeled with a nominal thickness of 1.454-in. The outer diameter and the thickness of the top and bottom end caps are the same as that for the NS15 shield insert. Figure 7-8 illustrates the thermal model of the NS15 shield insert in the waste canister. Except for sidewall thickness, the thermal modeling for the NS30 shield insert is similar.

Five thermal nodes are used to model the HDPE wall thickness of the NS15 shield insert and three nodes are used for the NS30 shield insert. The 5-in. node spacing in the axial direction matches that used for the canister shell. The top and bottom end caps are simulated with 9 thermal nodes in the radial direction and 6 nodes across the thickness. Radial heat transfer between the HDPE insert and the canister shell wall is simulated as conduction and radiation across the nominal 0.75-in. gap between the components. The use of a uniform radial gap is appropriate for NCT and HAC evaluations even though the RH-TRU 72-B package is transported horizontally since the increase in the radial gap on one side of the HDPE insert will be offset by a corresponding smaller gap on the opposing side. In addition, ignoring the narrow line contact that will exist for the horizontal package orientation will yield conservative temperature estimates for NCT conditions, while the bounding temperature achieved under HAC conditions can be conservatively estimated by assuming the inner surface reaches a temperature equivalent to that achieved by the outer surface.

Axial heat transfer between the HDPE insert and the base and lid ends of the canister is modeled as conduction and radiation across 0.125-in. and 0.375-in. gaps, respectively. The HDPE insert is conservatively assumed to have shifted forwarded slightly under horizontal transportation from its vertical loading position. This modeling arrangement yields conservative temperatures since the alternative arrangement of assuming a tight contact between the bases of the insert and canister shell will yield lower temperatures under the steady-state NCT conditions for the insert and payload because the thermal resistance would be lower. The alternative arrangement of assuming a tight contact between the bases of the insert and canister shell will also yield lower transient peak temperatures under HAC conditions for the base of the canister shell since the thermal mass of the HDPE insert would be closely coupled to the canister base and thus help absorb the transient heat flux during the fire event. Therefore, the peak canister temperature achieved under HAC conditions without contact with the HDPE insert will bound that achieved with contact and will also bound the peak HDPE insert temperature achieved with and without contact.

The payload for the NS15 canister is assumed to be contained within three (3) approximately 16-gallon containers. Each waste container and its contents are represented by 119 thermal nodes. The containers are assumed to be full of waste whose volumetric heat generation is evenly distributed and whose effective thermal conductivity is equal to that of air. The shell of the containers is simulated as 0.04-in. thick carbon steel.

Three alternative placements of the waste containers within the canister are considered: first, the containers are assumed to be stacked on the bottom of the canister cavity, the second configuration assumes the use of approximately 19.9-in. of dunnage at the bottom of the canister to elevate the top of the uppermost container to near the top of the canister cavity, and the third placement configuration assumes approximately 7.5-in. of dunnage at both the top and bottom of the canister to center the waste containers within the canister. The second placement configuration further assumes the use of slip sheets or some other separator between the containers, while the first and third container arrangement assumes the containers are in close, near physical contact with one another. The dunnage required for these various placement configurations are not specifically modeled, but are assumed to have the thermal conductance of an equivalent airspace. Even containers in near physical contact with one another are assumed to have an approximate airspace of 0.375-in. between their end face surfaces because the rolled rims and dished ends prevent tighter contact. Figure 7-9 illustrates the bottom and top positioning configurations of the waste containers, while Figure 7-10 illustrates the center positioning scheme.

To assess the effect of eccentric placement within the horizontal cask, a sensitivity evaluation was conducted for the bottom positioning configuration for the waste containers described above. The changes to the thermal modeling for the eccentric placement consisted of reducing the mean gap between the lower half of the horizontally oriented drums, poly insert, and canister and their adjacent component to one half of the gap assumed for the concentric placement of the components. The corresponding mean gap between the upper half of these same components was increased by 50% over that assumed for the concentric placement of the components. The thermal conductance due to the line contact between the components is conservatively ignored. All other aspects of the thermal model remained the same as discussed above.

The modeling approach used for the payload definition for the NS30 canister is similar to that for the N15 canister, except that the waste is assumed to be contained within six (6) approximately 8-gallon containers that, in turn, are housed within three (3) approximately 30-gallon drums. Figure 7-11 illustrates the assumed payload configuration for the NS30 shielded canister configuration. As with the payload definition for the NS15 canister, each waste container is assumed to be full of waste whose volumetric heat generation is evenly distributed and whose effective thermal conductivity is equal to that of air. The shell of the containers is simulated as 0.04-in. thick carbon steel. The shell and the contents are represented by 68 thermal nodes for each container.

The waste containers are assumed to be centered radially within the 30-gallon drums, to be in near contact with one another and the bottom of the drum, and within 0.75-in. of the drum lid. The near contact condition is simulated as a 0.125-in. gap to account for the axial offset provided by the rolled rims on the containers. The drums are assumed to be centered within the HDPE neutron shielding and in near physical contact with one another. Again, the near physical contact is simulated via 0.375-in. airspace because the rolled rims and dished ends prevent tighter contact. The 30-gallon drums are simulated as carbon steel shell elements with a thickness of 0.045-in.

7.5 Verification of Existing RH-TRU 72-B Thermal Models

The modeling approach of using a mixture of lumped-parameter and 'solids' modeling, together with the use of Version 5.1 of the SINDA/FLUINT computer program, was validated as producing similar results for both NCT and HAC codes when running the thermal models developed for the SINDA '85 code. This validation is documented in a scoping evaluation conducted on the NS15 and NS30 shielded insert concepts [16]. Table 7-1 summarizes the comparative results obtained between the original SINDA '85 modeling and that obtained using the modeling approach utilized in this evaluation. As seen, the results are very similar, thus verifying the modeling approach.

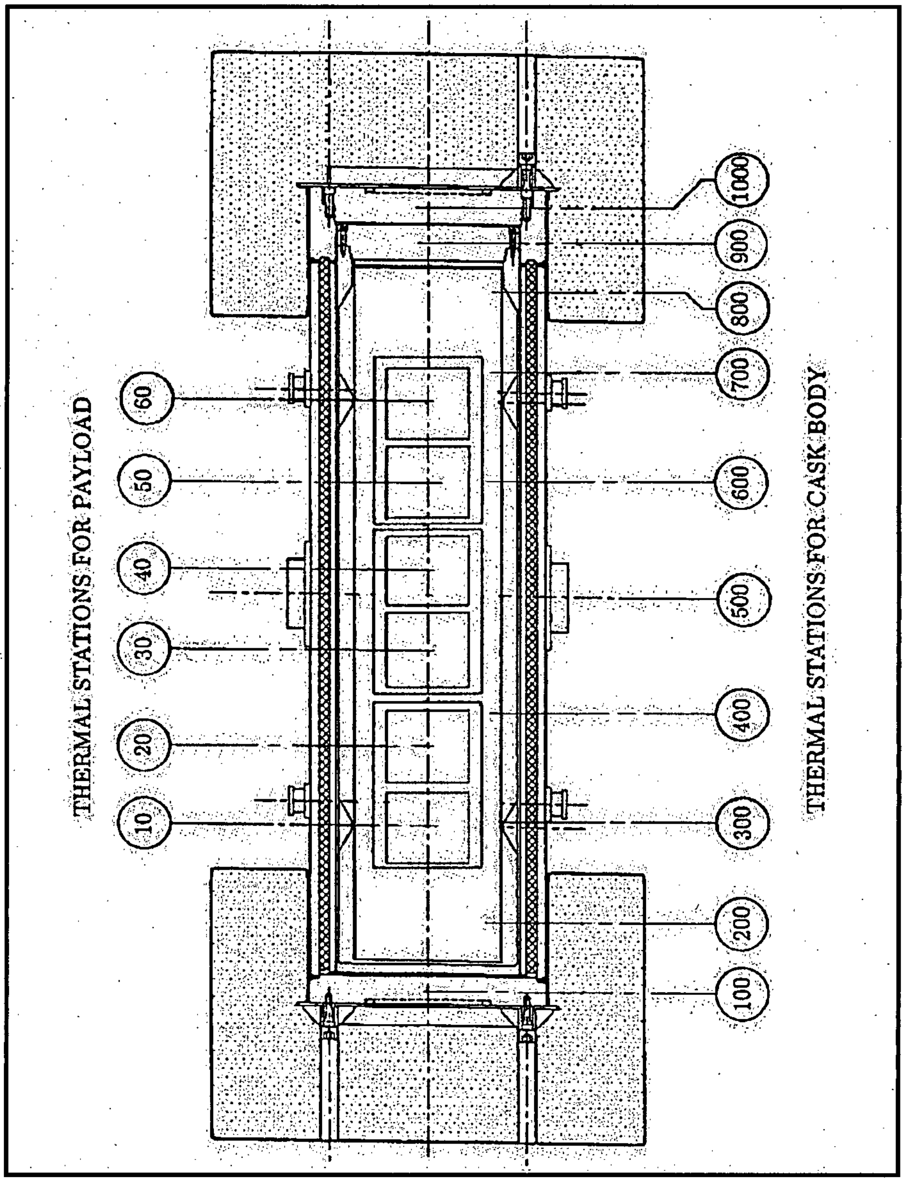

Figure 7-1 - Thermal Model Layout for RH-TRU 72-B Packaging

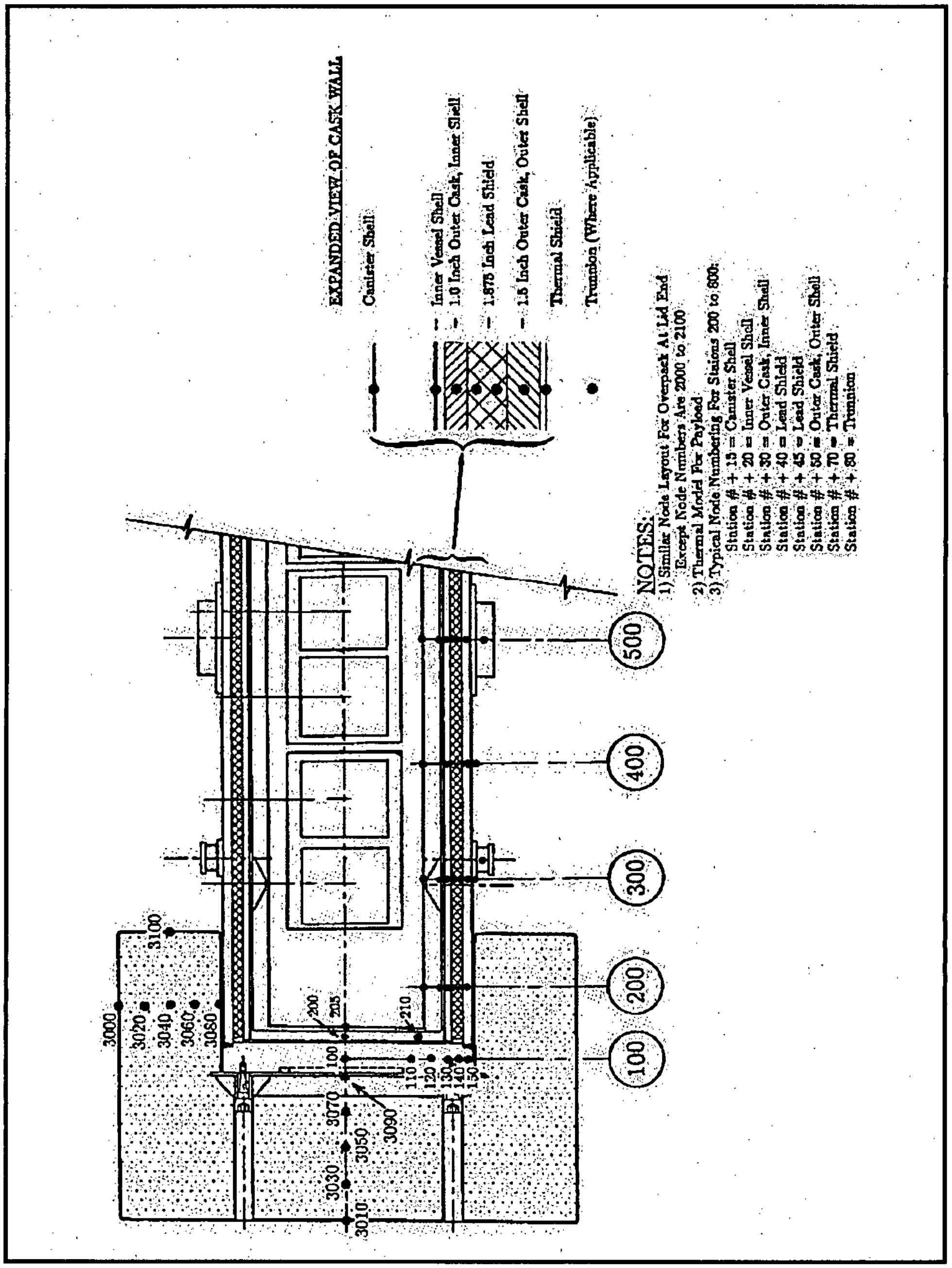

Figure 7-2 - Thermal Node Identification Scheme for Cask Body & Limiters

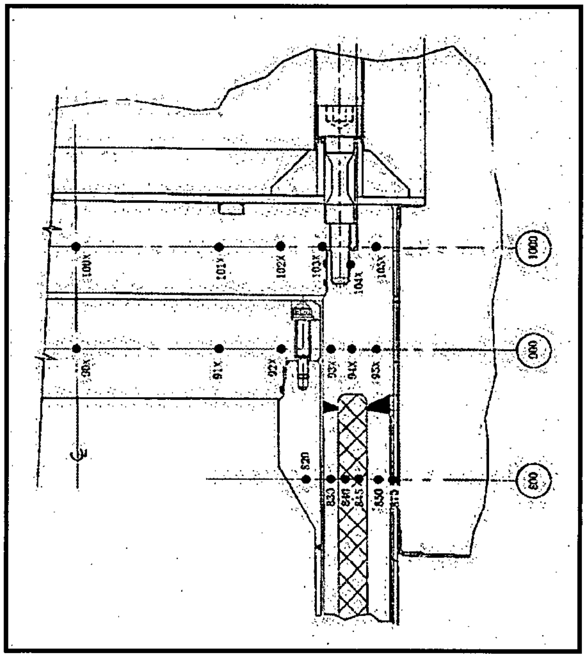

Figure 7-3 - Thermal Node Identification Scheme for Cask Lid End

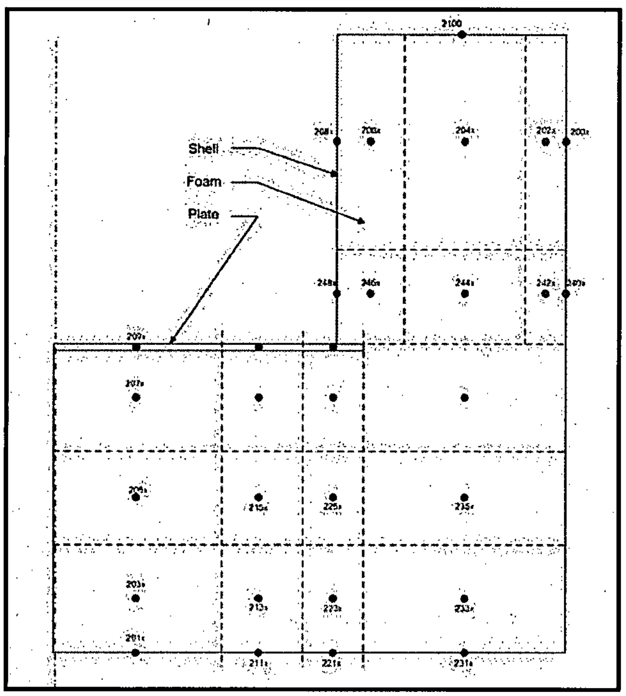

Figure 7-4 - Thermal Node Identification Scheme for Cask Lid End Impact Limiter

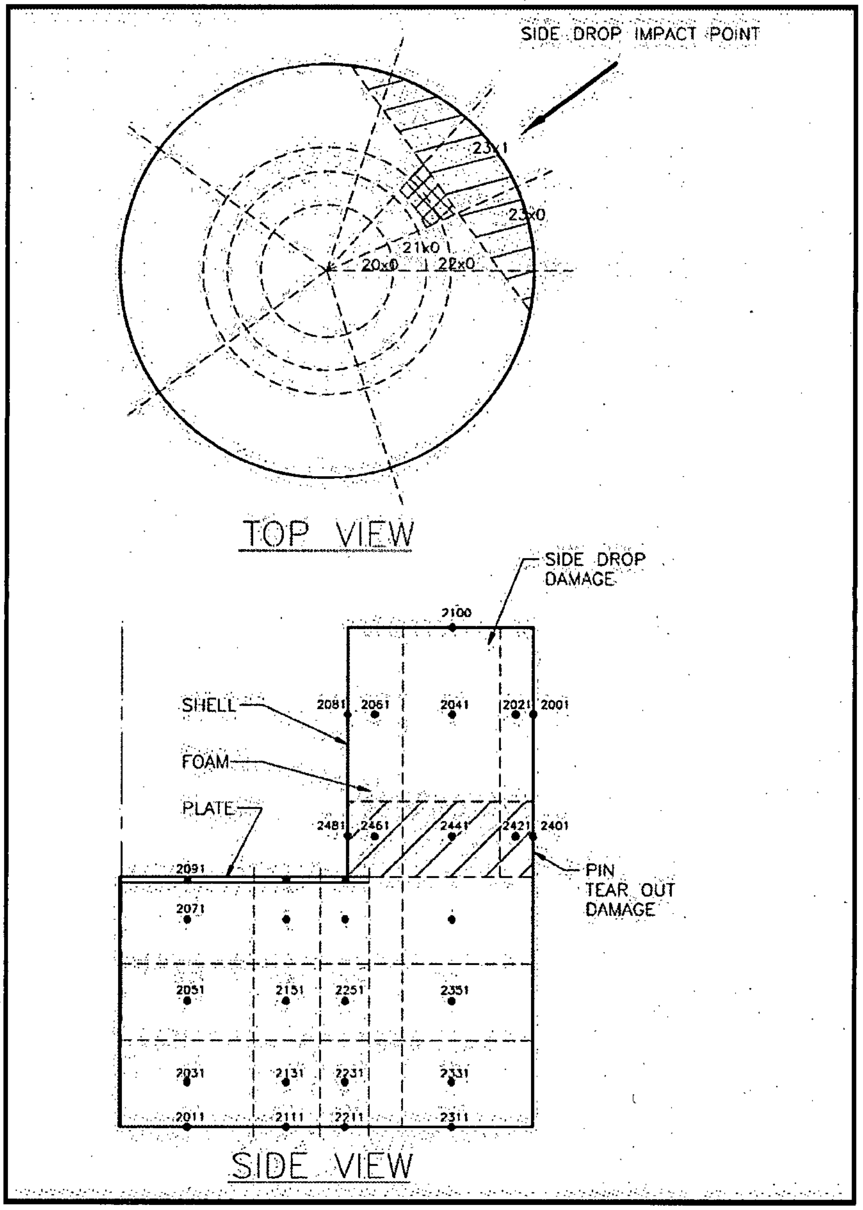

Figure 7-5 - Thermal Node Identification Scheme for Side Drop and Puncture Bar Damage to Impact Limiter

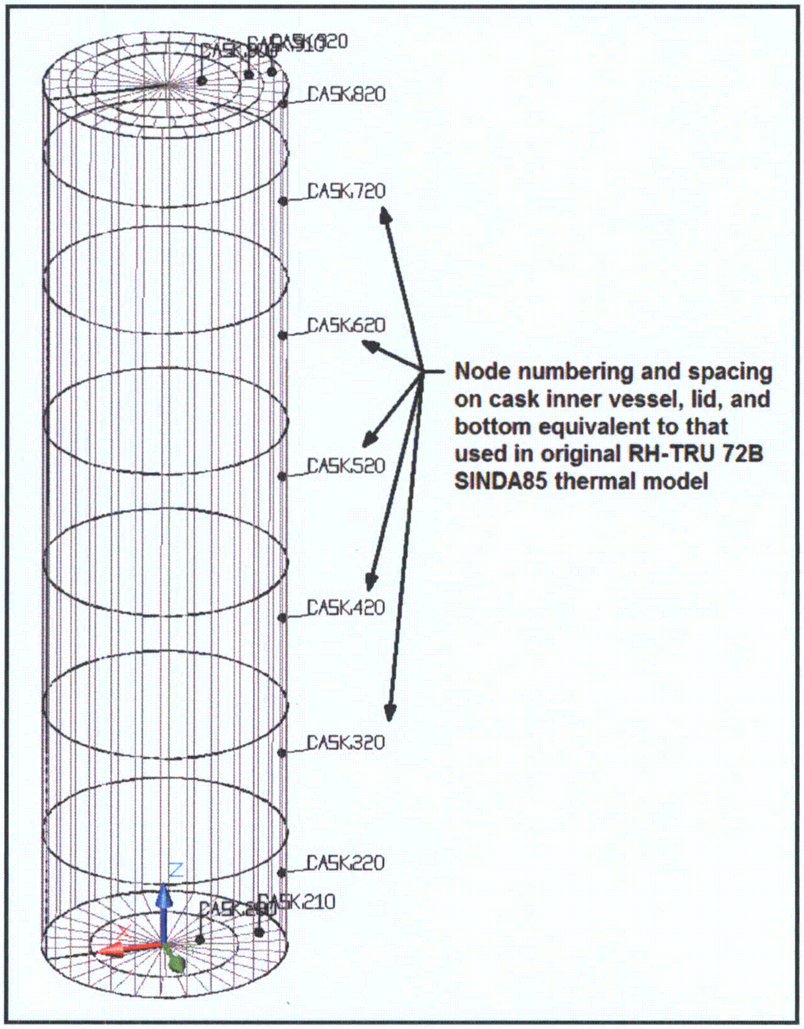

Figure 7-6 - Graphical Representation of RH-TRU 72-B Inner Vessel Sidewall, Base, and Lid Surfaces

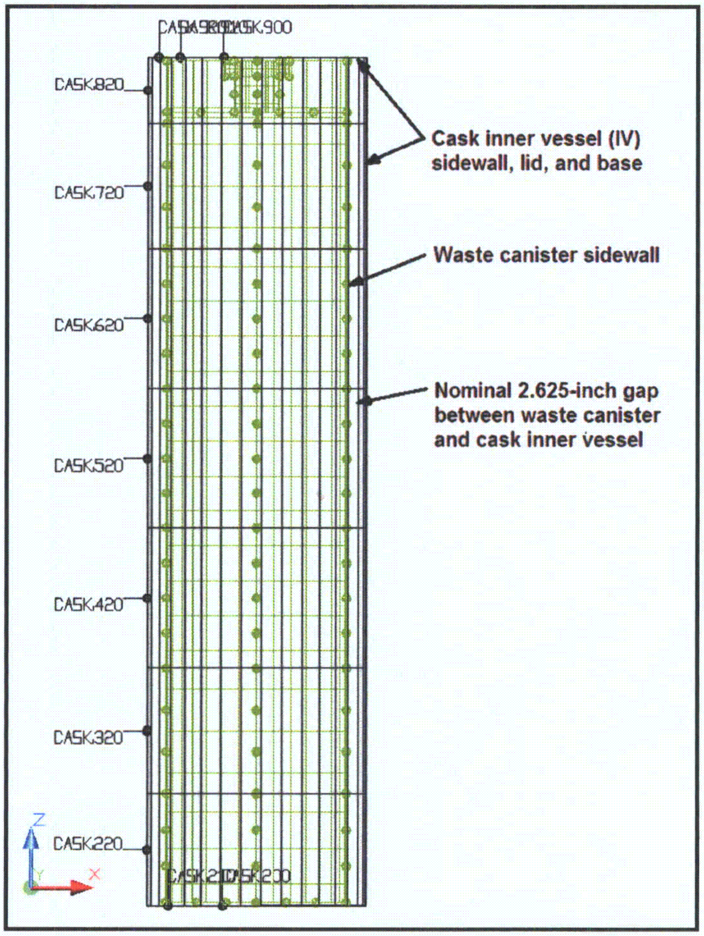

Figure 7-7 - Thermal Interface Scheme between RH-TRU 72-B Cask Model and Waste Canister Model

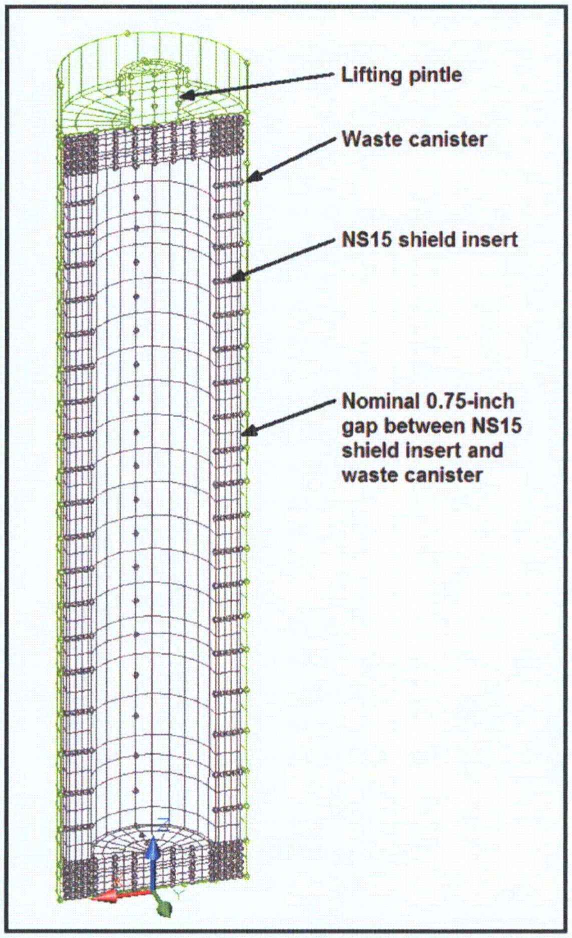

Figure 7-8 - Thermal Model Layout of NS15 Shielded Canister

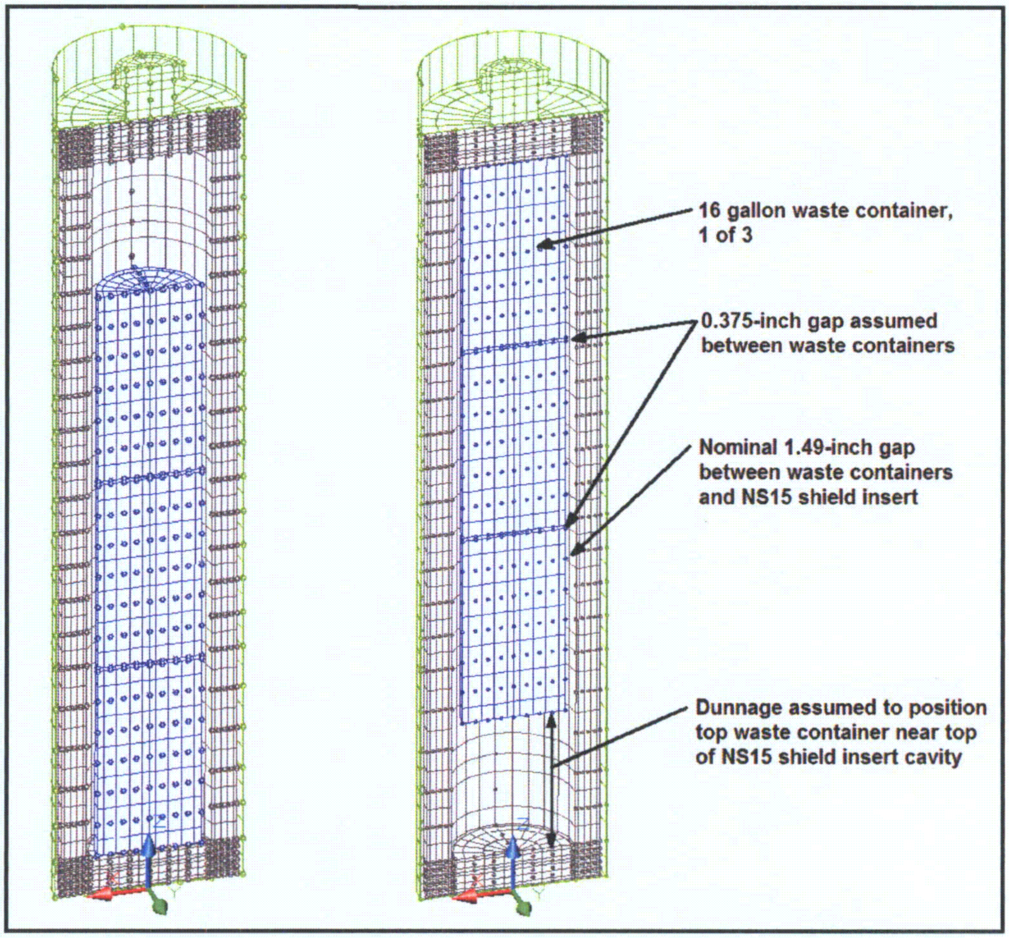

Figure 7-9 - Thermal Modeling of Waste Containers within NS15 Shielded Canister – Bottom and Top Positioning

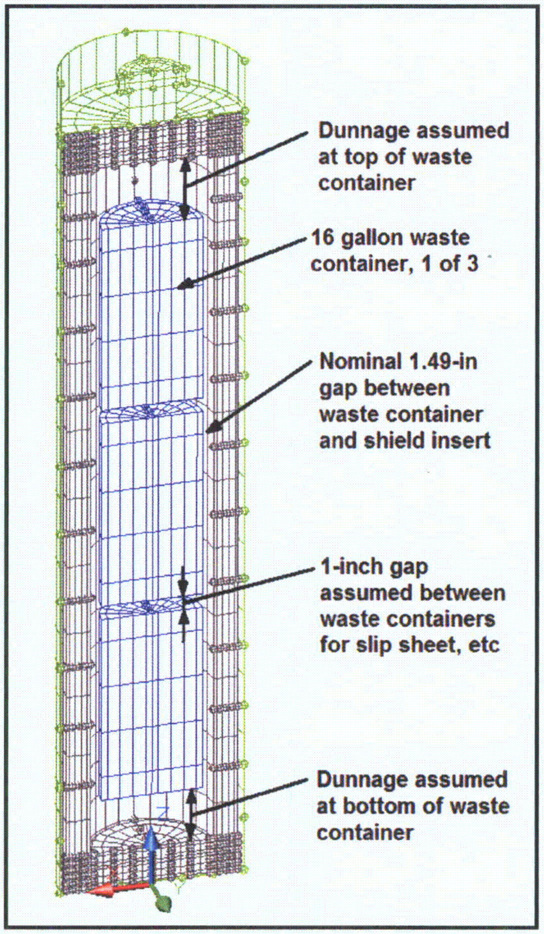

Figure 7-10 - Thermal Model Layout for Middle Positioning of Waste Containers within NS15 Shielded Canister

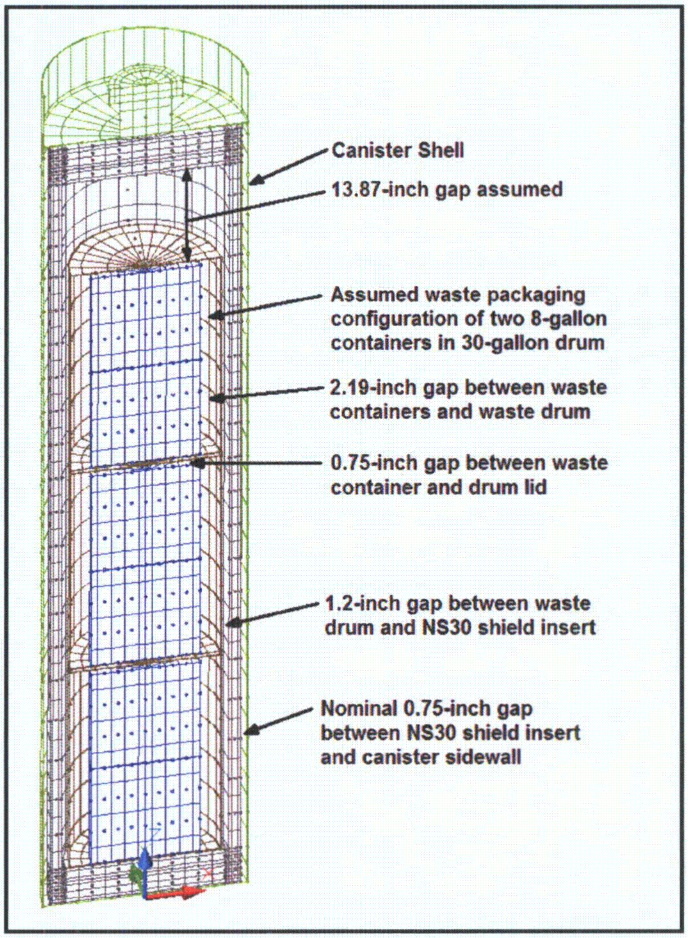

Figure 7-11 - Thermal Model Layout for Nested Waste Containers within NS30 Shielded Canister

Table 7-1 - Comparison of Results for Baseline HAC Thermal Models

Location	50 Watt Payload		300 Watt Payload	
	SAR Results	**Re-Run**	**SAR Results**	**Re-Run**
Waste Centerline	*219°F*	214°F	*196°F*	197°F
Canister Shell	*263°F*	265°F	*247°F*	244°F
IV Inner Shell	*327°F*	328°F	*343°F*	343°F
OC Inner Shell	*488°F*	488°F	*497°F*	497°F
OC Lead Shield	*544°F*	544°F	*554°F*	554°F
OC Outer Shell	*601°F*	602°F	*611°F*	611°F
OC Thermal Shield	*1,232°F*	1,232°F	*1,231°F*	1,226°F
OC Upper Ring Forging	*154°F*	159°F	*166°F*	170°F
IV O-Ring Seal	*150°F*	151°F	*159°F*	160°F
OC O-Ring Seal	*149°F*	150°F	*158°F*	158°F
IV Lid	*148°F*	151°F	*157°F*	160°F
OC Lid	*150°F*	150°F	*159°F*	158°F
Impact Limiter Shell	*1,424°F*	1,427°F	*1,425°F*	1,427°F

7.6 Material Data Sheets

For more information and technical assistance contact:

Performance Pipe, a division of
Chevron Phillips Chemical Company LP
P.O. Box 269006
Plano, TX 75026-9006
800.527.0662

PERFORMANCE PIPE
A Division of Chevron Phillips Chemical Company LP

DriscoPlex®
PE3608 / (PE3408) Pipe
Pipe and Fittings Data Sheet

Typical Material Physical Properties of DriscoPlex® PE3608 / (PE3408)

High Density Polyethylene Materials

Property	Unit	Test Procedure	Typical Value
Material Designation	---	PPI TR-4	PE3608
Cell Classification	---	ASTM D3350	345464C
Pipe Properties			
Density	gms / cm^3	ASTM D1505	0.955 (black)
Melt Index Condition 190 / 2.16	gms / 10 minutes	ASTM D1238	0.08
Hydrostatic Design Basis 73°F (23°C)	psi	ASTM D2837	1600
Hydrostatic Design Basis 140°F (60°C)	psi	ASTM D2837	800
Color; UV Stabilizer [C] [E]	---	ASTM D3350	Min 2% carbon Black Color UV Stabilizer
Material Properties			
Flexural Modulus 2% Secant - 16:1 span; depth, 0.5 in / min	psi	ASTM D790	>110,000
Tensile Strength at Yield	psi	ASTM D638 Type IV	3200
Elongation at Break 2 in / min., Type IV bar	%	ASTM D638	>700
Elastic Modulus	psi	ASTM D638	>150,000
Hardness	Shore D	ASTM D2240	62
PENT	hrs	ASTM F1473	>100
Thermal Properties			
Vicat Softening Temperature	°F	ASTM D1525	256
Brittleness Temperature	°F	ASTM D746	-103
Thermal Expansion	in / in / °F	ASTM D696	1.0×10^{-4}

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