Section 3

THERMAL EVALUATION

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Common Abbreviations Used in This Section

C	Celsius
Ci	Curie. A non-SI unit of radioactivity named after Marie and Pierre Curie. It is defined as 1 Ci = 3.7×10^{10} disintegrations per second
Co-60	Cobalt 60. Radioactive isotope
Cs-137	Cesium 137. Radioactive isotope
CMS	Computer Modeling Software
CFR	Code of Federal Regulations
F	Fahrenheit
HAC	Hypothetical Accident Conditions, as defined in 10 CFR 71.73
NCT	Normal Conditions of Transport, as defined in 10 CFR 71.71
UNC	Unified Coarse Thread
USNRC	United States Nuclear Regulatory Commission

3.0 THERMAL EVALUATION

This section will identify, describe, discuss, and analyze the principal thermal engineering design of the BU650B packaging, components and systems that are important to safety, and describe how the package complies with the performance requirements of 10 CFR 71.47 and 10 CFR 71.73.

3.1 Description of Thermal Design

This section identifies and describes the principal thermal design features of the BU650B Package that are important to safety. In addition, the thermal evaluations of the package under NCT (§71.71) and HAC (§71.73) that demonstrate compliance with the applicable performance requirements of 10 CFR 71 are discussed. The thermal evaluations demonstrate that the maximum temperatures of all components of the package remain below their respective temperature limits under both NCT and HAC. Further, the package is designed, constructed, and prepared for transport such that, in still air at 38°C and in the shade, no accessible surface of the package has a temperature exceeding 85°C. These results assure that the thermal performance of the package will not cause any loss or dispersal of radioactive contents, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging, in accordance with the requirements of §71.43(f) and §71.51(a)(1).

The BU650B package is a Type B non-fissile material package designed in accordance with Department of Transportation (DOT) and NRC regulations, therefore no fuel temperature evaluations are provided.

The BU650B package is designed as a Shell Assembly, made from a sandwich of Kaolite 1600, bound by 3/8" (inner) and 3/8" (outer) Grade 304 Stainless Steel walls. All joints within the Inner Shell are fully welded by arc or heli-arc and inspected to assure quality of welds. The 4 inches between the inner and outer stainless steel shells is filled with Kaolite 1600. There is a Closing Ring at the lid interface which consists of a ½" stainless steel plate cut to radius and fully welded to both the top and bottom sections, reinforced by 1/4" rings which are also fully welded to the circumference. The thickness of the Closing Ring is ½". Twenty-four bolts secure the Lid Assembly to the Lower Package Assembly through the Closing Ring. Surrounding the top and bottom of the package are Impact Limiters, attached at the

top and bottom of the package at four attachment points. The Impact Limiters are designed to absorb the shock generated as a result of a severe accident, simulated by the 30 foot free drop test. A secondary benefit of the Impact Limiters is realized during a fire or significant thermal event, should they remain attached to the BU650B after the 30' drop test.

A typical Shielded Liner (drawing BU650B-SL) is constructed of ¼" carbon steel plate, as a minimum, filled with lead. The lead is sealed in a fully welded containment. Approximate dimensions are ~34" high by ~28" diameter with a taper on one end and a center cavity for sealed sources. The Shielded Liner closure bolts are 5/8" – 11 UNC, Grade 5, or better. A typical Shielded Liner has a mass of approximately 6,500 pounds.

3.1.1 Design Features

The following features of the package are important to thermal performance:

- Cylindrical design. Affords the package a convection capability, even when lying horizontal in a hydrocarbon fire.

- Kaolite 1600 Thermal Barrier Material. Provides a tested thermal barrier against temperature escalation for an indefinite period at temperatures of 1600°F or lower. At temperatures of 1600°F or greater, the Kaolite 1600 loses effectiveness at a rate of approximately 13°F per minute.

- Impact Limiters filled with an insulating foam (note: Impact Limiters were considered sacrificial and not attached when models were constructed). The Impact Limiters have covered ventilation holes on the top and bottom (away-facing surfaces) of the Impact Limiters. When exposed to heat in excess of 800°F, the plastic ventilation plugs melt and allow escape of gasses and intumescing foam core material, which further insulates the Lower Package Assembly from extreme thermal event.

- Thermal capabilities of principal package materials. Grade 304 stainless steel walls a minimum of 3/8" thick. See Table 3-3 for thermal properties of stainless steel.

- Shielded liner is an encasement of lead surrounded by ¼" thick carbon steel plate and sits within the Inner Package. See Table 3-3 for thermal properties of carbon steel.

- Sealed Source is typically a double-encapsulated, stainless steel right cylinder that sits within the center cavity of the Shielded Liner. When the cumulative effect of the Outer Shell, Inner Shell, Shielded Liner Shell, and lead shielding are considered, Sealed Source location(s) present a minimal risk of a potential breach of containment or exposure resulting from a thermal event equivalent to that specified under Hypothetical Accident Conditions (§71.73). Because of the design restriction to 450 watts decay heat, there is no need for items such as cooling fins or thermal barriers. Additionally, there is no need for geometric configuration of the radioactive contents. Sealed Sources of Cs-137 and Co-60 do not have a criticality index.

3.1.2 Content's Decay Heat

The maximum activity of the payload is established at 29,250 Ci of Co-60 (450 watts) or limited to less than 30,000 Curies, Cs-137. The package payload with 29,250 Ci Co-60 produces an initial thermal energy of 450 watts. This is the same basis as used to derive the radiation source specification, further described in Section 5.2. There is no specific predominate thermal source. Multiple small sources can be carried, provided the aggregate amount does not exceed 450 watts. The Half-lives of these two isotopes are considered at 5.27 years for Co-60 and 30.2 years for Cs-137.

Calculation of decay heat is based upon the following formula:
(Cs-137 not considered as decay energy is approximately 31% of Co-60). Calculation is performed at Section 3.5.

1 watt = 1×10^{7} erg/sec

1 MeV = 1.6×10^{-6} erg

3.1.3 Summary Tables of Temperatures

Table 3-1 summarizes the maximum package temperatures resulting from NCT heat that affect structural integrity, containment, and

shielding. Because a transient thermal analysis is used for the evaluation of NCT heat, the table also reports the time that the peak temperatures are reached. The package has considerable thermal margin for NCT heat. The smallest thermal margins for NCT heat are 173.5°F for the Shielded Liner Cavity and 113.4°F for the package lid. The minimum package temperatures are influenced by the minimum ambient temperature and decay heat load, therefore, the minimum temperature for all package components is 286.6°F.

The peak temperatures of the package resulting from the HAC fire, along with the pre-fire damage conditions from which they result and the times at which they occur after fire initiation, are summarized in Table 3-2. As seen from the table, significant thermal margin exists for all package components, with the smallest margin of 89°F. The package temperatures under post-fire steady-state conditions will be equivalent to the peak temperatures for NCT heat. This is due to the decay of the thermal energy of the radioactive payload. See Figure 3-1 for BU650B Model, Temperature Locations of Interest.

Table 3-1
BU650B (450 Watts); Maximum Quasi Steady-State Temperatures, During NCT, 12 hour cycles

Temperature Location	**Maximum Quasi Steady-State Temperature (°F)**
Outside Shell Lid Top	245.3
Outside Shell Lid Bottom	229.7
Kaolite 1600 Middle	229.4
Outside Shell Mid-Height	210.5
Inner Shell Mid-Height	253.6
Shielded Liner Cavity	334.8
Shielded Liner Surface	323.9
Shielded Liner Lead*	332.3

Note: Assumption is that regardless of thickness of lead, the Shielded Liner lead will melt @ 620°F

Table 3-2
BU650B HAC Maximum Temperatures @ 30 Minutes

HAC maximum temperature (°F) after 30 Min				
Temperature Locations	No Heat Load		450 W Heat Load	
	Insolation during cool-down?		Insolation during cool-down?	
	No	Yes	No	Yes
Outside Shell Lid Top	1407.1	1407.1	1407.6	1407.6
Outside Shell Bottom	1439.8	1439.8	1444.0	1444.0
Kaolite Middle	551.3	553.2	601.4	603.4
Outside Shell Mid-Height	1452.5	1452.5	1453.4	1453.4
Inner Shell Mid-Height	263.5	272.4	337.6	345.7
Shielded Liner Cavity	150.1	165.8	348.4	371.1
Shielded Liner Surface	150.2	165.9	359.4	360.0

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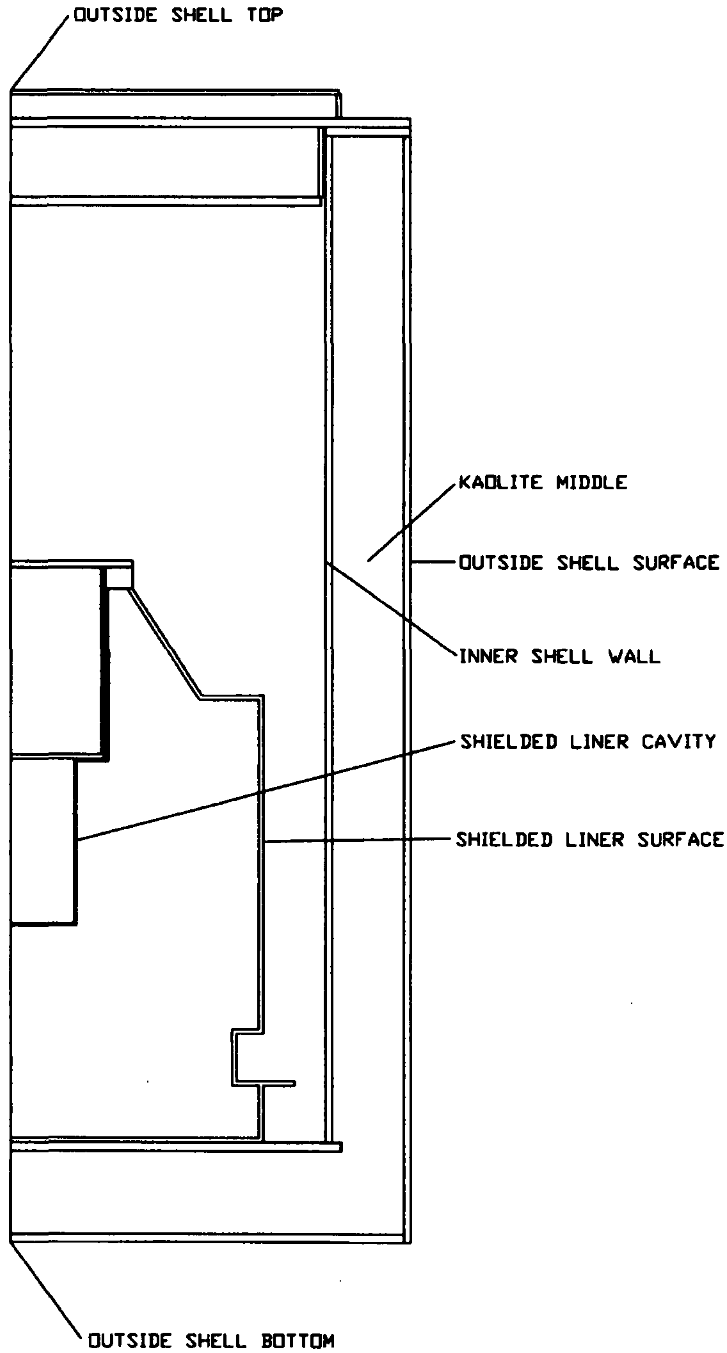
Figure 3-1

BU650B Model Temperature Locations of Interest



3.1.4 Summary Tables of Maximum Pressures

The BU650B as designed does not have a containment system and therefore meets the requirements identified in §71.73(c)(4). The package, when subjected to thermal evaluation, does not sustain sufficient thermally generated stresses or pressures that would result in the failure of any component or sub-assembly. As a consequence of the low stresses realized, the requirements of 10 CFR 71.73 (c)(4) are met.

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

The BU650B package is intended for the transport of sealed sources in special form only. There are no seals utilized within the package as the containment is achieved through use of the sealed source. Accordingly, there are no liquids or gasses present within the package. Gases external to the package are limited to those resulting from phase change of the polyurethane foam contained within the impact limiters. Vents for foam intumescence and gaseous emission face away from the package and do not affect package thermal characteristics. Table 3-3 lists the thermal properties for materials affecting heat transfer both within the package and from the package to the environment.

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Figure 3-2

Transient temperatures of the BU650B for NCT (450 watt Heat Load)

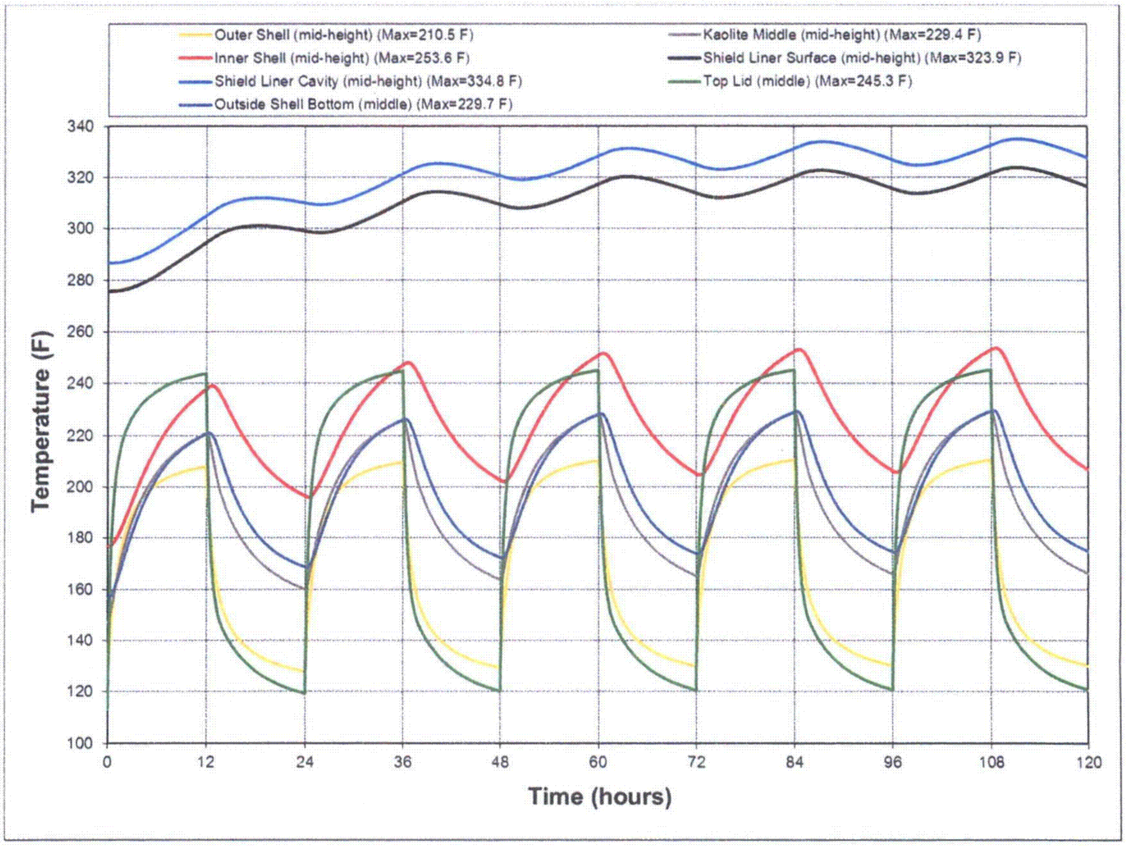

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Table 3-3
Thermal properties of the materials used in the thermal analyses.

Material	Temperature (°F)	Thermal Conductivity (Btu/h-in-°F)	Density (lbm/in³)	Specific Heat (Btu/lbm-°F)	Emissivity
Stainless Steel	-279.67	0.443[a]	0.285[a]	0.065[a]	0.22[a]
	-99.67	0.607	–	0.096	–
	260.33	0.799	–	0.123	–
	620.33	0.953	–	0.133	–
	980.33	1.088	–	0.139	–
	1340.33	1.223	–	0.146	–
	1700.33	1.348	–	0.153	–
	2240.33	1.526	–	0.163	–
Mild Carbon Steel	80.33	2.924[a]	0.284[a]	0.10366[a]	0.22[a]
	260.33	2.7400	–	0.11632	–
	620.33	2.3198	–	0.13351	–
	980.33	1.8945	–	0.16361	–
	1340.33	1.4499	–	0.27921	–
	1500	1.3194	–	0.1802	–
	1832	1.3194	–	0.15525	–
Lead	-279.67	1.9187[a]	0.411[a]	0.02818[a]	–
	-99.67	1.7737	–	0.02986	–
	80.33	1.7061	–	0.03081	–
	260.33	1.6432	–	0.03153	–
	620.33	1.5176	–	0.03392	–
Kaolite 1600	68	0.0093[b]	0.011[c]	0.2[d]	–
	212	0.0091	–	–	–
	392	0.0081	–	–	–
	572	0.0072	–	–	–
	1112	0.0082	–	–	–
Air	-9.67	1.074×10^{-3}[a]	4.064×10^{-5}[a]	0.240[a]	–
	80.33	1.266×10^{-3}	–	0.241	–
	170.33	1.445×10^{-3}	–	0.241	–
	260.33	1.628×10^{-3}	–	0.242	–
	350.33	1.796×10^{-3}	–	0.244	–
	440.33	1.960×10^{-3}	–	0.246	–
	530.33	2.114×10^{-3}	–	0.248	–
	620.33	2.258×10^{-3}	–	0.251	–
	710.33	2.393×10^{-3}	–	0.254	–
	800.33	2.523×10^{-3}	–	0.257	–
	890.33	2.644×10^{-3}	–	0.260	–
	980.33	2.759×10^{-3}	–	0.263	–
	1070.33	2.870×10^{-3}	–	0.265	–
	1160.33	2.985×10^{-3}	–	0.268	–
	1250.33	3.096×10^{-3}	–	0.270	–
	1340.33	3.212×10^{-3}	–	0.273	–
	1520.33	3.443×10^{-3}	–	0.277	–

(a) F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 2nd edition, John Wiley & Sons, New York, 1985.
(b) Hsin Wang, *Thermal Conductivity Measurements of Kaolite*, ORNL/TM-2003/49.
(c) Based on a baked density of 19.4 lbm/ft³ (0.011 lbm/in³).
(d) FAX communication from J. W. Breuer of Thermal Ceramics, Engineering Department, August 11, 19

Transient thermal analyses were performed on the finite element model of the BU650B shipping container to simulate NCT with a typical shield liner content having a maximum heat load of 450 watts. The insolation required for NCT per 10 CFR 71.71(c)(1) is applied to the top and sides of the Lower Package Assembly in alternating 12-hour periods (i.e., 12 hours on and 12 hours off) with the container bottom remaining adiabatic (no heat transfer) during the transient thermal analysis (Figure 3-2). An ambient temperature of 100°F, as stipulated in 10 CFR 71, is used in the NCT analysis. The initial temperature distribution within the package for the NCT transients was determined from steady-state analyses (with radiation and natural convection boundary conditions applied to the top and sides of the Lower Package Assembly). For the case with no internal heat source (0 w), the initial temperature distribution within the package was assumed to be at a uniform 100°F. As with the steady-state analyses, the content heat load is simulated by applying a uniform heat flux to the internal surfaces of the typical Shielded Liner inner void volume.

The transient thermal analyses simulate a five-day period of cyclic solar loading with 12 hours of insolation being applied at the beginning of each day (i.e., sunrise) followed by 12 hours in which there is no insolation to end the day (i.e., sunset). This five-day period allows for "quasi steady-state" conditions to be reached. While the temperature of a particular location within the model changes with respect to time in the transient analyses, the maximum temperature that location reaches from day-to-day does not change once a "quasi steady-state" condition is reached as illustrated in Figure 3-2.

The maximum temperatures of several locations within the model are summarized in Table 3-4. The maximum temperatures reported represent "quasi steady-state" conditions.

Table 3-4

Maximum "Quasi Steady-State" Temperatures during NCT

Temperature locations	Maximum quasi steady-state temperature (°F)
Outside Shell Lid Top	245.3
Outside Shell Bottom	229.7
Kaolite Middle	229.4
Outside Shell Mid-Height	210.5
Inner Shell Mid-Height	253.6
Shielded Liner Cavity	334.8
Shielded Liner Surface	323.9

3.2.2 Component Specifications

Technical specifications of components important to thermal performance of the BU650B package are listed in Section 3.5.2. For reference purposes, this package does not employ the use of valves, seals, coatings, or vents. Accordingly there are no designated operating ranges or temperature limits in excess of 450 watts decay heat. The temperature properties of the Kaolite 1600 thermal barrier material are reflected in Table 3-2. The material properties of Kaolite 1600 thermal barrier material are provided at Section 3.5.2, DAC-P09YCW01-0002. Likewise, the temperature properties of the Last-A-Form FR3712 are reflected in the DAC-P09YCW01-0002, at Section 3.5.2. The BU650B package, as tested, meets the requirements of the HAC and therefore meets the conditions specified under NCT.

3.3 Thermal Evaluation under Normal Conditions of Transport

Thermal analyses of the JL Shepherd & Associates BU650B shipping package with the typical Shielded Liner (450 watt heat load) content were performed to determine the temperature distribution within the packaging during NCT as specified in 10 CFR 71.71(c)(1). Transient thermal analyses are performed by treating the problem as a cyclic transient with the incident heat flux due to solar radiation applied and not applied in alternating 12-hour periods (Figure 3-2). This document details the BU650B shipping container with the typical shield liner content with a total heat load of 450 watts. The external thermal loading requirements are per 10 CFR 71.71 and 71.73 for NCT and HAC, respectively. It is assumed the heat transfer from the external surface of the packaging during NCT and HAC conditions will be free convection and radiation heat transfer to the environment. During NCT with the packaging in the upright orientation, the bottom surface is assumed to be adiabatic (no heat transfer across this boundary). Free convection is not modeled in the air space inside of the BU650B packaging, only radiation and conduction. Other assumptions including the material properties are stated throughout the modeled calculation and reference documents.

A two-dimensional axisymmetric finite element model of the BU650B shipping container was constructed using ANSYS software for application of boundary conditions, interactions, and loads. The actual material contents of the BU650B packaging were not specifically modeled—instead, the content source heat load (if desired) was modeled by applying a uniform heat flux to the inner surfaces of the typical Shielded Liner. DAC-P09YCW01-0002-000-00 presents a schematic of the finite element model used. See Section 3.5.2.

The model consists of five materials: stainless steel, Kaolite, mild carbon steel, lead and air in the gaps between the Shielded Liner and inside BU650B body

surface. Air is also modeled between the closure lid and container body. Because of the relatively small volume the content shoring takes up relative to air and axisymmetric nature of the Finite Element Analysis (FEA) model, the shoring is not modeled in these thermal analyses. Because the impact limiters absorb thermal energy during the burn, it is assumed the worse-case scenario is to analyze the BU650B packaging main body and contents without the impact limiters, even if there is a high probability the impact limiters will be retained after the free drop. Thermal properties of the materials used in the analysis are presented in Table 3-3.

During the NCT transient thermal analyses and the steady-state thermal analyses (used to obtain the starting temperature distribution in the package for NCT and HAC when a content heat load is present), the BU650B package is assumed to be in an upright (vertical) orientation. The top of the Lower Package Assembly is modeled as a heated horizontal flat plate facing up using the following correlation:

$$h=\left(\frac{k}{L}\right)C_1\,Ra^{C_2},$$

where, h = heat
k = thermal conductivity of air,
L = characteristic length (= D/4),
D = diameter of the package,
Ra = Rayleigh number,
C_1 = constant (see Table 3-4), and
C_2 = constant (see Table 3-4).

The Rayleigh number (Ra) in Eq. 6 is defined as:

$$Ra=\frac{g\beta\Delta T L^3}{\nu\alpha},$$

where, g = acceleration of gravity,
β = coefficient of thermal expansion,
ΔT = temperature difference,
ν = kinematic viscosity [μ/ρ],
μ = absolute viscosity,
α = thermal diffusivity [$k/(\rho C_p)$],
ρ = density of air, and
C_p = specific heat of air.
k = thermal conductivity of air

The properties of air used in the natural convection calculations are presented in Table 3-6.

During the NCT transient thermal analyses and the steady-state thermal analyses, the sides of the BU650B package body are modeled as a vertical flat plate using the following correlation:

$$h = \left(\frac{k}{L}\right)\left[C_3 + \frac{C_4\,Ra^{C_5}}{\left(1 + \left[\frac{0.492}{Pr}\right]^{9/16}\right)^{C_6}}\right]^{C_7},$$

where, L = characteristic length = the container height,
C_3 = constant (see Table 3-5),
C_4 = constant (see Table 3-5),
C_5 = constant (see Table 3-5),
C_6 = constant (see Table 3-5),
C_7 = constant (see Table 3-5), and
Pr = Prandtl Number.

The bottom of the container body is conservatively modeled as adiabatic during the NCT transient analyses and the steady-state analyses.

Table 3-5

Coefficients for Natural Convection Correlations

Coefficient	Rayleigh Number Range	Value
C_1	$10^4 < Ra < 10^7$	0.54
	$10^7 < Ra < 10^{11}$	0.15
C_2	$10^4 < Ra < 10^7$	0.25
	$10^7 < Ra < 10^{11}$	1/3
C_3	$Ra < 10^9$	0.680
	$Ra > 10^9$	0.825
C_4	$Ra < 10^9$	0.670
	$Ra > 10^9$	0.387
C_5	$Ra < 10^9$	0.25
	$Ra > 10^9$	1/6
C_6	$Ra < 10^9$	4/9
	$Ra > 10^9$	8/27
C_7	$Ra < 10^9$	1
	$Ra > 10^9$	2

Source: F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 2nd ed., John Wiley & Sons, New York, 1985.

Table 3-6

Properties of Air Used In Natural Convection Calculations.

Temperature (°F)	Thermal Conductivity (Btu/h-in.-°F)	Density (lbm/in^3)	Specific Heat (Btu/lbm-°F)	Kinematic Viscosity (in^2/h)	Thermal Diffusivity (in^2/h)	Prandtl Number
-9.67	1.074×10^{-3}	5.039×10^{-5}	0.240	6.384×10^{1}	8.872×10^{1}	0.720
80.33	1.266×10^{-3}	4.196×10^{-5}	0.241	8.867×10^{1}	1.255×10^{2}	0.707
170.33	1.445×10^{-3}	3.595×10^{-5}	0.241	1.167×10^{2}	1.668×10^{2}	0.700
260.33	1.628×10^{-3}	3.147×10^{-5}	0.242	1.474×10^{2}	2.137×10^{2}	0.690
350.33	1.796×10^{-3}	2.796×10^{-5}	0.244	1.807×10^{2}	2.634×10^{2}	0.686
440.33	1.960×10^{-3}	2.516×10^{-5}	0.246	2.164×10^{2}	3.164×10^{2}	0.684
530.33	2.114×10^{-3}	2.286×10^{-5}	0.248	2.543×10^{2}	3.722×10^{2}	0.683
620.33	2.258×10^{-3}	2.097×10^{-5}	0.251	2.940×10^{2}	4.291×10^{2}	0.685
710.33	2.393×10^{-3}	1.935×10^{-5}	0.254	3.360×10^{2}	4.871×10^{2}	0.690
800.33	2.523×10^{-3}	1.797×10^{-5}	0.257	3.800×10^{2}	5.468×10^{2}	0.695
890.33	2.644×10^{-3}	1.677×10^{-5}	0.260	4.261×10^{2}	6.082×10^{2}	0.702
980.33	2.759×10^{-3}	1.573×10^{-5}	0.263	4.739×10^{2}	6.696×10^{2}	0.709
1070.33	2.870×10^{-3}	1.480×10^{-5}	0.265	5.234×10^{2}	7.310×10^{2}	0.716
1160.33	2.985×10^{-3}	1.397×10^{-5}	0.268	5.742×10^{2}	7.979×10^{2}	0.720
1250.33	3.096×10^{-3}	1.324×10^{-5}	0.270	6.261×10^{2}	8.649×10^{2}	0.723
1340.33	3.212×10^{-3}	1.258×10^{-5}	0.273	6.802×10^{2}	9.374×10^{2}	0.726
1520.33	3.443×10^{-3}	1.144×10^{-5}	0.277	7.912×10^{2}	1.088×10^{3}	0.728

Source: F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 2nd ed., John Wiley & Sons, New York, 1985.

3.3.1 Heat and Cold

The BU650B package, as prepared for transport, does not sustain any significant reduction in packaging effectiveness as a consequence of NCT. There were no instances of material changes that affected containment or shielding (Criticality not considered. Fissile materials not intended for this package). There were no significant increases of temperature as a result of NCT. Likewise, there were no reductions in packaging effectiveness as a result of reduced temperatures. The thermal changes analyzed do not produce sufficient stresses, resulting from expansion and contraction of component items to diminish package integrity. Figure 3-2 reflects the package performance as a consequence of thermal changes analyzed each twelve hours for a period of five days. See Tables 3-7 for HAC maximum temperatures @ 30 minutes and 3-8 for HAC temperature differences from baseline. Therefore, the package meets the requirements of §71.43(g) and §71.71.

3.3.2 Maximum Normal Operating Pressure

The BU650B is not intended for storage or shipment of fuel, spent fuel or fissile materials. The package, as designed, does not have a sealing surface and therefore does not accumulate pressures in excess of atmosphere. Because the package is designed for transport of sealed sources in special form (§71.75), and the chemical composition of the isotopes intended to be carried are solids and do not emit hydrogen, helium or other gasses as a result of decay or decomposition, there are no excessive operating pressures applied to the package in excess of atmosphere. Additionally, there are no plastics or liquids intended to be loaded into shielded liners or within the package inner liner. Therefore these items are not addressed.

3.4 Thermal Evaluation Under Hypothetical Accident Conditions

Thermal analyses of the BU650B package with the typical shield liner (450 watt heat load) content were performed to determine the temperature distribution within the packaging during NCT as specified in 10 CFR 71.71(c)(1). Transient thermal analyses were performed by treating the problem as a cyclic transient with the incident heat flux due to solar radiation applied and not applied in alternating 12-hour periods. Thermal analyses of the BU650B package with the typical Shielded Liner (450 watt heat load) were performed to determine the thermal response of the packaging to HAC as specified in 10 CFR 71.73(c)(4).

3.4.1 Initial Conditions

The heat transfer mechanisms included in the thermal model that address thermal radiation, natural convection, and insolation (solar heat flux) are described in detail in the following sections. Considered in the model were the cumulative effects of the 30 foot drop and puncture tests. Steady-state thermal analyses are performed on the finite element model of the BU650B package having a total content heat load of 450 watts. The temperature distribution results from this analysis are used as the starting temperature distributions within the model when performing the transient thermal analyses for NCT and the HAC 30-minute fire. The boundary conditions for this steady-state analysis include a combination of thermal radiation exchange and natural convection applied to the top and sides of the container main body using an ambient temperature of 100°F, after the 30' drop test and puncture test with Impact Limiters removed. The bottom of the container body is modeled as an adiabatic surface (i.e., no heat transfer). Additionally, the content heat load is simulated by applying a uniform heat flux to the surfaces of the elements representing the inner surface of the Shielded Liner inner content void. The calculated steady-

state temperature distribution within the model of the BU650B shipping container are presented in Table 3-1.

3.4.2 Fire Test Conditions

A 30-minute fire of 1475°F (800°C) is simulated by applying natural convection and radiant exchange boundary conditions to all external surfaces of the container body (assuming the body is in a horizontal orientation) with a content heat load of 450 watts. There is no heat flux boundary condition simulating insolation applied to the model before and during the 30-minute fire. The initial temperature distribution within the package for all heat load cases is obtained from their respective steady-state analyses. As with the steady-state analyses discussed previously, the content heat load is simulated by applying a uniform heat flux to the internal surfaces of the elements representing the typical Shielded Liner inner void content area.

Following the 30-minute fire transient analyses, a 24-hour cool-down transient thermal analysis was performed using the temperature distribution at the end of the fire as the initial temperature distribution. During post-fire cool-down, natural convection and radiant exchange boundary conditions are applied to all external surfaces of the container body (assuming the body is in a horizontal orientation). Additionally, cases are analyzed in which insolation is included during the post-fire cool-down. For the cases in which insolation is applied to the model during cool-down, insolation is applied during the first 12-hour period following the 30-minute fire, then removed as was done for NCT.

The maximum temperatures calculated for the BU650B shipping container for HAC are summarized in Table 3-7. In addition to the maximum temperatures for HAC presented in Table 3-7, the temperature difference between a baseline transient case (no content heat load and no insolation during cool-down) and various other cases investigated in this report are calculated for several locations within the model. These calculated temperature differences may be added to physical test data to estimate package temperatures for parameters that cannot be easily included in a test (i.e., content heat load or insolation during cool-down). The calculated temperature differences between the baseline case and various HAC cases are presented in Tables 3-7 and 3-8. For a detailed description of the analysis used to evaluate the package under the fire test conditions, see Section 3.5.2.

Table 3-7
BU650B HAC Maximum Temperatures @ 30 Minutes

Temperature Locations	HAC maximum temperature (°F)			
	No Heat Load		450 w Heat Load	
	Insolation during cool-down?		Insolation during cool-down?	
	No	Yes	No	Yes
Outside Shell Lid Top	1407.1	1407.1	1407.6	1407.6
Outside Shell Bottom	1439.8	1439.8	1444.0	1444.0
Kaolite Middle	551.3	553.2	601.4	603.4
Outside Shell Mid-Height	1452.5	1452.5	1453.4	1453.4
Inner Shell Mid-Height	263.5	272.4	337.6	345.7
Shielded Liner Cavity	150.1	165.8	348.4	371.1
Shielded Liner Surface	150.2	165.9	359.4	360.0

Table 3-8
BU650B HAC Temperature Differences from Baseline

Temperature Locations	ΔT (°F)			
	No Heat Load		450 w Heat Load	
	Insolation during cool-down?		Insolation during cool-down?	
	No	Yes	No	Yes
Outside Shell Lid Top	—	0.0	0.5	0.5
Outside Shell Bottom	—	0.0	4.2	4.2
Kaolite Middle	—	1.9	50.1	52.1
Outside Shell Mid-Height	—	0.0	0.9	0.9
Inner Shell Mid-Height	—	8.9	74.1	82.2
Shielded Liner Cavity	—	15.7	198.3	221.0
Shielded Liner Surface	—	15.7	209.2	209.8

As a consequence of the tests applied and the results obtained, the package meets the requirements of 10 CFR 71.73(c).

3.4.3 Maximum Temperatures and Pressure

The BU650B has been evaluated for both transient peak temperatures of package components as a function of time both during and after the fire test, as well as maximum temperatures from the post-fire, steady-state condition. Figure 3-3 depicts locations at which measurements were obtained. Tables 3-7 and 3-8 provide information on temperatures obtained from the various locations, as well as the differences taken from baseline temperatures (Table 3-1), respectively.

Following the 30-minute fire transient analyses, 24-hour cool-down transient thermal analyses was performed using the temperature

distribution at the end of the fire as the initial temperature distribution. During post-fire cool-down, natural convection and radiant exchange boundary conditions are applied to all external surfaces of the container body (assuming the body is in a horizontal orientation). Additionally, cases are analyzed in which insolation is included during the post-fire cool-down. For the cases in which insolation is applied to the model during cool-down, insolation is applied during the first 12-hour period following the 30-minute fire, then removed. See Table 3-7 above.

As designed, the BU650B does not incorporate a seal within the package body, and therefore does not experience internal pressure increases as a consequence of thermal event. Additionally, none of the materials of construction is combustible. The main component parts of the package are stainless steel and are not anticipated to decompose within the 20-year projected package useful life.

Temperature adjustments were calculated for various locations in the BU650B shipping container for exposure of the package to HAC. These adjustments were the calculated temperature differences between a baseline case (i.e., no content heat load and no insolation during cool-down) and the case with 450 watt content heat load with and without insolation during the post-fire cool-down. The calculated temperature adjustments for HAC are presented in Table 3-7. The values obtained are clearly indicative of the package capability to prevent any release of radioactive materials into the environment or provide an increased risk of radiation exposure during HAC. Additionally the structural integrity of the Shielded Liner and BU650B package were not impaired as a consequence of the cumulative drop, puncture, and thermal tests applied. As a result of the above, the BU650B meets the conditions of 10 CFR 71.73(c)(4).

3.4.4 Maximum Thermal Stresses

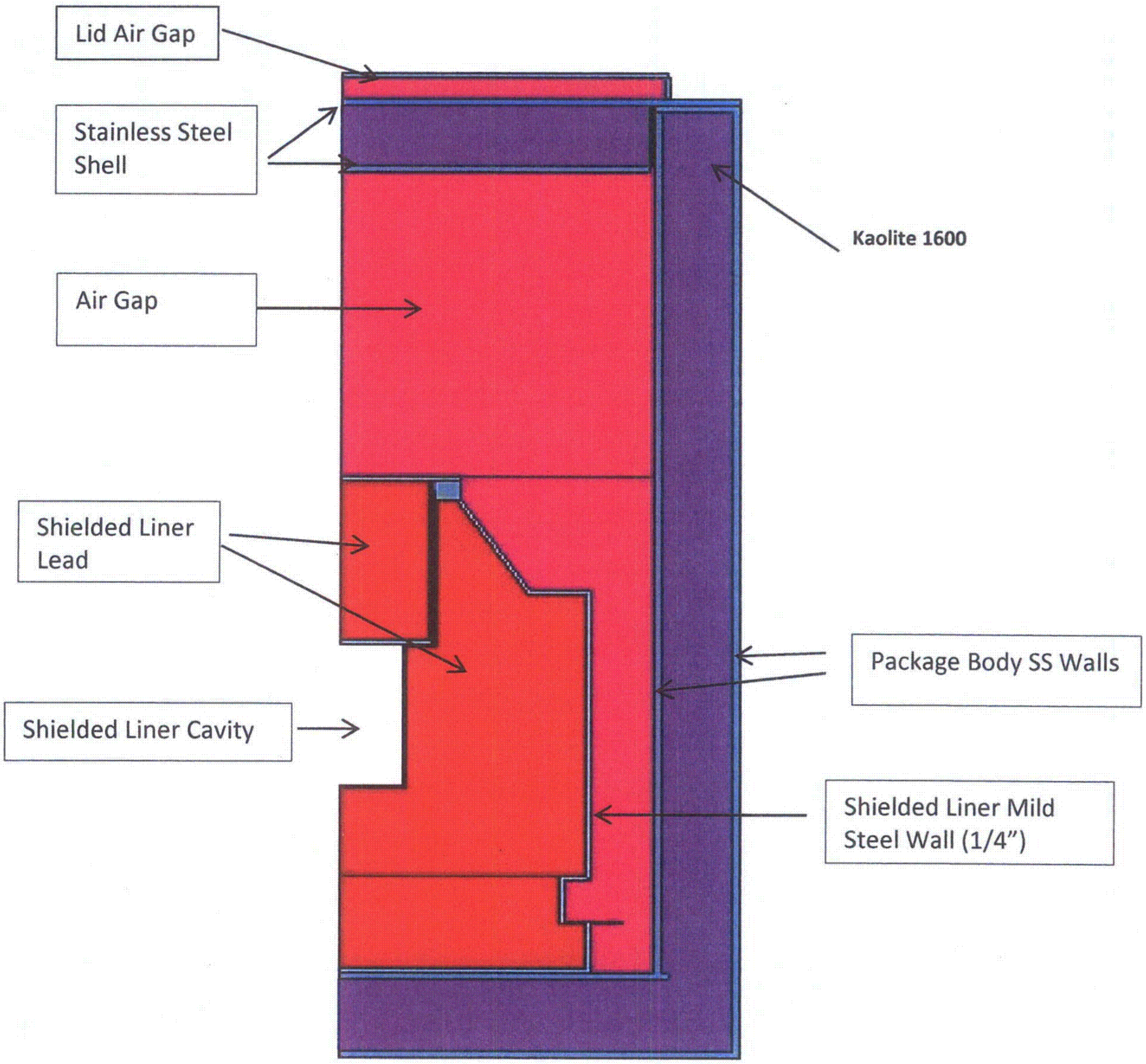
Because the temperatures achieved during the fire test and cool-down period remain low, any thermal stress applied to the package is localized at the exterior and has no significant effect on overall package performance. See Table 3-8.

3.4.5 Accident Conditions for Fissile Material Packages for Air Transport.

The BU650B package is not intended for transport of fissile materials. Therefore this section is not applicable and not addressed.

Figure 3-3

BU650B Side View (Cut Away) of Loaded Package and Points of Thermal Evaluation



3.5 Appendix

3.5.1 References:

[3.1] *Packaging and Transportation of Radioactive Materials,* U. S. Nuclear Regulatory Commission, Code of Federal Regulations, Title 10 – Energy, Part 71, January 1, 2007.

[3.2] R. Siegel and J. R. Howell, *Thermal Radiation Heat Transfer*, Second Edition, Hemisphere Publishing Corporation, 1981.

[3.3] F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, Second Edition, John Wiley & Sons, NY, 1985.

3.5.2 Calculation, DAC-P09YCW01-0002-000-00, Thermal Analyses (ANSYS) of JLS&A BU650B Shipping Container for NCT and HAC, Babcock & Wilcox Y-12, Oakridge, TN, April 23, 2012.

3.5.3 Calculation: Decay Heat

1 MeV = 1.6×10^{-6} erg or: 1 MeV = .0000016 erg

1 watt = 1×10^{7} erg/sec or: 1,000,000/60 or: 166,666 erg

1 watt = 65 Ci

450 watts = 29,250 Curies

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QUALITY RECORD

DESIGN CALCULATION SHEET

Job/Blueprint Number: 98-5159

Calculation No.: DAC-P09YCW01-0002 000 00

Total Number of Pages: 43

Revision No.: 0

Title/Scope: THERMAL ANALYSIS (ANSYS) OF THE J.L SHEPHERD ASSOCIATES BU6508 SHIPPING CONTAINER FOR NCT AND HAC

Design Input/Assumptions/References: SEE ATTACHED

Methodology/Formula/Computer Program Used (if any): SEE ATTACHED

CALCULATION: SEE ATTACHED

(ATTACH ADDITIONAL SHEETS AS NECESSARY AND MARK TOTAL NUMBER OF PAGES ABOVE)

RESULTS/CONCLUSIONS:

SEE PAGE 24 OF 43

Prepared By: W. BROWN [initials]
(Print Name / Initial)

Verified By: M. SHEPHERD — M Shepherd per MPB MFS
(Print Name / Initial)

Approved By: QUE PHO [signature]
(Print Name / Sign Name)

Date: 06-28-12

Form 3-2-1
Rev 2, 6-25-08

Design Analysis and Calculation
Title Page

Calculation No:	DAC-P09YCW01-0002 000 00
Calculation Title:	Thermal Analysis (ANSYS) of the JL Shepherd & Associates BU650B Shipping Container for NCT and HAC

Calculation Status:	Preliminary	Contains Unverified Assumptions	Verified	Superseded	Voided/Cancelled
	☐	☐	☒	☐	☐

Preparer's Org:	Engineering (Packaging)	**SSC Grade:**	N/A
Project/Task Name:	JLS&A BU650B Shipping Container		

Abstract (e.g., What, Why, How, Results):

The purpose of this Design Analysis Calculation Document is to determine the thermal response of the JL Shepherd & Associates BU650B Shipping Package, with typical Shield Liner Content and 450 Watt internal heat load, to the Regulatory Normal Conditions of Transport (NCT). Additionally, this work determines the temperature adjustments to be made to the burn test data for the Hypothetical Accident Conditions (HAC). ANSYS was used to analyze the thermal response of the BU650B with contents using an axisymmetric thermal model. The many thermal response values are shown within and are much to vast to summarize here.

Assumptions requiring subsequent verification:

None.

Software packages used:

ANSYS Mechanical Release 12.0.1 UP20090415

The ep0164 computer processor type and operating system version is Dell Precision PWS670, Intel Xeon CPU 3.6 GHz and Microsoft Windows XP Professional Version 2002.

The ep0148 computer processor type and operating system is Dell Precision PWS670, Intel Xeon CPU 3.2 GHz and Microsoft Windows XP Professional Version 2002.

Approvals

Rev. No.	Preparer (Print/Sign)	Date	Verifier/Checker (Print/Sign)	Date	Approver (Print/Sign)	Date
0	D. L. Lowe/ D. Lance Lowe	4/5/12	D. E. Winder/ [signature]	4/3/12	W. WORTH / [signature]	4/5/2012

Revisions

Rev. No.	Revision Description
0	Initial Issue

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ESO No.	Computed by	Checked by
P09YCW01	D. L. Lowe	D. E. Winder

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Job	Date	Sheet
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P09YCW01	DL D. L. Lowe	DEW D. E. Winder

REVISION LOG

Revision	Date	Description	Total Pages	Affected Pages
0	4/5/12	Initial Issue	Frontmatter, 1 - 4 Body, 6 - 25 Appendix A, 26 - 32 Appendix B, 33 - 38 Appendix C, 39 - 42	All

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THERMAL ANALYSES OF THE JL SHEPHERD & ASSOCIATES BU650B SHIPPING CONTAINER FOR NCT AND HAC

D. Lance Lowe

April 5, 2012

INTRODUCTION / PURPOSE

Thermal analyses of the JL Shepherd & Associates BU650B shipping container with the typical shield liner (450 Watt heat load) content are performed to determine the temperature distribution within the packaging during Normal Conditions of Transport (NCT) as specified in 10 CFR 71.71(c)(1).[Ref 1] Transient thermal analyses are performed by treating the problem as a cyclic transient with the incident heat flux due to solar radiation applied and not applied in alternating 12-hour periods.

Additionally, thermal analyses of the BU650B shipping container with the typical shield liner (450 Watt heat load) are performed to determine the thermal response of the packaging to Hypothetical Accident Conditions (HAC) as specified in 10 CFR 71.73(c)(4).[Ref 1] Although earlier revisions of 10 CFR 71 specifically state that insolation does not need to be evaluated before, during, or after HAC, the current version of 10 CFR 71 and associated guidance are unclear regarding the need for consideration following HAC testing. Since the Nuclear Regulatory Commission (NRC) has taken the position that insolation must be considered and evaluated following fire testing, analyses are conducted to determine the effect of insolation following the HAC fire on the BU650B shipping container. Assumptions are stated throughout the document.

REFERENCES

1. *Packaging and Transportation of Radioactive Materials*, U. S. Nuclear Regulatory Commission, Code of Federal Regulations, Title 10 – Energy, Part 71, January 1, 2007.

2. R. Siegel and J. R. Howell, *Thermal Radiation Heat Transfer*, Second Edition, Hemisphere Publishing Corporation, 1981.

3. F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, Second Edition, John Wiley & Sons, NY, 1985.

DESIGN INPUTS / ASSUMPTIONS

This calculation document details the BU650B shipping container with the typical shield liner content with a total heat load of 450 Watts. The external thermal loading requirements are per 10 CFR 71.71 and 71.73 for normal conditions of transport (NCT) and hypothetical accident conditions (HAC), respectively. It is assumed the heat transfer from the external surface of the packaging during NCT and HAC conditions will be free convection and radiation heat transfer to the environment. During NCT with the packaging in the upright orientation, the bottom surface is assumed to be adiabatic (no heat transfer across

this boundary). Free convection is not modeled in the air space inside of the BU650B packaging, only radiation and conduction. Other assumptions including the material properties are stated throughout this calculation and reference documents.

DESCRIPTION OF THE BU650B PACKAGING AND FINITE ELEMENT MODEL

The BU650B packaging is a Type B non-fissile material package designed in accordance with Department of Transportation (DOT) and NRC regulations.

The BU650B package is designed as a Shell Assembly, made from a sandwich of Kaolite 1600, bound by walls of 3/8" (inner) and 3/8" (outer) 304 Stainless Steel. All joints are fully welded by heli-arc and radiologically inspected to assure full penetration. The 4 inches between the inner and outer stainless steel shells is filled with Kaolite 1600. There is a closing ring at the lid interface which consists of stainless steel plate cut to radius and fully welded to both the top and bottom sections, reinforced with ½" rings also fully welded to the circumference. Thickness of the closing ring is ½". Twenty four bolts secure the Lid Assembly to the Lower Package Assembly through the ½" closing ring. Surrounding the top and bottom of the package are Impact Limiters, attached at the top and bottom of the package at four attachment points. The Impact Limiters are designed to absorb the shock generated as a result of a severe accident, simulated by the 30 ft free drop test.

A typical shielded liner (drawing BU650B-SL) is constructed of ¼" mild steel plate, as a minimum, filled with lead or lead equivalent. It is sealed in a fully welded containment. Approximate dimensions are 36" high by 30" diameter with a taper on one end with a center cavity for sealed sources. The shield liner closure bolts are 5/8" – 11 UNC, Grade 5.

A two-dimensional axisymmetric finite element model of the BU650B shipping container is constructed using ANSYS software for application of boundary conditions, interactions, and loads. The actual material contents of the packaging are not specifically modeled—instead, the content source heat load (if desired) is modeled by applying a uniform heat flux to the inner surfaces of the typical shield liner. A schematic of the finite element model is presented in Figure 1 with details of the upper and lower portions of the model shown in Figure 2 and Figure 3, respectively. The model consists of five materials: stainless steel, Kaolite, mild carbon steel, lead and air in the gaps between the shield liner and inside BU650B body surface. Air is also modeled between the closure lid and container body. Because of the relatively small volume the content shoring takes up relative to air and axisymmetric nature of the FEA model, the shoring is not modeled in these thermal analyses. Because the impact limiters absorb thermal energy during the burn, it is assumed worse-case scenario is to analyze the BU650B packaging main body and contents without the impact limiters even if there is a high probability the impact limiters will be retained after the free drop. Thermal properties of the materials used in the analysis are presented in Table 1.

MODELED HEAT TRANSFER MECHANISMS

The heat transfer mechanisms included in the thermal model such as thermal radiation, natural convection, and insolation (solar heat flux) are described in detail in the following sections.

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Heat Transfer between Package Exterior and Ambient

The heat transfer between the exterior of the package and the ambient (or fire) is modeled as a combination of radiant heat transfer and natural convection. The heat transfer due to radiant exchange with the environment is calculated as:

$$q''_{rad} = \sigma F_e \left(T_s^4 - T_a^4\right), \quad (1)$$

where,
- σ = Stefan-Boltzmann constant,
- F_e = overall exchange factor,
- T_s = container outer surface temperature (absolute), and
- T_a = ambient or fire temperature (absolute).

The overall interchange factor is calculated as:

$$F_e = \left[\frac{1}{\frac{1}{\varepsilon_p} + \frac{A_p}{A_s}\left(\frac{1}{\varepsilon_s} - 1\right)}\right], \quad (2)$$

where,
- ε_p = emissivity of package surface,
- A_p = surface area of the package,
- A_s = surface area of the surroundings, and
- ε_s = emissivity of surroundings.

For NCT and the cool-down period following the HAC fire, the area of the surroundings is assumed to be much larger than the surface area of the package; therefore, Eq. 2 reduces to:

$$F_e \approx \varepsilon_p . \quad (3)$$

An emissivity value of 0.22, which is typical of clean stainless steel, is assumed for the outer surfaces of the container body during NCT and during the cool-down period following the HAC fire. In reality, the outer surfaces of the body will have a much higher emissivity following the HAC fire; therefore, this assumption is conservative.

During the HAC fire, the area of the surroundings is assumed to be approximately equal to the surface area of the container body; therefore, Eq. 2 reduces to:

$$F_e = \left[\frac{1}{\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_s} - 1}\right]. \quad (4)$$

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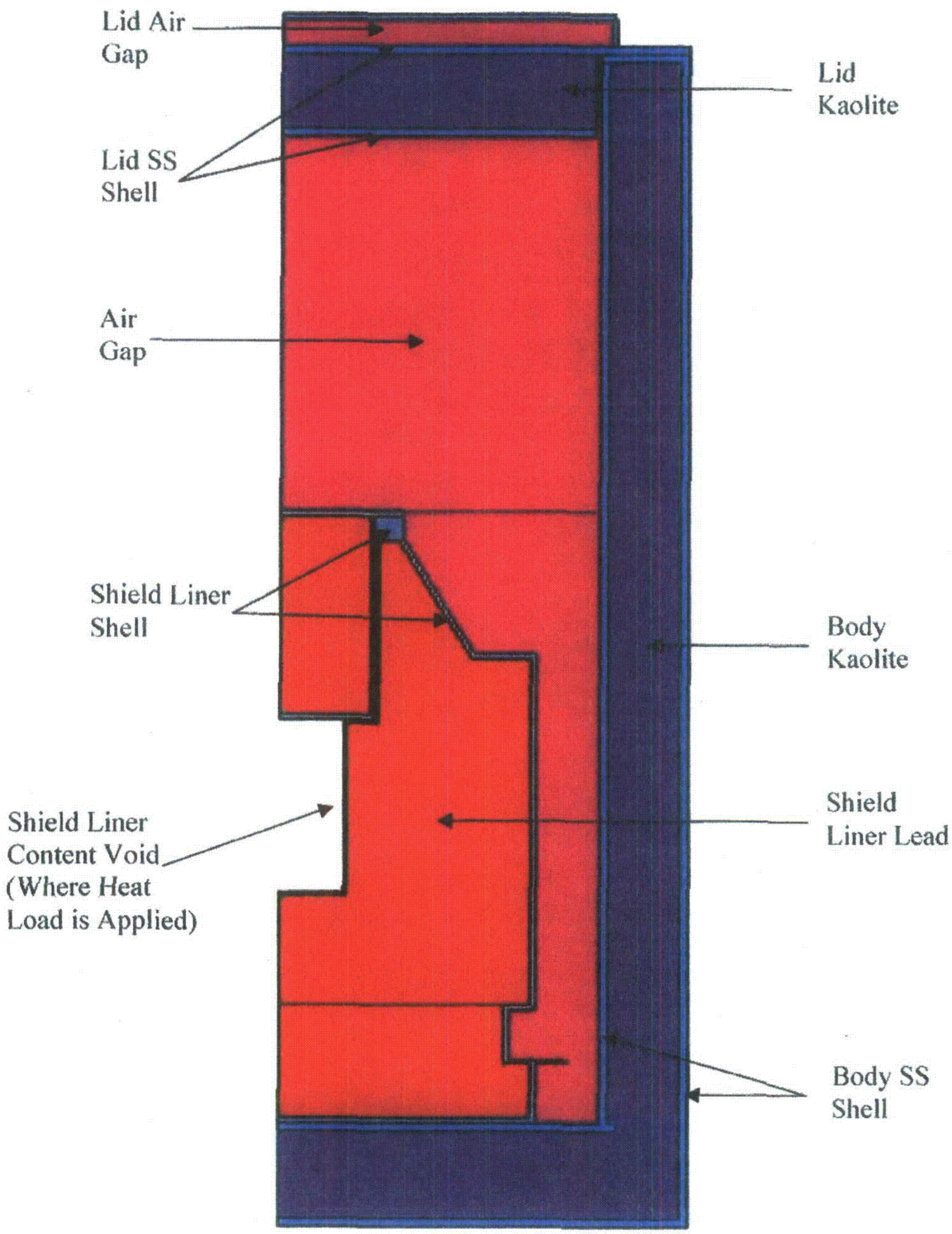

Figure 1. ANSYS axisymmetric model (areas shown) of the BU650B Shipping Container.

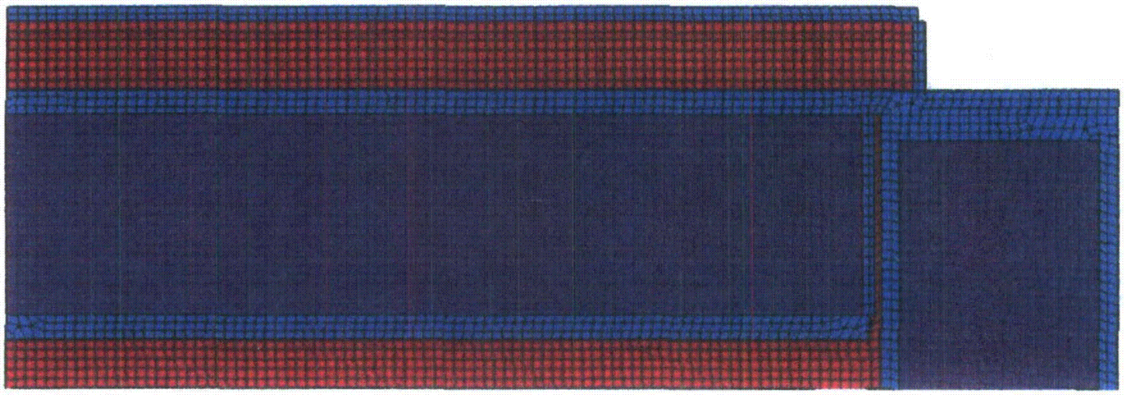

Figure 2. ANSYS axisymmetric finite element model of the BU650B (upper portion detail).

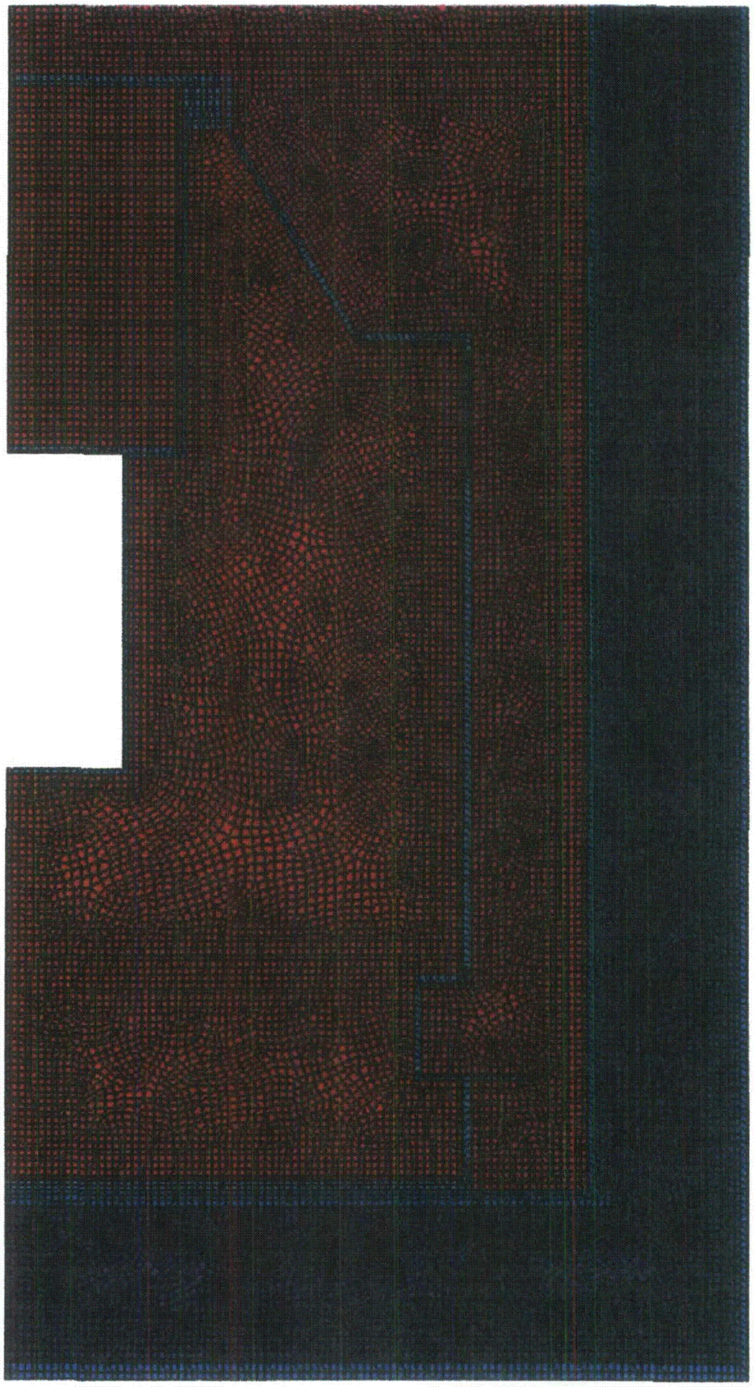

Figure 3. ANSYS axisymmetric finite element model of the BU650B (lower portion detail).

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Table 1. Thermal properties of the materials used in the thermal analyses.

Material	Temperature (°F)	Thermal Conductivity (Btu/h-in-°F)	Density (lbm/in^3)	Specific Heat (Btu/lbm-°F)	Emissivity
Stainless Steel	-279.67	0.443[(a)]	0.285[(a)]	0.065[(a)]	0.22[(a)]
	-99.67	0.607	–	0.096	–
	260.33	0.799	–	0.123	–
	620.33	0.953	–	0.133	–
	980.33	1.088	–	0.139	–
	1340.33	1.223	–	0.146	–
	1700.33	1.348	–	0.153	–
	2240.33	1.526	–	0.163	–
Mild Carbon Steel	80.33	2.924[(a)]	0.284[(a)]	0.10366[(a)]	0.22[(a)]
	260.33	2.7400	–	0.11632	–
	620.33	2.3198	–	0.13351	–
	980.33	1.8945	–	0.16361	–
	1340.33	1.4499	–	0.27921	–
	1500	1.3194	–	0.1802	–
	1832	1.3194	–	0.15525	–
Lead	-279.67	1.9187[(a)]	0.411[(a)]	0.02818[(a)]	–
	-99.67	1.7737	–	0.02986	–
	80.33	1.7061	–	0.03081	–
	260.33	1.6432	–	0.03153	–
	620.33	1.5176	–	0.03392	–
Kaolite 1600	68	0.0093[(b)]	0.011[(c)]	0.2[(d)]	–
	212	0.0091	–	–	–
	392	0.0081	–	–	–
	572	0.0072	–	–	–
	1112	0.0082	–	–	–
Air	-9.67	1.074×10^{-3}[(a)]	4.064×10^{-5}[(a)]	0.240[(a)]	–
	80.33	1.266×10^{-3}	–	0.241	–
	170.33	1.445×10^{-3}	–	0.241	–
	260.33	1.628×10^{-3}	–	0.242	–
	350.33	1.796×10^{-3}	–	0.244	–
	440.33	1.960×10^{-3}	–	0.246	–
	530.33	2.114×10^{-3}	–	0.248	–
	620.33	2.258×10^{-3}	–	0.251	–
	710.33	2.393×10^{-3}	–	0.254	–
	800.33	2.523×10^{-3}	–	0.257	–
	890.33	2.644×10^{-3}	–	0.260	–
	980.33	2.759×10^{-3}	–	0.263	–
	1070.33	2.870×10^{-3}	–	0.265	–
	1160.33	2.985×10^{-3}	–	0.268	–
	1250.33	3.096×10^{-3}	–	0.270	–
	1340.33	3.212×10^{-3}	–	0.273	–
	1520.33	3.443×10^{-3}	–	0.277	–

(a) F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 2nd edition, John Wiley & Sons, New York, 1985.
(b) Hsin Wang, *Thermal Conductivity Measurements of Kaolite*, ORNL/TM-2003/49.
(c) Based on a baked density of 19.4 lbm/ft^3 (0.011 lbm/in^3).
(d) FAX communication from J. W. Breuer of Thermal Ceramics, Engineering Department, August 11, 1995 (see Appendix C).

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During the HAC 30-minute fire, an emissivity of 0.8 is assumed for the container body, and an emissivity of 0.9 is assumed for the fire per the guidance of 10 CFR 71.74(c)(4) (Ref 1). This results in an overall exchange factor of 0.7347 during the HAC fire using Eq. 4.

The natural convection heat transfer from the package surface to the ambient air is calculated as:

$$q''_{convection} = h\left(T_s - T_a\right) \qquad (5)$$

where, h = natural convection heat transfer coefficient,
T_s = container outer surface temperature, and
T_a = ambient or fire temperature.

During the NCT transient thermal analyses and the steady-state thermal analyses (used to obtain the starting temperature distribution in the package for NCT and HAC when a content heat load is present), the shipping container is assumed to be in an upright (vertical) orientation. The top of the container body is modeled as a heated horizontal flat plate facing up using the following correlation:

$$h = \left(\frac{k}{L}\right) C_1 \, Ra^{C_2}, \qquad (6)$$

where, k = thermal conductivity of air,
L = characteristic length (= D/4),
D = diameter of the package,
Ra = Rayleigh number,
C_1 = constant (see Table 2), and
C_2 = constant (see Table 2).

The Rayleigh number in Eq. 6 is defined as:

$$Ra = \frac{g \beta \Delta T L^3}{\nu \alpha}, \qquad (7)$$

where, g = acceleration of gravity,
β = coefficient of thermal expansion,
ΔT = temperature difference,
ν = kinematic viscosity [μ/ρ],
μ = absolute viscosity,
α = thermal diffusivity [$k/(\rho \, C_p)$],
ρ = density of air, and
C_p = specific heat of air.

The properties of air used in the natural convection calculations are presented in Table 3.

During the NCT transient thermal analyses and the steady-state thermal analyses, the sides of the container body are modeled as a vertical flat plate using the following correlation:

$$h = \left(\frac{k}{L}\right)\left[C_3 + \frac{C_4\,Ra^{C_5}}{\left(1+\left[\frac{0.492}{Pr}\right]^{9/16}\right)^{C_6}}\right]^{C_7}, \qquad (8)$$

where, L = characteristic length = the container height,
C_3 = constant (see Table 2),
C_4 = constant (see Table 2),
C_5 = constant (see Table 2),
C_6 = constant (see Table 2),
C_7 = constant (see Table 2), and
Pr = Prandtl Number.

The bottom of the container body is conservatively modeled as adiabatic during the NCT transient analyses and the steady-state analyses.

During the HAC 30-minute fire and the post-fire cool-down, the shipping container is assumed to be in a horizontal orientation (as it is during furnace testing). As such, the top and bottom of the container body are modeled as vertical flat plates using Eq. 8 having a characteristic length, L, equivalent to the container body diameter, and the sides of the body are modeled as a horizontal cylinder using the following correlation ($10^{-5} < Ra < 10^{12}$):

$$h = \left(\frac{k}{D}\right)\left[0.60 + \frac{0.387\,Ra^{1/6}}{\left(1+\left[\frac{0.559}{Pr}\right]^{9/16}\right)^{8/27}}\right]^{2}, \qquad (9)$$

where, D = diameter of the package,

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Table 2. Coefficients for natural convection correlations.

Coefficient	Rayleigh Number Range	Value
C_1	$10^4 < Ra < 10^7$	0.54
	$10^7 < Ra < 10^{11}$	0.15
C_2	$10^4 < Ra < 10^7$	0.25
	$10^7 < Ra < 10^{11}$	1/3
C_3	$Ra < 10^9$	0.680
	$Ra > 10^9$	0.825
C_4	$Ra < 10^9$	0.670
	$Ra > 10^9$	0.387
C_5	$Ra < 10^9$	0.25
	$Ra > 10^9$	1/6
C_6	$Ra < 10^9$	4/9
	$Ra > 10^9$	8/27
C_7	$Ra < 10^9$	1
	$Ra > 10^9$	2

Source: F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 2nd ed., John Wiley & Sons, New York, 1985.

Table 3. Properties of air used in natural convection calculations.

Temperature (°F)	Thermal Conductivity (Btu/h-in.-°F)	Density (lbm/in^3)	Specific Heat (Btu/lbm-°F)	Kinematic Viscosity (in^2/h)	Thermal Diffusivity (in^2/h)	Prandtl Number
-9.67	1.074×10^{-3}	5.039×10^{-5}	0.240	6.384×10^{1}	8.872×10^{1}	0.720
80.33	1.266×10^{-3}	4.196×10^{-5}	0.241	8.867×10^{1}	1.255×10^{2}	0.707
170.33	1.445×10^{-3}	3.595×10^{-5}	0.241	1.167×10^{2}	1.668×10^{2}	0.700
260.33	1.628×10^{-3}	3.147×10^{-5}	0.242	1.474×10^{2}	2.137×10^{2}	0.690
350.33	1.796×10^{-3}	2.796×10^{-5}	0.244	1.807×10^{2}	2.634×10^{2}	0.686
440.33	1.960×10^{-3}	2.516×10^{-5}	0.246	2.164×10^{2}	3.164×10^{2}	0.684
530.33	2.114×10^{-3}	2.286×10^{-5}	0.248	2.543×10^{2}	3.722×10^{2}	0.683
620.33	2.258×10^{-3}	2.097×10^{-5}	0.251	2.940×10^{2}	4.291×10^{2}	0.685
710.33	2.393×10^{-3}	1.935×10^{-5}	0.254	3.360×10^{2}	4.871×10^{2}	0.690
800.33	2.523×10^{-3}	1.797×10^{-5}	0.257	3.800×10^{2}	5.468×10^{2}	0.695
890.33	2.644×10^{-3}	1.677×10^{-5}	0.260	4.261×10^{2}	6.082×10^{2}	0.702
980.33	2.759×10^{-3}	1.573×10^{-5}	0.263	4.739×10^{2}	6.696×10^{2}	0.709
1070.33	2.870×10^{-3}	1.480×10^{-5}	0.265	5.234×10^{2}	7.310×10^{2}	0.716
1160.33	2.985×10^{-3}	1.397×10^{-5}	0.268	5.742×10^{2}	7.979×10^{2}	0.720
1250.33	3.096×10^{-3}	1.324×10^{-5}	0.270	6.261×10^{2}	8.649×10^{2}	0.723
1340.33	3.212×10^{-3}	1.258×10^{-5}	0.273	6.802×10^{2}	9.374×10^{2}	0.726
1520.33	3.443×10^{-3}	1.144×10^{-5}	0.277	7.912×10^{2}	1.088×10^{3}	0.728

Source: F. P. Incropera and D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, 2nd ed., John Wiley & Sons, New York, 1985.

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Insolation

The following insolation (incident solar radiation) data is required for NCT per 10 CFR 71.71(c)(1) (Ref 1):

Form and location of surface	Total insolation for a 12-hour period (cal/cm²)
Flat surfaces transported horizontally Base Other surfaces	 None 800
Flat surfaces not transported horizontally	200
Curved surfaces	400

The total insolation values specified in the previous table are for a 12-hour period. For analytical purposes, these values are "time-averaged" over the entire 12-hour period (i.e., divided by 12). Therefore, the incident solar heat fluxes ($q''_{solar,i}$) used in the analyses for NCT and cool-down following the HAC fire are as follows:

During NCT, the container body is in an upright (vertical) orientation; therefore, the following heat fluxes are applied to the external surfaces of the container body to represent insolation:

Top $$q''_{solar,i} = 1.7074\,Btu/h-in^2, \quad (10)$$

Sides $$q''_{solar,i} = 0.8537\,Btu/h-in^2, \quad (11)$$

Bottom $$q''_{solar,i} = 0\,. \quad (12)$$

During the cool-down period following the HAC 30-minute fire, the container body is assumed to be in a horizontal orientation; therefore, the following heat fluxes are applied to the external surfaces of the container body to represent insolation:

Top $$q''_{solar,i} = 0.4269\,Btu/h-in^2, \quad (13)$$

Sides $$q''_{solar,i} = 0.8537\,Btu/h-in^2, \quad (14)$$

Bottom $$q''_{solar,i} = 0.4269\,Btu/h-in^2. \quad (15)$$

The insolation is applied as a square-wave function (i.e., alternating on and off in 12-hour periods) in the thermal analysis. The heat flux values presented in Eqs. 10 – 15 represent the insolation absorbed by the package surface since a surface absorptivity of 1.0 was conservatively assumed.

Heat Transfer across Gaps in the Package

Heat transfer across all gaps in the package is modeled by a combination of radiant exchange and conduction. Natural convection heat transfer is not included across the gaps in the model.

Content Heat Load

In order to simulate the decay heat generated by the BU650B shipping container contents, a uniform heat flux is applied to the element edges representing the inner surface of the shield liner inside void in the model. The total content heat load is 450 Watts. The uniform heat flux (q''_{source}) on the inside of the shield liner inside void for a given heat load is calculated using the following equation:

$$q''_{source} = \frac{Q \times 3.4123}{2\left(\frac{\pi D_i^2}{4}\right) + \pi(D_i)(H)}, \qquad (16)$$

where, Q = content heat load (W),
D_i = inside diameter of the shield liner content void (7.0 in.),
H = inside height of the shield liner content void (9.5 in.).

DISCUSSION OF ANALYTICAL RESULTS

All thermal analyses discussed in this report were performed using ANSYS Mechanical Release 12.0.1 UP20090415 (software properly verified by Y-12 QA Program). Temperatures are monitored at selected locations in the model as shown in Figure 4.

Steady-state Conditions Analyses Results (100°F ambient, no insolation)

Steady-state thermal analyses are performed on the finite element model of the BU650B shipping container having a total content heat load of 450 W. The temperature distribution results from this analysis are used as the starting temperature distributions within the model when performing the transient thermal analyses for NCT and the HAC 30-minute fire. The boundary conditions for this steady-state analysis include a combination of thermal radiation exchange and natural convection applied to the top and sides of the container main body using an ambient temperature of 100°F. The bottom of the container body is modeled as an adiabatic surface (i.e., no heat transfer). Additionally, the content heat load is simulated by applying a uniform heat flux to the surfaces of the elements representing the inner surface of the shield liner inner content void. The calculated steady-state temperature distribution within the model of the BU650B shipping container are presented in Table 4.

Normal Conditions of Transport Insolation Analyses Results

Transient thermal analyses are performed on the finite element model of the BU650B shipping container to simulate NCT with a typical shield liner content with a maximum heat load of 450 W. The insolation required for NCT per 10 CFR 71.71(c)(1) (Ref 1) is applied to the top and sides of the drum in alternating 12-hour periods (i.e., 12 hours on and 12 hours off) with the container bottom remaining adiabatic (no heat transfer) during the transient thermal analysis. An ambient temperature of 100°F as stipulated in 10 CFR 71 and is used in the NCT analysis. The initial temperature distribution within the package for the NCT transients was determined from steady-state analyses (with radiation and natural convection boundary conditions applied to the top and sides of the container body). For the case with no internal heat source (0 W), the initial temperature distribution within the package was assumed to be at a uniform

100°F. As with the steady-state analyses discussed previously, the content heat load is simulated by applying a uniform heat flux to the internal surfaces of the typical shield liner inner void volume.

The transient thermal analyses simulate a five-day period of cyclic solar loading with 12 hours of insolation being applied at the beginning of each day (i.e., sunrise) followed by 12 hours in which there is no insolation to end the day (i.e., sunset). This five-day period allows for "quasi steady-state" conditions to be reached. While the temperature of a particular location within the model changes with respect to time in the transient analyses, the maximum temperature that location reaches from day-to-day does not change once a "quasi steady-state" condition is reached as illustrated in Figure 5.

The maximum temperatures of several locations within the model are summarized in Table 5. The maximum temperatures reported in Table 5 represent "quasi steady-state" conditions.

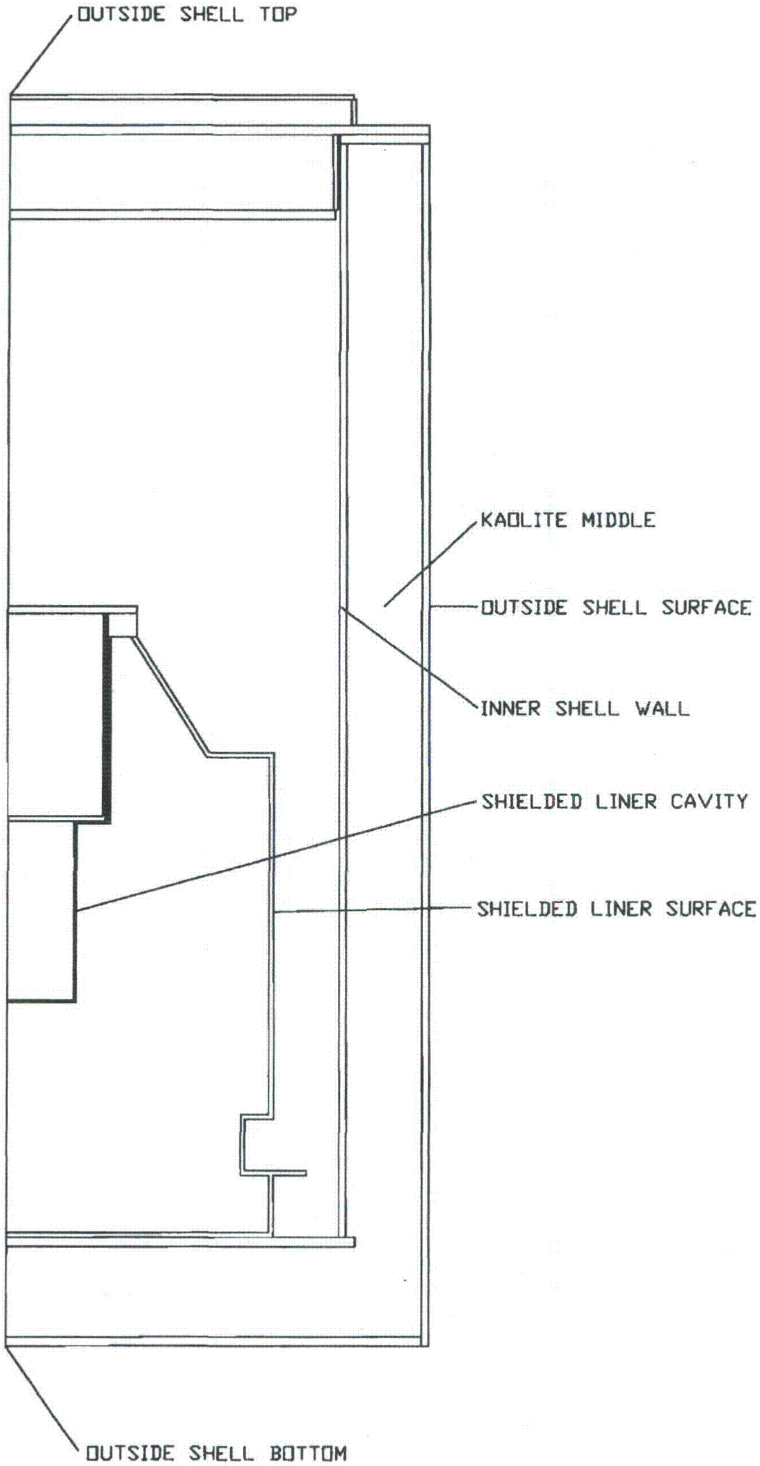

Figure 4. BU650B Model Temperature Locations of Interest

Table 4: BU650B (450 Watts); Steady-State Temperatures (100°F ambient, no insolation)

Temperature locations	Maximum steady-state temperature (°F)
Outside Shell Lid Top	113.4
Outside Shell Bottom	156.9
Kaolite Middle	147.3
Outside Shell Mid-Height	121.8
Inner Shell Mid-Height	176.9
Shielded Liner Cavity	286.6
Shielded Liner Surface	275.9

Table 5: BU650B (450 Watts); Maximum "Quasi Steady-State" Temperatures during NCT

Temperature locations	Maximum quasi steady-state temperature (°F)
Outside Shell Lid Top	245.3
Outside Shell Bottom	229.7
Kaolite Middle	229.4
Outside Shell Mid-Height	210.5
Inner Shell Mid-Height	253.6
Shielded Liner Cavity	334.8
Shielded Liner Surface	323.9

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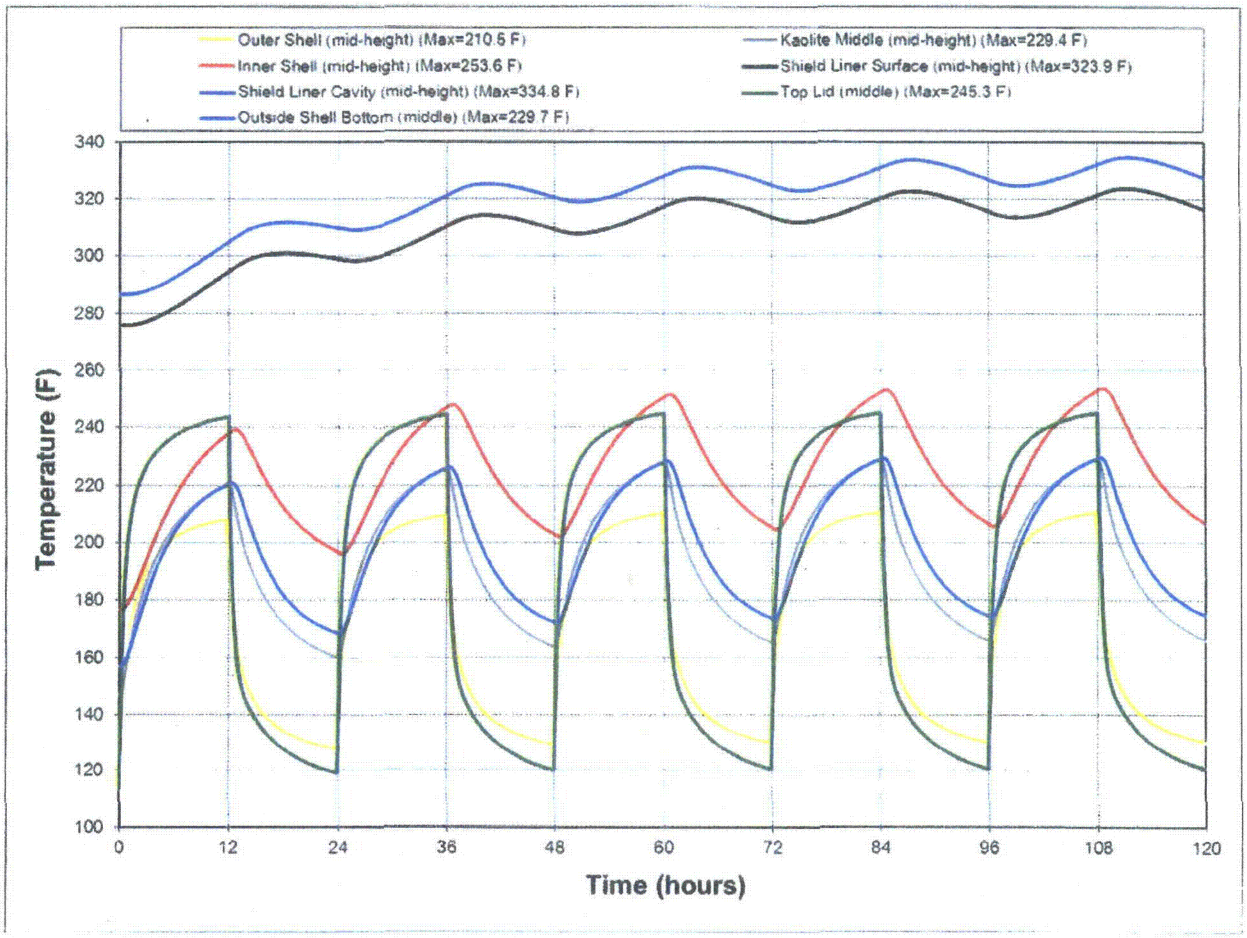

Figure 5. Transient temperatures of the BU650B for NCT (450 Watt Heat Load)

Hypothetical Accident Conditions Analyses Results

Transient thermal analyses are performed on the finite element model of the BU650B shipping container (undamaged configuration with impact limiters removed) to simulate HAC as prescribed by 10 CFR 71.73(c)(4) (Ref 1). A 30-minute fire of 1475°F (800°C) is simulated by applying natural convection and radiant exchange boundary conditions to all external surfaces of the container body (assuming the body is in a horizontal orientation) with content heat load of 450 W. There is no heat flux boundary conditions simulating insolation applied to the model before and during the 30-minute fire. The initial temperature distribution within the package for all heat load cases is obtained from their respective steady-state analyses. As with the steady-state analyses discussed previously, the content heat load is simulated by applying a uniform heat flux to the internal surfaces of the elements representing the typical shield liner inner void content area.

Following the 30-minute fire transient analyses, 24-hour cool-down transient thermal analyses are performed using the temperature distribution at the end of the fire as the initial temperature distribution. During post-fire cool-down, natural convection and radiant exchange boundary conditions are applied to all external surfaces of the container body (assuming the body is in a horizontal orientation). Additionally, cases are analyzed in which insolation is included during the post-fire cool-down. For the cases in which insolation is applied to the model during cool-down, insolation is applied during the first 12-hour period following the 30-minute fire, then removed as was done for NCT.

The maximum temperatures calculated for the BU650B shipping container for HAC are summarized in Table 6. In addition to the maximum temperatures for HAC presented in Table 6, the temperature difference between a baseline transient case (no content heat load and no insolation during cool-down) and various other cases investigated in this report are calculated for several locations within the model. These calculated temperature differences may be added to physical test data to estimate package temperatures for parameters that cannot be easily included in a test (i.e., content heat load or insolation during cool-down). The calculated temperature differences between the baseline case and various HAC cases are presented in Table 7.

The HAC thermal analyses presented in this report are performed using a finite element model that represents an undamaged BU650B shipping container. While the cumulative damage from all physical testing must be considered when evaluating the performance of the package to HAC, the temperature differences (i.e., adjustments) presented in Table 7 are of value when combined with the physical test data temperature label results when making this assessment.

Representative ANSYS macro files (excluding node, element, set, and surface definitions) used for the HAC analyses of the BU650B shipping container are presented in Appendix B for both fire and cool-down (with and without insolation during cool-down).

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Table 6. BU650B HAC Maximum Temperatures

Temperature Locations	HAC maximum temperature (°F)			
	No Heat Load		450 W Heat Load	
	Insolation during cool-down?		Insolation during cool-down?	
	No	Yes	No	Yes
Outside Shell Lid Top	1407.1	1407.1	1407.6	1407.6
Outside Shell Bottom	1439.8	1439.8	1444.0	1444.0
Kaolite Middle	551.3	553.2	601.4	603.4
Outside Shell Mid-Height	1452.5	1452.5	1453.4	1453.4
Inner Shell Mid-Height	263.5	272.4	337.6	345.7
Shielded Liner Cavity	150.1	165.8	348.4	371.1
Shielded Liner Surface	150.2	165.9	359.4	360.0

Table 7. BU650B HAC Temperature Differences from Baseline

Temperature Locations	ΔT (°F)			
	No Heat Load		450 W Heat Load	
	Insolation during cool-down?		Insolation during cool-down?	
	No	Yes	No	Yes
Outside Shell Lid Top	---	0.0	0.5	0.5
Outside Shell Bottom	---	0.0	4.2	4.2
Kaolite Middle	---	1.9	50.1	52.1
Outside Shell Mid-Height	---	0.0	0.9	0.9
Inner Shell Mid-Height	---	8.9	74.1	82.2
Shielded Liner Cavity	---	15.7	198.3	221.0
Shielded Liner Surface	---	15.7	209.2	209.8

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CONCLUSIONS

Steady-state (100°F ambient in shade)

The thermal response of the BU650B shipping container with content heat load of 450 W is evaluated for exposure to a 100°F ambient temperature in the shade (i.e., no insolation applied to the body). Steady-state thermal analyses are performed for these conditions to obtain the temperature distribution within the package at the start of NCT and HAC. Table 4 indicates the temperature values for various points of interest throughout the container.

NCT

The thermal response of the BU650B shipping container with content heat load of 450 W is evaluated for NCT with insolation. One important temperature value of interest is the maximum temperature of the shield liner as compared to the melt temperature of lead which will be conservatively assumed to be 600°F. As shown in Table 5, the maximum value both the inside and surface of the typical shield liner reaches is 334.8°F for content heat load of 450 W. This calculated maximum temperature for the shield liner is below 600°F and acceptable.

HAC

Temperature adjustments are calculated for various locations in the BU650B shipping container for exposure of the package to HAC. These adjustments are the calculated temperature differences between a baseline case (i.e., no content heat load and no insolation during cool-down) and the case with 450 W content heat load with and without insolation during the post-fire cool-down. The calculated temperature adjustments for HAC are presented in Table 7. These calculated temperature adjustments may be added to physical test data to estimate package temperatures for parameters that cannot be easily included in a test (i.e., content heat loads or insolation during cool-down).

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APPENDIX A
Typical ANSYS Input File for BU650B NCT Model

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Bu650b_nctwithsolar.mac

```
! BU-650B 2D Axisymmetric model

fini
/clear
/plopts,date,0

sb_c=1.19e-11   !steffan boltzman constant
t_amb=100       !ambient temperature
t_amb2=1475     !fire temperature
ext_rad=1       !include external radiation to environment; 0-no; 1-yes
ht_antyp=1      !0 steady state; 1-transient cyclic; 2-burn
air_mod=1       !0 no air; 1-include air in model
int_rad=1       !0-do not include internal rad; 1-include internal radiation

t_off=460       !offset temperature for radiation calculations
em_drum=0.22    !drum external emissivity for normal conditions
em_drum2=0.8    !drum fire emissivity
hflux_s=0.8537  !solar heat flux on side
hflux_t=1.7074  !solar heat flux on top
air_con=1       !air thermal conductivity(0-low; 1-nominal)
q_int=450       !contents heat generation, watts
t_days=5        !number of total days in transient
int_ems=1       !include internal rad. emiss (0- emiss=1; 1- emiss=.7)

*afun,deg

! material properties (Units; btu; in; lb;F)

/input,bu650b,mtp

/prep7

! element type definitions
!
et,1,plane55,1,,1                            ! 2D axisymmetric elements

et,3,surf151,,,1                             ! Surface effect elements (Heat flux application)
keyopt,3,8,1
et,4,matrix50,1                              ! radiation matrix
et,5,link32                                  ! Conduction bars for radiation matrix calculation

k,1,0.0,10.5
k,2,21.875,10.5
k,3,21.875,73.75
k,4,17.875,73.75
k,5,17.5,73.75
k,6,17.5,74.25
k,7,22.25,74.25
k,8,22.25,10.0
k,9,0.0,10.0
k,10,17.875,15.75
k,11,18.375,15.75
k,12,18.375,15.25
k,13,0.0,15.25
k,14,0.0,15.75
k,15,17.5,15.75
k,16,14.0,15.75
k,17,14.0,19.0
k,18,15.75,19.0
k,19,15.75,19.25
k,20,12.5,19.25
k,21,12.5,22.0
k,22,14.0,22.0
k,23,14.0,41.5
k,24,10.5773,41.5
k,25,6.75,47.625
k,26,6.4541,47.623
k,27,10.4376,41.248
k,28,13.75,41.25
k,29,13.75,22.25
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k,31,12.25,19.0
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k,33,13.75,16.0
k,34,0.0,16.0
k,35,0.0,28.25
k,36,3.625,28.25
k,37,3.625,37.75
k,38,5.375,37.75
k,39,5.375,47.625
k,40,5.25,47.625
k,41,5.25,37.875
k,42,5.125,37.875
k,43,3.5,37.875
k,44,3.5,28.375
k,45,0.0,28.375
k,46,0.0,37.875
k,47,0.0,38.125
k,48,5.0,38.125
k,49,5.0,48.875
k,50,5.125,48.875
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k,53,6.75,49.25
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k,56,0.0,69.75
k,57,17.25,69.75
k,58,17.25,70.25
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k,60,0.0,70.25
k,61,17.375,70.25
k,62,17.125,74.25
k,63,17.375,74.25
```

GENERAL DESIGN AND COMPUTATION SHEET

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```
k,64,0.0,74.25
k,65,0.0,74.75
k,66,18.125,74.75
k,67,18.375,74.75
k,68,22.25,74.75
k,69,18.375,76.125
k,70,18.25,76.125
k,71,18.125,76.125
k,72,0.0,76.125
k,73,0.0,76.375
k,74,12.75,76.375
k,75,18.25,76.375
k,76,22.5,76.375
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k,78,34.5,62.375
k,79,34.5,86.375
k,80,12.75,86.375
k,81,12.8545,76.4795
k,82,22.6045,76.4795
k,83,22.6045,62.4795
k,84,34.3955,62.4795
k,85,34.3955,86.2705
k,86,12.8545,86.2705
k,87,21.875,10.0
k,88,12.75,10.0
k,89,12.75,0.0
k,90,34.5,0.0
k,91,34.5,24.0
k,92,22.5,24.0
k,93,22.5,10.0
k,94,22.6045,9.8955
k,95,12.8545,9.8955
k,96,12.8545,0.1045
k,97,34.3955,0.1045
k,98,34.3955,23.8955
k,99,22.6045,23.8955
k,110,17.5,49.25
k,111,0.0,22.25
!
! Kaolite 1600
!
asel,none
a,1,2,3,4,10,11,12,13
a,60,59,62,64
aatt,2,1
!
! SS Shell material & Inner Steel 12 gauge Plates
!
asel,none
a,1,2,3,4,5,6,7,8,87,88,9
a,4,5,110,15,16,14,13,12,11,10
a,56,57,58,59,60
a,58,59,62,63,61
a,64,62,63,6,7,68,67,66,65
a,66,67,69,70,71
a,75,74,73,72,71,70
aatt,1,3
!
! Inner Air Regions
!
asel,none
a,65,66,71,72
aatt,5,5
asel,none
a,56,57,58,61,63,6,5,110,53,54
a,110,15,16,17,18,19,20,21,22,23,24,25,52,53
aatt,5,15
asel,none
a,41,42,50,51,40
aatt,5,16
!
! Inner Steel Shield Liner
!
asel,none
a,14,16,17,18,19,20,21,22,29,30,31,32,33,34
a,22,29,28,27,26,25,24,23
a,25,26,39,40,51,52
a,39,40,41,42,43,44,45,35,36,37,38
a,55,49,50,51,52,53,54
a,49,50,42,43,46,47,48
aatt,1,7

! Lead Areas; Inner Shield
!
asel,none
a,47,48,49,55
a,34,33,32,31,30,111
a,111,30,29,28,27,26,39,38,37,36,35
aatt,3,8
!
esize,0.2
alls
amesh,all

/pnum,mat,1
/num,1
eplot
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
!define radiation enclosures

type,5
! between cv and drum

esel,s,real,,5
```

```
nsle
esln,s,0
esel,u,real,,5
mat,1
real,100
esurf

esel,s,real,,15
nsle
esln,s,0
esel,u,real,,15
mat,1
real,101
esurf

esel,s,real,,16
nsle
esln,s,0
esel,u,real,,16
mat,1
real,102
esurf


! generate radiation matrix elements
!
/aux12
!
geom,1,36
emis,1,em_steel         !Mild Steel (Fire), 0.22 normal
emis,3,0.28             !Lead

stef,sb_c
vtype,0,1000
!
esel,s,real,,100                  ! cv/drum gap radiation exchange

nsle
mprint,1
/output,argap1,out
write,argap1
/output,term

esel,s,real,,101                  ! cv/drum gap radiation exchange
nsle
mprint,1
/output,argap2,out
write,argap2
/output,term

esel,s,real,,102                  ! cv/drum gap radiation exchange
nsle
mprint,1
/output,argap3,out
write,argap3
/output,term
!
/prep7
!
alls
type,4
real,110
se,argap1
se,argap2
se,argap3
!
! mesh surface effect elements on side of drum for application of boundary conditions
!
! top
lsel,s,line,,35
lsel,a,line,,39,40
lsel,a,line,,43,44
lsel,a,line,,47
nsll,s,1
type,3
mat,1
real,200
esurf

! side
lsel,s,line,,16
lsel,a,line,,34
nsll,s,1
type,3
mat,1
real,201
esurf

!bottom
lsel,s,line,,17,19
nsll,s,1
type,3
mat,1
real,202
esurf
!
! Apply the boundary conditions that don't change during the transient
!
/solu
!
*if,ext_rad,eq,1,then  !include convection and radiation
   hfmat_s=15
   hfmat_t=16
*else                  ! include only convection
   hfmat_s=17
   hfmat_t=18
*endif
```

```
!
*if,ht_antyp,ne,2,then
   esel,s,type,,3
   esel,r,real,,201
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_s,T_amb
!
   esel,s,type,,3
   esel,r,real,,200
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_t,T_amb
*elseif,ht_antyp,eq,2
   esel,s,type,,3
   esel,r,real,,201
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_s,T_amb2
!
   esel,s,type,,3
   esel,r,real,,200
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_t,T_amb2
*endif

!
! apply heat flux from contents
!
a_1=2*3.1416*3.5*9.5
a_2=2*3.1416*3.5**2
a_tot=a_1+a_2

lsel,s,line,,83,84
lsel,a,line,,93
nsll,s,1
sf,all,hflux,q_int*3.413/a_tot
!
!
! Perform the transient analysis
!
/solu
!
antype,trans                                            !steady-state solution
timint,off                                              !transient integration off
toffst,T_off
tunif,100
time,0.001
kbc,0                                                           !0=ramped, 1=stepped
alls
outres,all,all
nsubst,1
!
esel,s,type,,1,4
*if,int_rad,ne,1,then
esel,u,type,,4                                          !matrix 50 radiation superelements
*endif
*if,air_mod,eq,0,then
esel,u,mat,,5
*endif
nsle
solve
!
timint,on
autots,on
kbc,1
*do,_i,1,t_days                                         ! transient solution for N days
!
! day time
!
esel,s,type,,3
esel,r,real,,201
sfe,all,1,hflux,,hflux_s
!
esel,s,type,,3
esel,r,real,,200
sfe,all,1,hflux,,hflux_t
!
time,12+((_i-1)*24)
deltim,0.01,0.001,1.0
esel,s,type,,1,4
*if,int_rad,ne,1,then
esel,u,type,,4                                          !matrix 50 radiation superelements
*endif
*if,air_mod,eq,0,then
esel,u,mat,,5
*endif
nsle
solve
!
! night time (1.5 hr after sunset)
!
esel,s,type,,3
esel,r,real,,201
sfedele,all,1,hflux
!
esel,s,type,,3
esel,r,real,,200
sfedele,all,1,hflux
!
time,13.5+((_i-1)*24)
deltim,0.001,0.001,0.033
esel,s,type,,1,4
*if,int_rad,ne,1,then
esel,u,type,,4
*endif
```

```
*if,air_mod,eq,0,then
esel,u,mat,,5
*endif
nsle
solve
!
! night time
!
esel,s,type,,3
esel,r,real,,201
sfedele,all,1,hflux
!
esel,s,type,,3
esel,r,real,,200
sfedele,all,1,hflux
!
time,24+((_i-1)*24)
deltim,0.01,0.001,1.0
esel,s,type,,1,4
*if,int_rad,ne,1,then
esel,u,type,,4
*endif
*if,air_mod,eq,0,then
esel,u,mat,,5
*endif
nsle
solve

*enddo
!
! Post-process the results
!
/post26
!
nd_A=node(22.25,42.375,0)          !Outside of Outer Shell Midway up
nd_B=node(19.875,42.375,0)         !Middle of Wall Kaolite Midway up
nd_C=node(17.5,42.375,0)           !Inside of Inner Shell Midway up
nd_D=node(14.0,33.125,0)           !Outside of Inner Shield Adjacent to Center of Source Volume
nd_E=node(3.625,33.125,0)          !Inside of Inner Shield Lead Adjacent to Center of Source Volume
nd_F=node(0.0,76.375,0)            !Outside Middle Top of Lid
nd_G=node(0.0,10.0,0)              !Outside Bottom Middle

t_outshellmid=temp(nd_A)
t_midkaolitewall=temp(nd_B)
t_insideinnershell=temp(nd_C)
t_outshieldliner=temp(nd_D)
t_insideshieldliner=temp(nd_E)
t_outsidemidtopoflid=temp(nd_F)
t_outsidebottommiddle=temp(nd_G)
!
nsol,2,nd_A,temp,,t_outshellmid
nsol,3,nd_B,temp,,t_midkaolitewall
nsol,4,nd_C,temp,,t_insideinnershell
nsol,5,nd_D,temp,,t_outshieldliner
nsol,6,nd_E,temp,,t_insideshieldliner
nsol,7,nd_F,temp,,t_outsidemidtopoflid
nsol,8,nd_G,temp,,t_outsidebottommiddle

plvar,2,3,4,5,6,7,8
/output,bu650bncttemps,out
prvar,2,3,4,5,6
prvar,7,8
/output,term
!
parsav,all,param,sav
save,bu650bnct,db
```

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APPENDIX B
Typical ANSYS Input Files for BU650B HAC Model

Bu650b_hacwithsolar.mac

```
! BU-650B 2D Axisymmetric model

fini
/clear
/plopts,date,0

sb_c=1.19e-11   !steffan boltzman constant
t_amb=100       !ambient temperature
t_amb2=1475     !fire temperature
ext_rad=1       !include external radiation to environment; 0-no; 1-yes
ht_antyp=1      !0 steady state; 1-transient cyclic; 2-burn
air_mod=1       !0 no air; 1-include air in model
int_rad=1       !0-do not include internal rad; 1-include internal radiation

t_off=460       !offset temperature for radiation calculations
em_drum=0.22    !external SS shell emissivity for normal conditions
em_drum2=0.8    !external SS shell fire emissivity
hflux_s=0.8537  !solar heat flux on side
hflux_tb=0.4269 !solar heat flux on top & bottom
air_con=1       !air thermal conductivity(0-low; 1-nominal)
q_int=450       !contents heat generation, watts
t_days=5        !number of total days in transient
int_ems=1       !include internal rad. emiss (0- emiss=1; 1- emiss=.7)

*afun,deg

! material properties (Units; btu; in; lb;F)

/input,bu650b,mtp

/prep7

! element type definitions
!
et,1,plane55,1,,1                                   ! 2D axisymmetric elements

et,3,surf151,,,1                                    ! Surface effect elements (Heat flux application)
keyopt,3,8,1
et,4,matrix50,1                                     ! radiation matrix
et,5,link32                                         ! Conduction bars for radiation matrix calculation

k,1,0.0,10.5
k,2,21.875,10.5
k,3,21.875,73.75
k,4,17.875,73.75
k,5,17.5,73.75
k,6,17.5,74.25
k,7,22.25,74.25
k,8,22.25,10.0
k,9,0.0,10.0
k,10,17.875,15.75
k,11,18.375,15.75
k,12,18.375,15.25
k,13,0.0,15.25
k,14,0.0,15.75
k,15,17.5,15.75
k,16,14.0,15.75
k,17,14.0,19.0
k,18,15.75,19.0
k,19,15.75,19.25
k,20,12.5,19.25
k,21,12.5,22.0
k,22,14.0,22.0
k,23,14.0,41.5
k,24,10.5773,41.5
k,25,6.75,47.625
k,26,6.4541,47.623
k,27,10.4376,41.248
k,28,13.75,41.25
k,29,13.75,22.25
k,30,12.25,22.25
k,31,12.25,19.0
k,32,13.75,19.0
k,33,13.75,16.0
k,34,0.0,16.0
k,35,0.0,28.25
k,36,3.625,28.25
k,37,3.625,37.75
k,38,5.375,37.75
k,39,5.375,47.625
k,40,5.25,47.625
k,41,5.25,37.875
k,42,5.125,37.875
k,43,3.5,37.875
k,44,3.5,28.375
k,45,0.0,28.375
k,46,0.0,37.875
k,47,0.0,38.125
k,48,5.0,38.125
k,49,5.0,48.875
k,50,5.125,48.875
k,51,5.25,48.875
k,52,6.75,48.875
k,53,6.75,49.25
k,54,0.0,49.25
k,55,0.0,48.875
k,56,0.0,69.75
k,57,17.25,69.75
k,58,17.25,70.25
k,59,17.125,70.25
k,60,0.0,70.25
k,61,17.375,70.25
k,62,17.125,74.25
k,63,17.375,74.25
```

```
k,64,0.0,74.25
k,65,0.0,74.75
k,66,18.125,74.75
k,67,18.375,74.75
k,68,22.25,74.75
k,69,18.375,76.125
k,70,18.25,76.125
k,71,18.125,76.125
k,72,0.0,76.125
k,73,0.0,76.375
k,74,12.75,76.375
k,75,18.25,76.375
k,76,22.5,76.375
k,77,22.5,62.375
k,78,34.5,62.375
k,79,34.5,86.375
k,80,12.75,86.375
k,81,12.8545,76.4795
k,82,22.6045,76.4795
k,83,22.6045,62.4795
k,84,34.3955,62.4795
k,85,34.3955,86.2705
k,86,12.8545,86.2705
k,87,21.875,10.0
k,88,12.75,10.0
k,89,12.75,0.0
k,90,34.5,0.0
k,91,34.5,24.0
k,92,22.5,24.0
k,93,22.5,10.0
k,94,22.6045,9.8955
k,95,12.8545,9.8955
k,96,12.8545,0.1045
k,97,34.3955,0.1045
k,98,34.3955,23.8955
k,99,22.6045,23.8955
k,110,17.5,49.25
k,111,0.0,22.25
!
! Kaolite 1600
!
asel,none
a,1,2,3,4,10,11,12,13
a,60,59,62,64
aatt,2,1
!
! SS Shell material
!
asel,none
a,1,2,3,4,5,6,7,8,87,88,9
a,4,5,110,15,16,14,13,12,11,10
a,56,57,58,59,60
a,58,59,62,63,61
a,64,62,63,6,7,68,67,66,65
a,66,67,69,70,71
a,75,74,73,72,71,70
aatt,4,3
!
! Inner Air Regions
!
asel,none
a,65,66,71,72
aatt,5,5
asel,none
a,56,57,58,61,63,6,5,110,53,54
a,110,15,16,17,18,19,20,21,22,23,24,25,52,53
aatt,5,15
asel,none
a,41,42,50,51,40
aatt,5,16
!
! Inner Mild Steel Shield Liner
!
asel,none
a,14,16,17,18,19,20,21,22,29,30,31,32,33,34
a,22,29,28,27,26,25,24,23
a,25,26,39,40,51,52
a,39,40,41,42,43,44,45,35,36,37,38
a,55,49,50,51,52,53,54
a,49,50,42,43,46,47,48
aatt,1,7

! Lead Areas; Inner Shield
!
asel,none
a,47,48,49,55
a,34,33,32,31,30,111
a,111,30,29,28,27,26,39,38,37,36,35
aatt,3,8
!
esize,0.2
alls
amesh,all

/pnum,mat,1
/num,1
eplot
!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
!
!define radiation enclosures

type,5
! between cv and drum

esel,s,real,,5
```

```
nsle
esln,s,0
esel,u,real,,5
mat,1
real,100
esurf

esel,s,real,,15
nsle
esln,s,0
esel,u,real,,15
mat,1
real,101
esurf

esel,s,real,,16
nsle
esln,s,0
esel,u,real,,16
mat,1
real,102
esurf

! generate radiation matrix elements
!
/aux12
!
geom,1,36
emis,1,em_steel         !Mild Steel (Fire), 0.22 normal
emis,3,0.28             !Lead

stef,sb_c
vtype,0,1000
!
esel,s,real,,100                  ! cv/drum gap radiation exchange

nsle
mprint,1
/output,argap1,out
write,argap1
/output,term

esel,s,real,,101                  ! cv/drum gap radiation exchange
nsle
mprint,1
/output,argap2,out
write,argap2
/output,term

esel,s,real,,102                  ! cv/drum gap radiation exchange
nsle
mprint,1
/output,argap3,out
write,argap3
/output,term
!
/prep7
!
alls
type,4
real,110
se,argap1
se,argap2
se,argap3
!
! mesh surface effect elements on side of drum for application of boundary conditions
!
! top
lsel,s,line,,35
lsel,a,line,,39,40
lsel,a,line,,43,44
lsel,a,line,,47
nsll,s,1
type,3
mat,1
real,200
esurf
! side
lsel,s,line,,16
lsel,a,line,,34
nsll,s,1
type,3
mat,1
real,201
esurf

!bottom
lsel,s,line,,17,19
nsll,s,1
type,3
mat,1
real,202
esurf
!
! Apply the boundary conditions that don't change during the transient
!
/solu
!
*if,ext_rad,eq,1,then  !include convection and radiation
   hfmat_s=15
   hfmat_t=16
*else                  ! include only convection
   hfmat_s=17
   hfmat_t=18
*endif
!
*if,ht_antyp,ne,2,then
```

```
   esel,s,type,,3
   esel,r,real,,201
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_s,T_amb
!
   esel,s,type,,3
   esel,r,real,,200
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_t,T_amb
*elseif,ht_antyp,eq,2
   esel,s,type,,3
   esel,r,real,,201
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_s,T_amb2
!
   esel,s,type,,3
   esel,r,real,,200
   nsle
   esel,s,type,,1
   sf,all,conv,-hfmat_t,T_amb2
*endif
!
! apply heat flux from contents
!
a_1=2*3.1416*3.5*9.5
a_2=2*3.1416*3.5**2
a_tot=a_1+a_2

lsel,s,line,,83,84
lsel,a,line,,93
nsll,s,1
sf,all,hflux,q_int*3.413/a_tot
!
/solu
!
!
antype,trans                                    !steady-state solution
timint,off                                      !transient integration off
toffst,T_off
tunif,200
time,0.001
kbc,0                                                 !0=ramped, 1=stepped
alls
outres,all,all
nsubst,1
  !
esel,s,type,,1,4
*if,int_rad,ne,1,then
  esel,u,type,,4                  !matrix 50 radiation superelements
*endif

*if,air_mod,eq,0,then
  esel,u,mat,,m_air
*endif
nsle

solve
!
timint,on
autots,on
kbc,1

esel,s,type,,3
esel,r,real,,201
nsle
esel,s,type,,1
sf,all,conv,-19,T_amb2

esel,s,type,,3
esel,r,real,,202
nsle
esel,s,type,,1
sf,all,conv,-20,T_amb2
!
esel,s,type,,3
esel,r,real,,200
nsle
esel,s,type,,1
sf,all,conv,-20,T_amb2
!
esel,s,type,,1,4
*if,int_rad,ne,1,then
  esel,u,type,,4                   !matrix 50 radiation superelements
*endif

*if,air_mod,eq,0,then
  esel,u,mat,,m_air
*endif
nsle

outres,all,all

deltim,0.001,1e-6,0.01667
!
autots,on
kbc,1
time,0.5
toffst,T_off
timint,on
outres,all,all

solve

! change drum emissivity back to 0.22
```

```
! insolation post fire (yes or no) if yes add back in

!set key to apply transient solar insolation

esel,s,type,,3
esel,r,real,,201
nsle
sf,all,hflux,0.8537
esel,s,type,,1
sf,all,conv,-21,T_amb
!
esel,s,type,,3
esel,r,real,,200
nsle
sf,all,hflux,0.4269
esel,s,type,,1
sf,all,conv,-22,T_amb

esel,s,type,,3
esel,r,real,,202
nsle
sf,all,hflux,0.4269
esel,s,type,,1
sf,all,conv,-22,T_amb

esel,s,type,,1,4
*if,int_rad,ne,1,then
  esel,u,type,,4                    !matrix 50 radiation superelements
*endif

*if,air_mod,eq,0,then
  esel,u,mat,,m_air
*endif
nsle

time,12.5
deltim,0.01,0.001,0.5
solve
!
! turn off solar insolation after 12 hrs
!
esel,s,type,,3
esel,r,real,,201
nsle
sfdele,all,hflux
esel,s,type,,1
sf,all,conv,-21,T_amb
!
esel,s,type,,3
esel,r,real,,200
nsle
sfdele,all,hflux
esel,s,type,,1
sf,all,conv,-22,T_amb

esel,s,type,,3
esel,r,real,,202
nsle
sfdele,all,hflux
esel,s,type,,1
sf,all,conv,-22,T_amb

esel,s,type,,1,4
*if,int_rad,ne,1,then
  esel,u,type,,4                    !matrix 50 radiation superelements
*endif

*if,air_mod,eq,0,then
  esel,u,mat,,m_air
*endif
nsle

time,24.5
deltim,0.01,0.001,0.5
solve
!
! Post-process the results
!
/post26
!
nd_A=node(22.25,42.375,0)        !Outside of Outer Shell Midway up
nd_B=node(19.875,42.375,0)       !Middle of Wall Kaolite Midway up
nd_C=node(17.5,42.375,0)         !Inside of Inner Shell Midway up
nd_D=node(14.0,33.125,0)         !Outside of Inner Shield Adjacent to Center of Source Volume
nd_E=node(3.625,33.125,0)        !Inside of Inner Shield Lead Adjacent to Center of Source Volume
nd_F=node(0.0,76.375,0)          !Outside Middle Top of Lid
nd_G=node(0.0,10.0,0)            !Outside Bottom Middle

nsol,2,nd_A,temp,,t_outshellmid
nsol,3,nd_B,temp,,t_midkaolitewall
nsol,4,nd_C,temp,,t_insideinnershell
nsol,5,nd_D,temp,,t_outshieldliner
nsol,6,nd_E,temp,,t_insideshieldliner
nsol,7,nd_F,temp,,t_outmidlidtop
nsol,8,nd_G,temp,,t_outbottommid
!
plvar,2,3,4,5,6,7,8
/output,bu650bhacwithsolar,out
prvar,2,3,4,5,6
prvar,7,8
/output,term
!
```

APPENDIX C

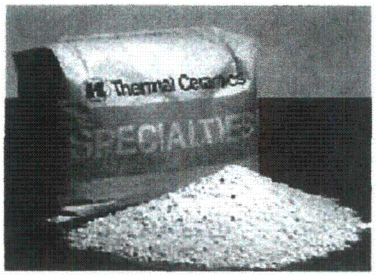
Kaolite Data Sheet and Specific Heat FAX Communication

Job	Date	Sheet
Thermal Analyses (ANSYS) of JLS&A BU650B Shipping Container for NCT and HAC	April 5, 2012	40 of 42
ESO No.	Computed by	Checked by
P09YCW01	D. L. Lowe	D. E. Winder

Thermal Ceramics

Kaolite Super Lightweight Insulating Castables

Product Information



Super lightweight Kaolite castables reduce both the quantity of heat storage and heat transfer through the lining producing significant savings in furnace fuel consumption. The lower densities of these vermiculite based Kaolite castables reduce the amount of supporting furnace steel work required and provide more insulation with a thinner lining. These products can be cast, poured, or gunited.

Kaolite 1600 is a super lightweight, low thermal conductivity vermiculite based castable designed for backup insulation up to 1600°F. Kaolite 1600 contains portland cement which limits its use temperature to 1600°F; however, this makes it an economical product based on cost per cubic foot.

Kaolite 1800 is a super lightweight, low thermal conductivity vermiculite castable designed for both backup insulation and some hot face applications up to 1800°F. Kaolite 1800 contains a calcium-aluminate cement which gives it better high-temperature stability when compared to Kaolite 1600. Typical applications would be low-temperature lining for ovens and ductwork lining.

Instructions For Using

Casting

Highest strength is obtained with castable refractory by using the least amount of clean mixing water. This will allow thorough working of material into place by lightly vibrating or rodding. A mechanical mixer is required for proper placement (paddle-type mortar mixers are best suited). After achieving a ball-in-hand consistency, mix for 6 minutes. Place material within 20 minutes after mixing.

Gunning

Use suitable gunite equipment. Material should be predampened uniformly with approximately 10 - 12% by weight of clean water in mechanical mixer before placing into gun. This will reduce rebound and dust. Add required water at nozzle for effective placement. Suggested air pressure at the nozzle is between 15 and 25 psi.

Precautions

Store bagged castables in a dry place, off the ground and, when possible, with the original shrink wrapping intact. Watertight forms must be used when placing material. All porous surfaces that will come into contact with the material must be waterproofed with a suitable coating or membrane. For maximum strength, cure 24 hours under damp conditions before initial heat-up. Keep freshly placed castable warm during cold weather, ideally between 70°F and 80°F. *New castable installations must be heated slowly the first time.* Freshly placed lightweight castables are prone to a deteriorating condition called alkali hydrolysis when they are kept in a non-dried state for a sustained period of time in a warm, humid environment. Under these conditions, the castables should be force dried soon after placement or coated with Kao-Seal to resist the possible deterioration effects.

For mor information on castable placement, consult your Thermal Ceramics representative or call 1-800-329-7444 to receive faced instruction manuals.

Physical Properties[a]

	1600	**1800**
Specifications	cast,gunned	cast,gunned
Recommended use limit, °F *(°C)*	1600 *(871)*	1800 *(982)*
Pounds per bag *(kg)*	50 *(23)*	50 *(23)*
Method of installation[b]	C,G,P	C,G,P
Shelf life, months	12	12

Figure 6. Kaolite data sheet (sheet 1 of 2).

Kaolite Super Lightweight Insulating Castables

Product Information

Physical Properties[1]	1600	1800
Average lb required to place one cubic ft[*] *(kg)*	23. 36[*] *(10.16)*	23. 35[*] *(10.15)*
Nominal density, fired, pcf *(kg/m³)*	20 - 25, 31 - 39 *(320-400, 496-625)*	20 - 25, 29 - 38 *(320-400, 464-609)*
Recommended water ranges, % by weight		
Casting (by vibrating)	120 - 145	145 - 165
Pouring	150 - 180	175 - 190
Modulus of rupture, psi *(Mpa)* ASTM C 133		
Dried 18-24 hrs. @ 220°F *(104°C)* cast	45 - 75 *(0.31 - 0.52)*	25 - 40 *(0.01 - 0.27)*
gunned	70 - 120 *(0.48 - 0.83)*	50 - 100 *(0.34 - 0.69)*
Fired 5 hrs. @ 1500°F *(816°C)* cast	25 - 40 *(0.17 - 0.28)*	30 - 50 *(0.21 - 0.34)*
gunned	35 - 55 *(0.24 - 0.38)*	40 - 60 *(0.27 - 0.41)*
Fired 5 hrs. @ use limit, cast	25 - 40 *(0.17 - 0.27)*	25 - 40 *(0.01 - 0.27)*
gunned	35 - 50 *(0.24 - 0.34)*	35 - 55 *(0.24 - 0.34)*
Cold Crushing strength, psi *(Mpa)*		
Dried 18-24 hrs. @ 220°F *(104°C)* cast	80 - 120 *(0.55 - 0.83)*	35 - 50 *(0.24 - 0.34)*
gunned	125 - 175 *(0.86 - 1.21)*	70 - 120 *(0.48 - 0.83)*
Fired 5 hrs. @ 1500°F *(816°C)* cast	50 - 70 *(0.34 - 0.48)*	50 - 80 *(0.34 - 0.55)*
gunned	90 - 120 *(0.62 - 0.83)*	80 - 110 *(0.55 - 0.76)*
Fired 5 hrs. @ use limit, cast	50 - 70 *(0.34 - 0.48)*	40 - 60 *(0.27 - 0.41)*
gunned	90 - 120 *(0.62 - 0.83)*	60 - 80 *(0.41 - 0.55)*
Perm. linear change, % (ASTM C 113)[4]		
Fired 5 hrs. @ 1500°F *(816°C)*	-1.0 to -2.0	-0.5 to -1.5
Fired 5 hrs. @ use limit	-1.5 to -2.5	-1.5 to -2.5
Chemical Analysis, Nominal, %		
Alumina, Al_2O_3	11	29
Silica, SiO_2	33	32
Ferric oxide, Fe_2O_3	7.9	7.0
Titanium oxide, TiO_2	1.4	2.3
Calcium oxide , CaO	30	14
Magnesium oxide, MgO	12.1	12
Alkalies, as, Na_2O	3.7	3.5
Thermal Conductivity, Btu•in./hr•ft²•°F *(w/m•k)* (ASTM C 417)		
Mean temperature	cast, gunned	cast, gunned
@ 500°F *(260°C)*	0.87, 1.03	0.79, 0.93
@ 1000°F *(538°C)*	1.02, 1.11	0.95, 1.06
@ 1500°F *(816°C)*	1.19, 1.20	1.11, 1.26

*Note: For overhead gunning applications, pounds required to place one ft³ should be increased to 40-50 pcf. Does not include rebound loss.

1. Gunite installation may require 10-30% overage due to rebound and on-site loss.
2. Installation key: C-cast, G-gun, P-pour
3. Properties indicated are for vibratory cast materials unless specified otherwise.
4. Fired linear change values reflect samples taken from a dried to fired state.

The values given herein are typical average values obtained in accordance with accepted test methods and are subject to normal manufacturing variations. They are supplied as a technical service and are subject to change without notice. Therefore, the data contained herein should not be used for specification purposes. Check with your Thermal Ceramics office to obtain current information.

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Figure 7. Kaolite data sheet (sheet 2 of 2).

Job Thermal Analyses (ANSYS) of JLS&A BU650B Shipping Container for NCT and HAC	Date April 5, 2012	Sheet 42 of 42
ESO No. P09YCW01	Computed by DLL D. L. Lowe	Checked by DEW D. E. Winder

THERMAL CERAMICS

ENGINEERING DEPARTMENT

P.O. BOX 923
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PHONE: 9-010-1-706-796-4490

TELECOPY REQUEST

FAX NUMBED: 9-1-615-576-4722	
TO: MR. J. ANDERSON OAK RIDGE	DATE: 8-11-95
	FILE NUMBER:
SUBJECT: SPECIFIC HEAT	PAGES TO FOLLOW: -0-
FROM: J.W.BREUER	

MR. ANDERSON,

YOU REQUESTED THE SPECIFIC HEATS OF KAOLITE 1600, 1800, AND 2000. WE DON'T HAVE THIS INFORMATION AND CAN ONLY SPEAK GENERALLY ABOUT THE SPECIFICS HEATS OF CASTABLES. SPECIFIC HEAT OF REFRACTORIES IS RARELY FOUND BECAUSE IT IS RELATIVELY CONSTANT FOR A GIVEN TYPE OF MATERIAL. FOR REFRACTORY CASTABLES, IT RANGES FROM ABOUT 0.2 BTU/LB/°F AT 100oF TO ABOUT 0.29 AT 2500oF. THIS CAN VARY ABOUT +/- 0.025, DEPENDING UPON THE TYPE OF AGGREGATE USED.

J.W.BREUER

Figure 8. FAX communication regarding Kaolite specific heat.

Section 4

CONTAINMENT

Table of Contents

Common Abbreviations Used in This Section

Co-60	Cobalt 60. Radioactive isotope.
Cs-137	Cesium 137. Radioactive isotope.
CFR	Code of Federal Regulations
HAC	Hypothetical Accident Conditions, as defined in 10 CFR 71.73
ISO	International Organization for Standardization
NCT	Normal Conditions of Transport, as defined in 10 CFR 71.71

4.0 Containment

In order to assure no loss or dispersal of radioactive contents under the tests specified in 10 CFR 71, §71.71 and §71.73, this section describes the package's containment system design and how it meets the containment requirements under NCT and HAC tests. The requirement for leak-rate testing during package fabrication, use, maintenance, and repair is also addressed.

4.1 Description of the Containment System

The package utilizes a simple, robust containment method: Co-60 and Cs-137 sealed sources in special form. Neither Co-60 nor Cs-137 are capable of generating radioactive daughter products. Consequently, there are no radioactive gasses or aerosols generated by either isotope. Typical special form sources are doubly encapsulated right cylinders of welded construction. Through the use of these types of sealed sources, there is available a secondary and tertiary containment system which is designed to prevent a release of radioactive materials into the environment. The Shielded Liner lid and main closure serve as additional barriers to potential penetrations to the primary containment system. There are no valves or pressure relief devices of any kind. The package does not rely on any filter or mechanical cooling system to meet containment requirements.

The Sealed Source materials of construction are evaluated in Section 2.2.2 and selected to avoid chemical, galvanic, or other reactions. The materials of construction are compatible with each other and the chemical form of the payload. Both Cs-137 and Co-60 are chemical solids that do not react with stainless steel the only metal used by the source manufacturing industry to encapsulate both isotopes. Water is naturally extracted from these isotopes during the encapsulation process such that there is no presence of hydrogen within the source capsule prior to sealing. As a consequence of the chemical form encapsulated, both Cesium-137 and Cobalt 60 capsules resist rupture as a result of thermal expansion during exposures to heat in excess of decay heat. Due to the type of seal installed (typically weldment) in-leakage of water or other liquid is not possible. Therefore release of any amount of isotope into the environment is prevented without destruction of the sealed source capsule itself. Additionally, there are no flammable gasses generated as a consequence of radiolysis during transport, storage, or use of the isotopes to be transported (Cs-137 and Co-60) within the package due to their being sealed sources.

The containment system (sealed source) is designed, fabricated, examined, tested, and inspected in accordance 49 CFR 173.469 and 10 CFR 71.75, USNRC RegGuide 7.9, Section 2.10, and meets the minimum

Leak Test methods provided in ISO TR4826-1979(E), ISO 2919-1980(e) [4.2], or those test methods identified in 49 CFR 173.469(a)(4)(i). For purposes of evaluation, this package relies upon the use of a shielded liner capable of transporting one or more sealed sources in special form. Due to the capabilities of the LS Dyna Software used, the sealed source was modeled as a large mass (25 pounds) which is intended to simulate the combined weight of 24 sources, contained by .020" aluminum outer shell (most damaging scenario) and held within the cavity of the Shielded Liner.

4.2 Containment Under Normal Conditions of Transport

4.2.1 NCT Pressurization of the Containment Vessel

The package maximum normal operating pressure conditioned upon environmental conditions at the time of measurement. There are no seals present within the package. Containment is achieved through use of Sealed Sources in Special Form only. Section 3.3.2 further discusses the NCT pressurization.

4.2.2 NCT Containment Criterion

The package is designed to accommodate the transport of Sealed Sources in Special Form. Each sealed source is tested to a "leak-tight" containment criterion per ANSI N14.5 [4.1] and ISO 2919-1980(e) [4.2].

4.2.3 Compliance with NCT Containment Criterion

Compliance with the NCT containment criterion is demonstrated by analysis. The structural evaluation in Section 2.6 shows that there would be no loss or dispersal of radioactive contents, and that the containment boundary, (sealed source) and closure bolts do not undergo any inelastic deformation when subjected to the conditions of §71.71. The thermal evaluation in Section 3.3.1 shows that the sealed source and closure bolts do not exceed their temperature or structural limits when subjected to the conditions of §71.71.

4.3 Containment under Hypothetical Accident Conditions

4.3.1 HAC Pressurization of the Containment Vessel

The containment evaluation for HAC is performed assuming that the maximum package pressure is equivalent to atmosphere at the time of the test. Further, the internal pressure within the radioactive

sealed source is undeterminable and the package does not incorporate a sealing surface.

4.3.2 HAC Containment Criterion

The package as designed does not have a containment boundary. Sealed Sources are tested to a "leak-tight" criterion per ISO-2919-1980(e) [4.2] of 1.3 x 10^{-4} atm/^{cm3} sec. Therefore the package containment criteria is met.

4.3.3 Containment Under Hypothetical Accident Conditions

Compliance with the HAC containment criterion is demonstrated by analysis. The structural evaluation in Section 2.7 shows that there would be no loss or dispersal of radioactive contents, and that the containment boundary, sealed source(s), and closure bolts do not undergo any inelastic deformation when subjected to the conditions of §71.73. The thermal evaluation in Section 3.4.3 shows that the sealed sources and bolts materials of construction do not exceed their temperature limits when subjected to the conditions of §71.73.

4.4 Leakage Rate Tests for Type B Packages

4.4.1 Fabrication Leak Rate Test

The BU650 B has no sealing surfaces. Therefore this section is not evaluated or addressed. Sealed Sources, when fabricated are leak tested to the standards identified in ISO 2919-1980(e) [4.2].

4.4.2 Maintenance Leak Rate Test

The BU650B does not have a sealing surface, and therefore cannot undergo a leak rate test as a consequence of maintenance. Sealed Sources are maintained under criteria established by the license to possess.

.

4.4.3 Periodic Leak Rate Test

The BU650B as designed relies upon a Sealed Source for containment. Sealed Sources are designed, fabricated, and maintained under criteria established in 49 CFR 73.469, 10 CFR 71.75 and ISO 2912-1980(e) [4.2] and are periodically leak tested s a condition of the licensee's authority to possess. The leak tests are intended to ensure that the radioactive sealed source containment capabilities have not deteriorated over an extended period of use.

4.4.4 Pre-shipment Leak Rate Test.

Each Sealed Source is verified to be leak-free prior to loading. Leak tests are conducted in accordance with the licensee's authority to possess under issued radioactive materials license criteria.

4.5 Appendix

4.5.1 References

[4.1] ANSI N14.5, *American National Standard for Radioactive Materials - Leakage Test on Packages for Shipment*, American National Standards Institute, Inc., 1997.

[4.2] ISO 2912-1980(e), International Organization for Standardization, Standard for Helium Leak Testing of Radioactive Source Capsules.

[4.3] 49 CFR 173.469

[4.4] 49 CFR 173.469(a)(4)(i) Test Methods

[4.5] 10 CFR 71.75

[4.6] USNRC Reg Guide 7.0, Section 2.10 "Special Form"

4.5.2 Drawings.

Not required per USNRC RegGuide 7.9, Section 2.10, "Special Form"

Section 5.0

Shielding Evaluation

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Table of Contents

Common Abbreviations Used in This Section

A_2	A value identified in Table-A1, Appendix A, 10 CFR Part 71
Co-60	Cobalt 60. Radioactive isotope.
Cs-137	Cesium 137. Radioactive isotope.
Ci	Curie. A non-SI unit of radioactivity named after Marie and Pierre Curie. It is defined as 1 Ci = 3.7×10^{10} disintegrations per second.
HAC	Hypothetical Accident Conditions, as defined in 10 CFR 71.73.
Mev	Multiples and sub-multiples of the electron volt unit. In this case the "M" indicates Mega.
NCT	Normal Conditions of Transport, as defined in 10 CFR 71.71
rem	Roentgen equivalent in man. Named after Wilhem Roentgen. A deprecated unit used to measure the biological effects of ionizing radiation.
mrem	milli-rem. One thousandth of a rem.
R/hr	Roentgen per hour. A unit of measure of ionizing radiation measured over a one-hour period.
mR/hr	milli-Roentgens per hour. A measurement of ionizing radiation measured over a one-hour period.
NBS	National Bureau of Standards
NIST	National Institute of Standards and Technology (formerly NBS)

5.0 SHIELDING EVALUATION

This section will identify, describe, discuss and analyze the principal radiation shielding design of the packaging, components and systems that are important to safety.

5.1 Description of Shielding Design

The BU650B package is designed to meet the regulatory requirements of 10 CFR 71 for a non-fissile package. This section will provide the description of the packaging's Shielded Liner inserts and the shielding evaluation of each insert consistent with the provisions of §71.73 HAC, and §71.35(a). Section 1 provides the general package description (§71.33).

The BU650B is designed, fabricated, assembled, tested, maintained and used in accordance with the codes and standards described in Sections 1, 7, and 8 to assure radiological safety (§71.31(c)).

The BU650B package is designed, constructed, and prepared for shipment so that under the NCT tests specified in §71.71 there will be no loss or dispersal of radioactive contents as demonstrated to a sensitivity of 10^{-6} A_2 per hour, no significant increase in external surface radiation levels and no substantial reduction in the effectiveness of the packaging (§71.43(f)). Additionally, the Structural Evaluation identified in Section 2.7 shows that there would be no loss or dispersal of radioactive contents, and that the containment boundary, sealed source(s), closure bolts, shielding and structural walls of the Shielded Liner do not undergo any inelastic deformation when subjected to the conditions of §71.73.

Sections 5.1.2 and 5.4.4 will show that, under the NCT tests specified in §71.71, the external radiation levels are less than the requirements of §71.47(a); and that under the HAC tests specified in §71.73, the external radiation level does not exceed 1000 mrem/hr at a distance of one meter from the surface of the package exterior surface (§71.51(a)(2)).

5.1.1 Shielded Liner Design Features

Figure 5-1A shows the shielding features of the Shielded Liner Assemblies intended to be shipped within the BU650B Radiological Materials Transportation Package. The major subassemblies are the sealed source, Shielded Liner body, plug or drawer assembly (dependent upon the model of Shielded Liner to be used), and

closure assembly. Shielding within the Shielded Liner is void-free solid lead contained in welded carbon steel/stainless steel containments, minimum ¼" thick exterior and 1/8" thick interior for the cavity and plug sections. Plug Assemblies may be fabricated from solid tungsten alloy with a minimum density factor of 17, provided the tungsten plug assembly does not exceed the weight restrictions identified in Table 5-1.

The Special Form sealed sources within the cavity are contained in metal (aluminum or stainless steel) racks, cages, spiders, or Bailer cans which limit both axial and radial movement during NCT and HCT. There are no issues of incompatibility between an aluminum spider, Bailer can or source holder and a stainless steel encapsulated special form source.

All Plug Assemblies are secured by bolts, the number and size based upon the weight of the plug (see Table 5-1), with a sacrificial cover to withstand both NCT and HCT and provide a safety margin of ≥ 2 without displacement failure.

All Shielded Liners are equipped with either lifting lugs, embedded acorn nuts, or exterior welded coupling nuts to accept eyebolts, each of which can lift the liner with a safety factor of 1.5 or greater.

Cavity diameters of Shielded Liners range from ½" to 8-1/8" in diameter and vary from 1" to 19" in height. Graphs showing lead shielding thickness as a function of strength of source loading (Curies) for both Cs-137 and Co-60 are provided at Section 5.5.2 and Section 5.5.3.

The Shielded Liner design is intended to mitigate the effects of post-accident dose rate increases that could occur if any portion of the BU650B package were to rupture as a consequence of HAC.

FIGURE 5-1A.

Shielded Liner with Center Cavity Exposed

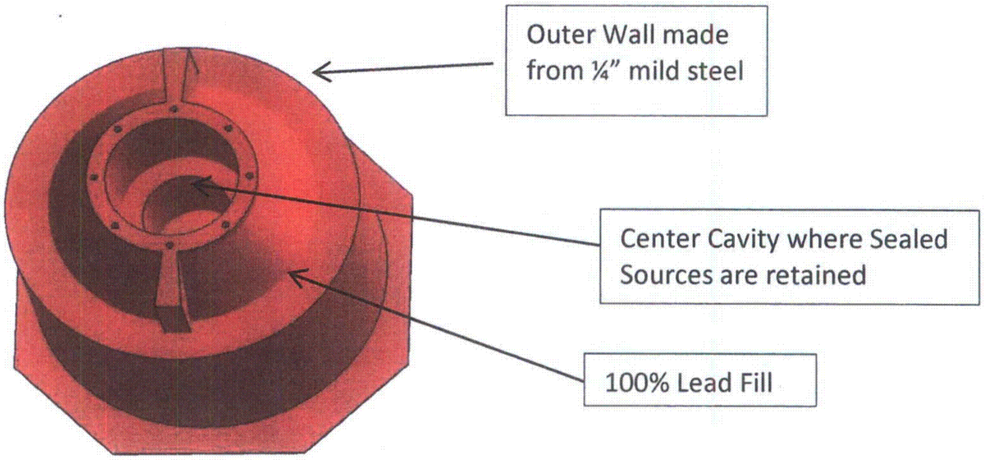


Figure 5-1B.

Modeled Shielded Liner Plug Assembly

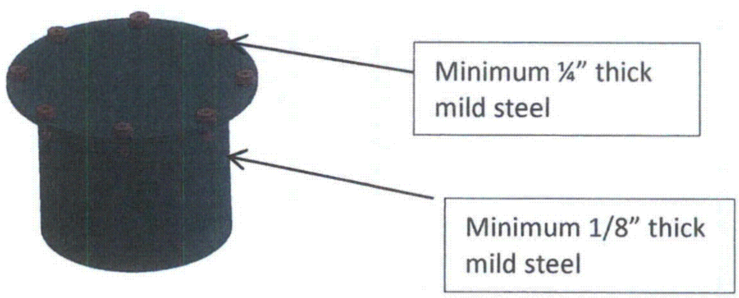


Table 5-1

Closure Bolt Loading Matrix

Weight of Plug & Closure Flange (lbs)	Force at 60g's (psi)	Min. No. Bolts Required	Min. Bolt Size (dia)	Min Bolt Strength Req'd (psi)	Cum. Bolt Strength	Safety Factor
1	60	4	¼"	1,612	6,448	10.8
10	600	4	¼"	1,612	6,448	10.7
50	3,000	6	3/8"	4,067	24,402	8.1
100	6,000	6	3/8"	4,067	24,402	4.05
250	15,000	4	½"	7,540	30,160	2.01
500*	30,000	6	½"	7,540	45,240	1.5
750	45,000	6	5/8"	12,108	72,648	1.61
1000	60,000	6	¾"	18,114	108,684	1.81

*Actual size modeled. See Section 1.3.8, DAC-P09YCW01-0001 000 00.

5.1.1.1 Payload (Shielded Liner) Shielding Design Features

Shielded Liners are designed so that Sealed Source(s) may be loaded into a Shielded Liner either remotely (hot cell) or directly from another shield. Sealed Sources are constructed of materials and methods defined by 49 CFR 173.469 and §71.75. Sealed sources may have a double or tertiary containment depending upon design, date of manufacture, or re-encapsulation, but in all cases are right cylinders having welded containments. Sealed sources are retained within the center cavity of Shielded Liners in a manner that restricts or minimizes movement resulting from impact incidents occurring during HAC. Shielded Liners are designed such that at least 50% of the energy generated during a HAC event can be absorbed by the combined capabilities of the carbon steel wall and dense lead wall of the inner Shielded Liner, exclusively. Shielded Liners are capable of absorbing the energy generated from a 1 meter free drop to any surface or exterior feature, exposure to 158°F thermal event continuously, and puncture from an object or projectile weighing 13.2 lbs, falling from a distance of one meter, with no release of radioactivity to the environment or increase in radiation levels.

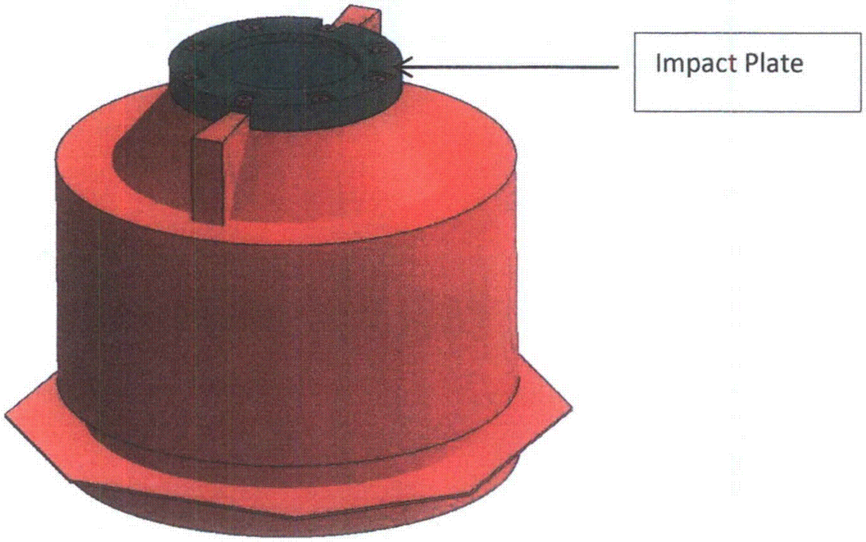
5.1.1.2 Shielding Features

The Shielded Liner includes the primary Shielded Liner body, shield plug, and Shielded Liner closure lid assemblies. The Shielded Liner body is constructed from carbon steel parts, fully welded and then poured, via prescribed process, with molten lead, into the vacant spaces within the Shielded Liner, creating a no-void fill. The shield plug is constructed in a similar manner and is designed with a shoulder or step diameter to prevent radiation streaming. Dimensional tolerances are analyzed and controlled to minimize the potential for radiation streaming while allowing for ease of fabrication, maintenance, use, and survival in event of a transportation incident.

5.1.1.3 Shielded Liner Closure Features (Shielded Plug or Drawer). In order to mitigate the radiological consequences of the HAC free drop, the Shielded Liner has a Closure Lid that is retained by a prescribed number of bolts. These bolts are covered by a free-fitting impact plate (see Figure 5-2, below) in order to protect the bolt heads from shear during HAC events. The Closure Lid serves as a secondary containment in protecting the radioactive special form source material. The Closure Lid and plug has a stepped diameter which prevents radiological streaming and secures the radioactive sealed source(s) within the Shielded Liner center cavity. There are variations in closure lid configurations which accommodate various sizes of radioactive special form sources. Each lid configuration is dependent upon the size cavity required for transport of radioactive special form sources. The configuration shown and modeled is that required to transport the maximum 450 watt radioactive payload. Smaller radioactive payloads will require less shielding and therefore equal or less mass is required of the Shielded Liner.

Figure 5-2

Shielded Liner with Impact Plate



5.1.2 Summary Table of Maximum Radiation Levels

Table 5-2 shows the BU650B with Shielded Liner maximum NCT dose rates for non-exclusive use shipment (29,250 Ci, Co-60). On the package surface, the dose rates comply with the regulatory limits in 10 CFR 71.47 within a large margin (factors of 4). At 1 meter, the dose rates comply, and the margins are even larger (factor of 2). It should be noted, that at no time during NCT or HAC events do the emitted radiation levels rise to a level requiring exclusive use.

Table 5-2

SUMMARY OF NCT RADIATION LEVELS

Normal Conditions of Transport	BU650B With Shielded Liner Package Surface mSv/hr (mrem/hr)			BU650B With Shielded Liner, 1 Meter from Package Surface mSv/hr (mrem/hr)		
Location	Top	Bottom	Side	Top	Bottom	Side
Radiation*	.01 (10.0)	.515 (51.5)	.454 (45.5)	.025 (2.5)	.046 (4.67)	.047 (4.7)
10CFR71.47 (a) Limit	2 (200)	2 (200)	2 (200)	0.1 (10)	0.1 (10)	0.1 (10)

*Based upon a maximum load: 29,250 Ci, Co-60, using a factor of 1.3 R/hr per Ci at a distance of one meter.

Table 5-3 shows the total package maximum HAC dose rates. At 1 meter, the dose rates comply, and the margins are a factor of 2. The NCT results consistently show the largest margin on the Shielded Liner sides, followed by the top/bottom surfaces. The HAC results do not differ because of the protective design of the BU650B package, the combination of carbon steel used in the retaining methods of the Shielded Liner, and the attenuation characteristics of the stacking of stainless steel used in the package lid and bottom.

Table 5-3

SUMMARY OF HAC RADIATION LEVELS*

BU650B with Sheilded Liner 1 Meter from Package Surface mSv/hr (mrem/hr)		
Top	Bottom	Side
.017 (1.7)	.046 (4.67)	.047 (4.7)
10 (1000)	10 (1000)	10 (1000)

*Calculated estimates based upon an Exclusive Use Shipment of Co-60, at 450 Watts.

5.2 Source Specification (Gamma Sources)

The shielding safety evaluations are performed assuming a bounding product activity of 29,250 Curies of Co-60 and less than 30,000 Curies of Cs-137 in Special Form. For lower activity specifications (refer to Section 1.2.2), the shielding graphs provided at Sections 5.5.2 and 5.5.3 may be used to determine the amount of lead shielding required to adequately attenuate radioactive output for the intended isotopes to be transported. The payload is a chemical form solid that does not vary in composition, other than the concentration (radioactive decay). The package, as designed, is not intended for transport of spent fuels or neutron generators, radioactive gasses or liquids.

5.2.1 Co-60 and Cs-137 (Gamma Sources)

The nuclides Co-60 and Cs-137 are the isotopes to be transported in the proposed BU650B Radioactive Materials Transport package.

5.2.1.1 Co-60.

Co-60 emits beta particles, electrons, and photons with a half-life of 5.27 years with 100% 1.17 and 1.33 MEV photon emission. Dose rate constant is 1.3 R/hr at a distance of one meter per National Bureau of Standards (NBS) Handbook 54. There are no radioactive daughter products associated with Co-60.

5.2.1.2 Cs-137.

Cs-137 emits beta particles, electrons, and photons with a half-life of 30.2 years with 86% 0.622 MEV photon emission. The Dose Rate constant is .32 R/hr at a distance of one mater per NBS Handbook 54. There are no radioactive daughter products associated with Cs-137.

Each isotope decays in a metastable state. The betas, electrons, photons, and gammas are absorbed by the shielding materials contained within the Shielded Liner and because of their stability provide reliable, calculable data in determining estimated dose rates at surface and one meter distance levels. Gamma source strength is measured by measuring dose rates with National Institute of Science and Technology (NIST) -traceable Ionization Chambers.

5.2.2 Neutron Sources

Neutron sources are not intended to be shipped within the BU650B. Therefore this section is not applicable or considered.

5.3 Shielding Model

The Shielding Model is described at Section 3.5.2 (DAC-Thermal Model). Figure 5-3 provides an overview of the BU650B Shielded Liner performance during HAC. As a consequence of the Shielded Liner's acceptable performance during HAC tests, it is assumed that the NCT tests will not significantly affect the nominal package configuration from the shielding standpoint. Section 5.5.2 and Section 5.5.3 show the recommended thickness required for shielding. Use of Monte Carlo (MCNP) for shielding has not been performed, due to the fact that this package is designed for the transportation of sealed sources in special form, utilizing the isotopes of Co-60 and Cs-137, for which there exists a substantial amount of historically valid information. Additionally, the BU650B package is a non-precision package, designed to protect a Shielded Liner and sealed source; therefore, the tolerances are relatively large, and manufacturing tolerances on the components do not significantly impact the package shielding performance features. Figure 5-1A (paragraph 5.1.1) is an illustration of the normal, upright orientation model of the intended Shielded Liner. The figure identifies the different materials of construction as labeled.

5.3.1 Configuration of Source and Shielding

5.3.1.1 NCT Shielding Models

Figure 5-3 shows an overview of the baseline HAC stress results and the impact of those results on the proposed Shielded Liner, including the significant shielding features discussed above. None of the NCT tests significantly affect the nominal package configuration from the shielding standpoint. Section 1.3.6 provides Shielded Liner design information and description. The description of the model used can be found in Section 2.12.

5.3.1.2 HAC Shielding Models

The post-HAC test package configuration is reflected in Figure 5-4 below. Regardless of the drop orientation, the Shielded Liner contained within the package does not experience any significant plastic strain which would result in a release of radioactive materials or exposure to the environment. Because of the limited

damage, there are no additional dose point locations which would provide a streaming path or irregular geometry resulting in a surface radiation level increase. Maximum radiation levels are identified in Tables 5-2 and 5-3.

5.3.2 Material Properties

The shielding evaluations were performed using the material densities shown in Table 5-5. These properties are valid for the purpose of shielding evaluations modeled at the standard, nominal stainless steel density of 8.027 g/cm^3. The Impact Limiter foam and Kaolite 1600 were not considered as each is part of a specific purposed element and not intended to provide attenuation of radioactivity.

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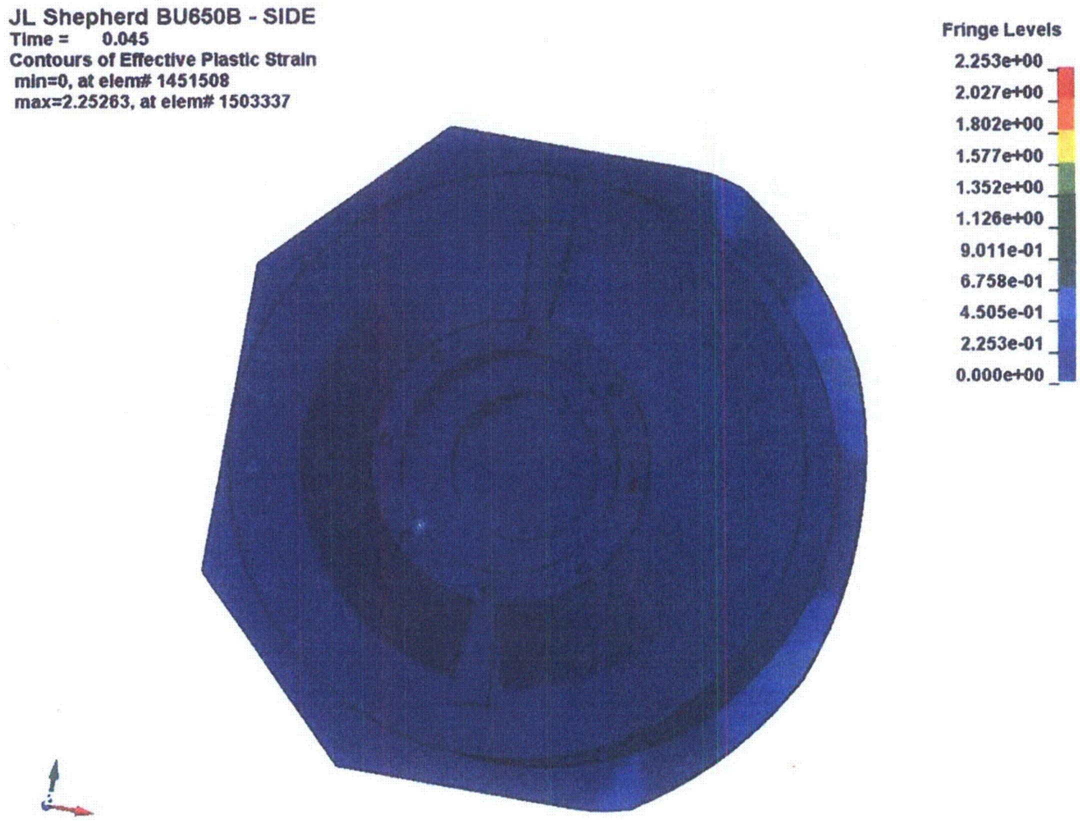
Figure 5-3

Shielded Liner Performance During HCT.



Note: All indicated plastic strains occurred as a result of a side drop and affect only the spacing lip at the bottom of the Shielded Liner. This lip is a solid plate extending along the bottom of the primary shield and is welded in place on both sides. There are no measurable deformations occurring on the side wall of the Shielded Liner, therefore only an assumption regarding lead slump can be made: Due to the process used for volumetric pour of molten lead into a vessel, there are no voids in shielding. This is verified by radiological assay (sealed source inserted into cavity center of Shielded Liner and then measurements taken around circumference of Shielded Liner). Given that there are no measurable deformations of the retaining material, there can be no measurable deformations of the material retained (lead).

5.4 Shielding Evaluation

J.L. Shepherd & Associates has opted to provide manually calculated data relative to capabilities of Shielded Liners and shielding requirements based upon historical and empirical information utilized throughout the industry. This decision is based upon the fact that JLS&A does not ship fissile materials, radioactive gasses, liquids, or solids in normal form. Tables identifying shielding requirements for primary isotopes intended to be shipped within Shielded Liners appear in Section 5.5.2 and Section 5.5.3.

Table 5-4

SHIELDING REQUIRED
HALF-VALUE AND TENTH-VALUE LAYERS

kVp or Source	Half-Value Lead		Half-Value Steel		Tenth-Value Lead		Tenth-Value Steel	
	in	mm	in	mm	in	mm	in	mm
50	0.002	0.05			0.006	0.16		
70	0.0059	0.15			0.02	0.5		
100	0.0094	0.24			0.03	0.8		
125	0.011	0.27			0.035	0.9		
150	0.011	0.29			0.037	0.95		
200	0.019	0.48			0.063	1.6		
250	0.035	0.9			0.12	3		
300	0.055	1.4			0.18	4.6		
400	0.087	2.2			0.29	7.3		
500	0.14	3.6			0.47	11.9		
Ir-192	0.24	6	0.5	12.7	0.79	20		
Cs-137	0.26	6.5	0.64	16.3	0.84	21.3	2.1	53
1,000	0.31	7.9			1.0	26		
Co-60	0.49	12.0	0.82	21	1.6	40	2.7	60
2,000	0.5	12.7			1.7	42		
3,000	0.58	14.7			1.9	48.5		
4,000	0.65	16.5	1.08	27	2.16	54.8	3.6	91
Ra-226	0.65	16.6	0.88	22	2.2	55	2.9	74
6,000	0.67	17	1.2	30	2.3	56.6	4.0	100
10,000	0.65	16.5			2.8	55.0		

5.4.1 Methods

5.4.1.1 Assumptions. For purposes of this evaluation, the presence of Impact Limiters and/or Kaolite 1600 was ignored in determining dose rates for both Co-60 and Cs-137 at the surface of the top, bottom and side of the package and again at a distance of one meter from the surface of the top, bottom and side of the package.

5.4.1.2 Shielding Determination.

To determine the dose rate for each location (top, bottom, and side), it is necessary to determine the dose rate by the cumulative attenuation factors for lead, stainless steel, and steel. (For purposes of these calculations it was assumed that steel and stainless steel possess the same attenuation factor and any attenuating benefit from the Kaolite 1600 thermal barrier material and Impact Limiter foam was not considered).

The dose rates were then divided by the cumulative attenuation factors to determine the attenuated dose rates for the package.

See Section 5.5.3 for formula used. All calculations are based upon a maximum radioactive content.

5.4.2 Input and Output Data

Use of a modeled shielding program such as Monte Carlo was not considered for this evaluation. This consideration is based upon the fact that the shielding media used in Shielded Liners is calculated by hand calculation to attenuate emitted radiation levels per NBS Handbook 54, and as constructed is intended to provide sufficient reduction of radioactive output to reduce radiation levels to no more than 200 mR/hr at the surface, and no more than 10 mR/hr at 1 meter. See paragraph 5.2.1 for appropriate attenuation factors and paragraph 5.5.4 for specific calculation models.

5.4.3 Flux-to-Dose-Rate Conversion

Calculation results are converted based upon the information contained in Paragraph 5.2.1, above, per NBS Handbook 54, and as supplemented by NBS Handbook 73.

5.4.4 External Radiation Levels

5.4.4.1 NCT Radiation Levels

Figure 5.2 summarizes the NCT radiation levels along the package surface. Figure 5.2 also summarizes the NCT radiation levels 1 meter from the package surface. The maximum dose rate is estimated at 4.7 mrem/hr, occurring at the package side. Because the bottom and radial shields are similar, the contact dose rate is almost the same at the package bottom on centerline. Since these data are for the 1-meter package surface, the effect is less pronounced than the surface results. Sections 5.4.4.2 through 5.4.4.7 discuss the calculated profiles along the individual sides of the package in more detail.

The dose rates calculated do not show a rise with increasing radial distance from the package. Due to spatial attenuation, the dose rates eventually drop off in the radial direction.

5.4.4.2 NCT Radiation Levels – Package Top, 1 Meter NCT Profile

Table 5-2 shows the worst-case results for the 1-meter surface above the top end of the package. Due to the layers of steel and stainless steel between the top of the Shielded Liner and lid exterior, all dose rates at the top end of the package are very low, on the order of a factor of 5 below the regulatory limit of 10 mrem/hr. The results show that the highest dose rates at the top end occur when the package is in the inverted position. This places the product closest to the top end, and most directly challenges the streaming paths around the package shield plug. The peak dose rates are relatively flat out to the package radius, then rise slightly in the radial direction, indicating that the shield plug has a "shadowing" effect and that the streaming paths around the shield plug are not a dominating factor.

5.4.4.3 NCT Radiation Levels – Package Side, 1 Meter NCT Profile

All dose rates are low, on the order of a factor of 2 below the regulatory limit of 10 mrem/hr at 1 meter. The highest peak dose rate on the side remains constant regardless of package position.

5.4.4.4 NCT Radiation Levels – Package Bottom, 1 Meter NCT Profile

Worst case results at a distance of one 1-meter from the surface below the bottom end of the package, indicates all dose rates to be low, on the order of a factor of 2 below the regulatory limit of 10 mrem/hr at 1 meter. The results show the dose rates at the bottom end to be consistent regardless of package orientation. Additionally, the bottom of the package presents the highest radiation levels due to the location of the radioactive source materials within the Shielded Liner and the Shielded Liner's orientation within the package.

The maximum calculated dose rate is found on the package bottom at 1-meter from surface is 0.467 mrem/hr (T.I. = 0.5).

5.4.4.5 NCT Radiation Levels – Package Top Surface NCT Profile

Due to the layers of mild and stainless steel within the lid, all dose rates at the top end of the package are very low, on the order of a factor of 5 below the regulatory limit of 200 mrem/hr. The very large margin is due to the attenuation of multiple layers of stainless steel within the package Lid Assembly,

5.4.4.6 NCT Radiation Levels – Package Side Surface NCT Profile

The peak dose rate at the package side surface is low, on the order of a factor of 4 of the regulatory limit of 200 mrem/hr. The highest peak dose rate on the side surface remains constant, regardless of package orientation. There is no re-location of product (radioactive materials) within the package as a consequence of a change in package orientation.

5.4.4.7. NCT Radiation Levels – Package Bottom Surface NCT Profile

The peak dose rate at the bottom end of the package is low, a factor of 4 on the regulatory limit of 200 mrem/hr. The highest peak dose rate was produced by the baseline upright package orientation illustrated in Figure 5-2. The peak dose rates occur at the centerline of the package.

5.5 Appendix

5.5.1 References

[5.1] *Federal Register*/Vol. 68, No. 75/Friday, April 18, 2003/Notices.

[5.2] Lederer, C., Shirley, V. Ed., *Table of Isotopes*, 7th Edition, John Wiley & Sons, New York, 1978.

[5.3] American National Standard ANSI/ANS-6.1.1-1977, *Neutron and Gamma-Ray Flux-to-Dose-Rate Factors*.

[5.4] U.S. Department of Commerce, National Bureau of Standards Handbook 54, *Protection Against Radiations from Radium, Cobalt-60, and Cesium-137,* Superintendent of Documents, Washington 25, D.C., September 1, 1954. Figure 7.

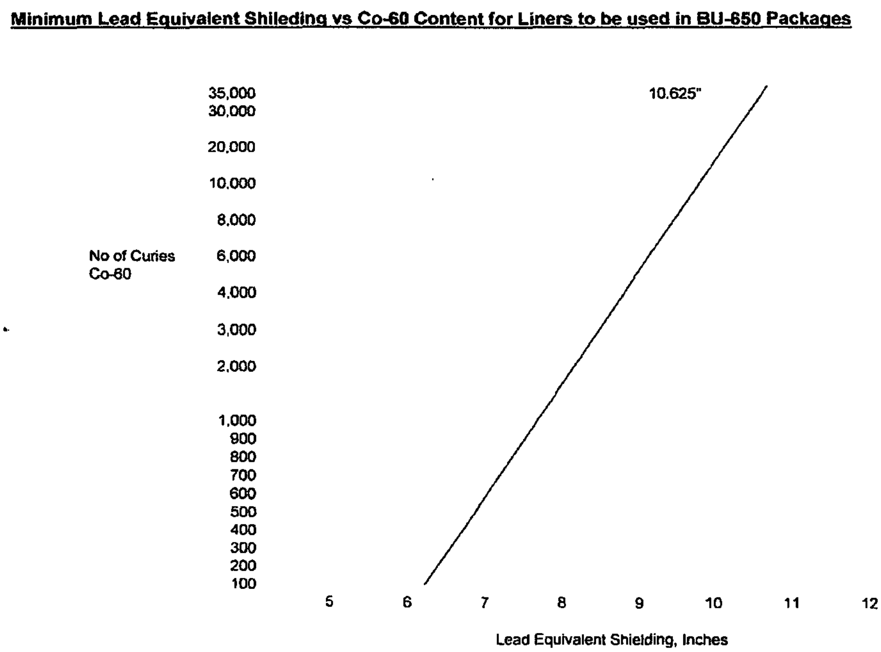
[5.5] U.S. Department of Commerce, National Bureau of Standards Handbook 73, *Protection Against Radiations from Sealed Gamma Sources,* Superintendent of Documents, Washington 25, D.C., July 1, 1960, Figure 7.

[5.6] U.S. Department of Commerce, National Bureau of Standards Handbook 93, *Safety Standard for Non-Medical X-ray and Sealed Gamma-Ray Sources, Part-1 General,* Superintendent of Documents, Washington 25, D.C., January 3, 1964 (Re-printed April 1966), Figure 5.

[5.7] National Council on Radiation Protection and Measurements Report No. 34: Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV. Structural Shielding Design and Evaluation, NCRP Publications, March 2, 1970.

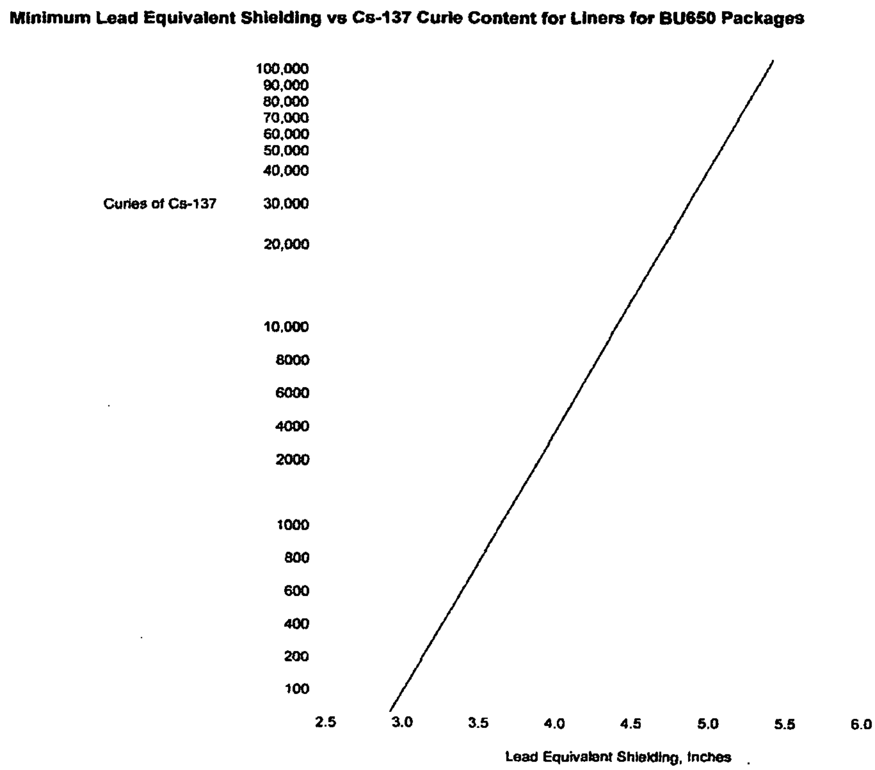
[5.8] ORNL-TM-2410, Irradiated Fuel Shipping Cask Design Guide, L.B. Shappert, January 1969, pages 47, 48.

5.5.2 Minimum Required Lead Equivalent Shielding vs Co-60



Developed from Figure 7, NBS Handbook 54.

5.5.3 Minimum Required Lead Equivalent Shielding vs. Cs-137



Developed from Figure 7, NBS Handbook 54

5.5.4 Calculations

Calculation of Cobalt 60 Dose Rate Activity, Package Top, Side, and Bottom

Dose rates for sides, top and bottom of the package (ignoring Kaolite 1600 and Impact Limiter foam) were determined using 29,250 Curies, Cobalt 60 (450 Watt decay heat load) with an output of 38,000 R/hr at a distance of one meter. Dose rates for 30,000 Curies of Cesium 137, the maximum amount intended to be shipped within the BU650B are calculated on a basis of 136.4 Watts decay heat with an output of 9,600 R/hr at a distance of one meter.

For side (radial) calculations all activity is assumed to be adjacent to the side of the Shielded Liner cavity, closest to the surface under calculation. For top calculation all activity is assumed to be at the top of the cavity and for bottom calculation all activity is assumed to be at the bottom of the cavity. All are worst case scenarios. In actual practice, activity would be evenly distributed throughout the Shielded Liner cavity.

Formula Used for all Calculations:

$$\frac{U}{A} = \text{Final Dose Rate}$$

U= Unattenuated dose rate
A= Attenuation Factor

(Distance of one meter ÷ measured distance)^2 x (Curie content x 1.33 MEV) = Dose Rate (1.62 x 10^8 mR/hr). (Unattenuated Dose Rate)

Determine type of shielding: Lead
Amount of available shielding: 10.125"
Reduction factor: ~2 x 10^6

Additional shielding: Steel/Stainless Steel
Amount of available shielding: 1.125"
Reduction factor: 1.85

Combine Reduction factors of all shielding available: 3.85 x 10^6 x 1.85

45.4 mR/hr (Attenuated Dose Rate)

Side Calculations for Cobalt 60

Distance from surface to source: 18.75"
Dose Rate: $(39.4 + 18.75)^2$ x 38,000 R/hr or 1.68×10^8 = 7.418e+8
Shielding is comprised of 10.125" lead with a reduction factor of 2×10^6 and 1.125" Stainless Steel with a reduction factor of 1.85

Distance to surface is 18.75"
Dose Rate: $(39.4 + 18.75)^2$ x 38,000 R/hr = 1.68×10^8 mr/hr
Available shielding: 10.125" lead (reduction factor of ~ 2×10^6); and 1.125" Stainless Steel (reduction factor of 1.85) for a cumulative reduction factor of 3.85
3.7×10^6 = 45.4 mR/hr

1 Meter from Surface (Transport Index):
Dose Rate: $[39.4 + (39.4+18.75)]^2$ x 38,000 R/hr = 1.745×10^7 mr/hr divided by 3.85×10^6 = 4.5 mR/hr (attenuated dose rate)

Bottom Calculations for Cobalt 60

Distance from surface to source: 17"
Dose Rate: $(39.4+17)^2$ x 38,000 R/hour = 2.04×10^8 mR/hr
Available Shielding: 10" with a reduction factor of 1.65×10^6
1.5" of steel/stainless steel for an attenuation factor of 2.4
Cumulative Attenuation Factor: 3.96×10^6

Dose Rate at bottom surface: 51.5 mR/hr

Dose Rate at 1 meter from surface:

Dose rate is: $[39.4 + (39.4 + 17)]^2$ x 38,000 R/hr = $1.85 \times 10^7 \div 3.96 \times 10^6$ = 4.67 mR/hr.

Side Calculations for Cs-137

Distance from source to surface: 18.75"
Dose Rate: $(39.4-18.75)^2$ x 9,600 R/hr, or 4.23×10^7 mR/hr
Attenuation Factor: 10 1/8" lead for Cs-137 is 1×10^{12}.
Calculated Dose Rate: 4.23×10^{-5} mR/hr (negligible).

Dose Rate 1 meter from surface (TI): Negligible.

Bottom Calculations for Cs-137

Distance from source to surface: 17"
Dose Rate: $(39.4 - 17)^2 \times 9{,}600$ R/hr or 4.8×10^7
Attenuation Factor: 11" lead: 1.6×10^{13}
Calculated Dose Rate: 2.2×10^{-6}

Dose Rate: Negligible

Top Calculation for Co-60

Distance from source to top: 37":
Dose Rate: $(39.4 - 37)^2 \times 38{,}000$ R/hr or 2.2×10^6 mR/hr
Attenuation Factor: 10" lead + 1.5" steel/stainless steel. Total reduction factor: 3.96×10^6
Calculated Dose Rate: 10 mR/hr at surface.

1 meter from surface (TI)
Dose Rate: $(39.4 - 37.0)^2 \times 38{,}000$ R/hr = 1.7 mR/hr

Top Calculation for Cs-137

The Cs-137 attenuation factor for 11" lead is 1.6×10^{12}. Energy produced by Cs-137 is approximately 25% of that generated by Co-60. At a 50% energy generation level, the radioactive output of Cs-137 at 30,000 Curies or less is negligible at both the top surface and at 1 meter.

Section 6

Criticality Evaluation

6.0 CRITICALITY EVALUATION

Not applicable. The BU650B package is not intended for transportation of fissile materials and therefore does not have to comply with the requirements of 10 CFR71.55 and 10 CFR 71.59.

Section 7

PACKAGE OPERATIONS

Table of Contents

Common Abbreviations Used in this Section

ALARA	"As low as reasonably achievable" – a statement used in assessing and managing risk of radiation exposure
CFR	Code of Federal Regulations
dpm	Disintegrations per minute
DOT	U.S. Department of Transportation
JLS&A	J.L. Shepherd & Associates
lb	Pound
NRC	U.S. Nuclear Regulatory Commission
QA	Quality Assurance
UNC	Unified Coarse Thread
"	Symbol for inch(es)

7.0 PACKAGE OPERATIONS

This section describes the operations used to load the BU650B package and prepare it for transport (Section 7.1), unload the BU650B package (Section 7.2), and prepare the empty BU650B package for transport (Section 7.3). Contained within this chapter are the fundamental operating steps in the order in which they are to be performed. The operating steps are intended to ensure that the BU650B package is properly prepared for transport, consistent with the package evaluation in Sections 2 through 6, and to ensure that the occupational exposure rates are as low as reasonably achievable (ALARA) as required by the "Standards for Protection Against Radiation" in 10 CFR 20.110(b).

The BU650B package shall be operated in accordance with detailed written procedures that are based on, and consistent with, the operations described in this section. To provide a comprehensive description of the BU650B operations, this section describes a particular sequence of steps intended to be taken in preparation for shipment of a Type B quantity of radioactive materials. While the operational sequence is stated, it may be modified to accommodate safety within a particular facility or environment, but in no event shall an incomplete package be transported beyond a reasonably secure area.

7.1 Package Loading

This section describes the minimum loading-related preparations, tests, and inspections for the BU650B package to be included in written procedures. These include the inspections made before loading the BU650B package to determine that it is not damaged and that radiation and surface contamination levels are within regulatory limits. There are no inspections required for seals or special tests required for closure.

7.1.1 Preparation for Loading

Equipment Required: *Radioactive contamination detection equipment*
Radiation Survey Meter
15,000# Capacity Forklift for handling the BU650B
Appropriately rated lifting equipment sufficient for removal of the BU650B Impact Limiter, Lid Assembly, and Shielded Liner

Special Controls: *Assume the BU650B package is always loaded, and therefore capable of radioactive output. Therefore, in order to avoid injury, the BU650B package is not to be opened until a radiation survey is performed.*

1. Perform a radiation survey to confirm the BU650B is empty by using a radiation survey meter. If radiation levels are detected, discontinue operation and determine the cause. Take corrective action as necessary.

2. Move the empty BU650B to a loading area using a 15,000 lb capacity forklift.

3. Visually inspect the exterior portions of the BU650B package for cleanliness and overall physical condition. If visual inspection reveals damage, remove the BU650B from service in accordance with JLS&A Quality Assurance Procedures. Swipe for radioactive contamination and evaluate using appropriate radioactive contamination equipment in accordance with facility procedures. Clean or decontaminate the BU650B package as necessary. If decontamination is necessary, determine the cause and take precautionary measures prior to opening the BU650B package. (Precautionary measures include moving the package to an area within the facility where adequate preparations can be made which will limit any dispersal of radioactive materials into the environment.

4. Locate and install a minimum of two ½" lifting eyes atop the upper Impact Limiter.

5. Attach lifting straps and shackles appropriately rated for the load to be lifted to the lifting eyes.

6. Remove four clips and pins retaining the upper Impact Limiter. Visually inspect. If acceptable, set aside. If unacceptable, advise JLS&A Quality Assurance and process in accordance with JLS&A Quality Assurance Procedures.

7. Lift the upper Impact Limiter from the BU650B package with an appropriately rated forklift or overhead crane and set it aside. (Use caution to set down evenly and place in an area where other equipment moving within the area cannot damage the Impact Limiter).

8. Using a 1.25" socket, remove the 24 lid closure bolts and lid. Visually inspect bolts. If acceptable, set aside. If unacceptable, notify JLS&A Quality Assurance.

9. Using appropriately rated lifting equipment (forklift or overhead crane), attach the lifting mechanism to the lifting eye located at the center of the Lid Assembly, then slowly lift and remove the Lid Assembly.

10. Visually inspect the package interior to determine physical condition of the inner package and package cleanliness. If damage is noted, remove the package from service and notify JLS&A Quality Assurance.

11. Swipe accessible interior surfaces and assess for surface contamination utilizing appropriate radioactive contamination detection equipment in accordance with facility procedures. Clean or decontaminate interior surfaces if necessary. If contamination is found, determine the cause and take precautionary measures before proceeding further.

12. Verify the contents to be loaded meet the requirements of the CoC and that required maintenance has been performed.

13. There are no neutron moderators or gaskets required for closure of the package therefore these items are not addressed or considered.

7.1.2 Loading of Shielded Liner Into BU650B

Shielded liners are always considered loaded. Loading occurs at facilities and locations operating under appropriate Radioactive Materials License, in accordance with appropriate facility operating procedures. As such, shielded liners are opened, inspected, loaded, and closed in accordance with facility operating procedures. Shielded liner radioactive protection (shielding) is verified upon completion of loading under appropriate facility operating procedures.

Special Equipment Required:

Calibrated torque wrench
Radioactive materials contamination detection equipment
Radiation Survey Meter
15,000 lb capacity forklift
Overhead crane capable of lifting payload and BU650B Package Components

Special Controls or Precautions:

Because the contents within the Shielded Liner are radioactive, the Shielded Liner must be identified as containing radioactive material. Verify all closure bolts on the Shielded Liner

are secure prior to loading. Do not open the Shielded Liner lid until ready to remove radioactive source materials.

1. Verify the intended Shielded Liner with payload meets the contents specification in the Certificate of Compliance. Using a radiation survey meter, perform a radiation survey of the Shielded Liner in order to verify integrity and that emitted radiation levels will not exceed 10 mS/hr (1,000 mrem/hr) at the package exterior surface.

2. Verify Shielded Liner lid closure bolts are secure and have been tightened to a level of 50 (+/- 10) ft/lbs each, using a calibrated torque wrench. (Prior to installation of bolts, verify each is in serviceable condition. If not, notify JLS&A Quality Assurance).

3. Utilizing appropriately rated forklift or overhead crane, lifting eyes, shackles, and straps, carefully lift the Shielded Liner and place into the bottom-center of the BU650B package.

4. Set the Shielded Liner Impact Plate over the shielded liner lid assembly so that it registers over the lifting ears and nests onto the lid assembly.

5. Install the Shoring Assembly (Drawing BU650B-SA). Using a measuring tape, measure the gap between the top plate of the shoring assembly and the bottom-most plate of the Lid Assembly. There should be ½" or less between the upper plate of the Shoring Assembly and the bottom of the Lid Assembly. Adjust by adding 1/8" thick carbon steel shim plates to the top of the Shoring Assembly as necessary to achieve the required dimension.

6. Install the package lid assembly. Using appropriately rated lifting equipment, lift the Lid Assembly using the ring provided at center of lid. (Note: closure flanges should be clean of any foreign matter and allow a surface to surface fit between the package closing flange and lid).

7. Install 24ea, ¾"-10UNC x 2.0" grade 316 Stainless Steel Closure Bolts. (Note: Ensure all bolts are serviceable prior to installation. If not notify JLS&A Quality Assurance).

8. Utilizing a criss-cross pattern, torque the closure bolts to 50 ft/lbs each (+/- 10 ft/lbs) using a calibrated torque wrench.

9. Install tamper resistant seal between lid and package body.

10. Remove all lifting equipment from Lid Assembly.

11. Carefully lift and install the Upper Impact Limiter into position. Insert retaining pins and clips. (Note: Ensure all pins and clips are serviceable prior to installation. If not, nofity JLS&A Quality Assurance).

12. Remove lifting eyes and straps.

7.1.3 Preparation for Transport

1. Perform a contamination survey of the external package surfaces to determine any fixed contamination is at or below 300 dpm / 300 cm^2, by taking 300cm^2 wipes and reading those wipes using radioactive materials contamination detection equipment.

2. Using a radiation survey meter, perform a radiation survey of the loaded BU650B package. If the external radiation levels exceed the maximum allowable level of 1000 mrem/h on surface contact, return the Shielded Liner to the loading facility and investigate cause. (49 CFR 172.403).

3. Complete and affix the appropriate Transport Index Labels. (On opposite sides of the package exterior). (Per 49 CFR 172.441, Transport Index labels are referred to as "White I, Yellow II, and Yellow III", as appropriate to the determined Transport Index. Radiation levels in excess of the 200 mrem/hr maximum for Exclusive Use are shipped as Highway Route Control quantities).

4. Review the BU650B package loading/closure documentation for completeness.

5. Prepare required Shipping documents, Quality Assurance documents, and Bill of Lading and ensure that TI and tamper resistant seal information are recorded on documents.

6. Utilizing an appropriately rated forklift (15,000#) transfer the package to the conveyance.

7. Provide Consignee copies of the package Certificate of Compliance, Drawings, and procedures for opening, unloading, and shipping a loaded or unloaded (empty)BU650B package , as appropriate.

8. Release the BU650B to the carrier for transport to the consignee.

7.2 Package Unloading

This section describes the package unloading operations, including the inspections, tests, and preparations necessary for unloading the Shielded Liner from the BU650B package.

7.2.1 Receipt of Package from Carrier

Equipment Required: *Radiation survey meter, Radioactive materials contamination detector 15,000 lb capacity forklift, overhead crane capable of lifting BU650B payload.*

Special Controls or Precautions: None.

The following operational steps identify the safety requirements of 10 CFR 20.1906, Procedures for Receiving and Opening Packages.

1. Before handling the BU650B package, the Consignee must have been trained in the proper procedures for opening and unloading the BU650B package.
2. Using a radiation survey meter, perform a radiation survey of the BU650B package in accordance with facility operating procedures. If the external radiation levels or Transport Index exceed the emitted radiation levels stated on shipping documents or Bill of Lading, take the following steps:

   a. Notify the Consignor immediately.

   b. Investigate the cause of the high radiation level(s) before proceeding.

   c. Take necessary precautions when proceeding with the remaining unloading steps.

   d. Notify NRC Operations Center if damaged (301-816-5100).
3. Utilizing radiation contamination detection equipment, perform a contamination survey of the external surfaces of the BU650B package to determine if any contamination has occurred during transit and that smearable contamination is at or below 300dpm/300cm^2 by taking 300cm^2

wipes. Read wipes using radioactive materials contamination detection equipment. If contamination levels exceed shipping release levels, then:

a. Notify the Consignor immediately.

b. Investigate the cause of the contamination.

c. Decontaminate using appropriate facility-approved methods.

d. Take extra precautions as necessary before opening the package for unloading.

e. Notify NRC Operations Center if the contamination limits of 10 CFR 71.87(i) are exceeded. (301-816-5100).

4. Remove tie-down or securing apparatus and remove package from conveyance utilizing appropriately rated forklift.

5. Move package to designated receiving area via appropriately rated forklift.

7.2.2 Removal of Shielded Liner from BU650B

Equipment Required:	*Radioactive materials contamination detector,* *Radiation survey meter.* *Socket wrench with 1.25" socket wrench* *15,000 lb capacity forklift* *Overhead crane capable of lifting package payload contents*
Special Controls or Precautions:	*DO NOT REMOVE THE LID FROM THE SHIELDED LINER WITHOUT ADEQUATE SHIELDING AND RADIATION PROTECTION IN PLACE.*

1. Locate and install a minimum of two ½" lifting eyes at the top of the Impact Limiter.

2. Attach lifting straps and shackles appropriately rated for the load to be lifted.

3. Remove four clips and pins retaining the upper Impact Limiter.

4. Using appropriately rated lifting equipment, lift the upper Impact Limiter from the package and set it aside. (Use caution to set down evenly and place in an area where other equipment moving within the area cannot damage the Impact Limiter).

5. Inspect the Security Seal for visible signs of damage or tampering. If the seal provides indication of tampering or replacement, nofity consignor and NRC Operations Center immediately. Stop all unloading operations and secure the package until a safe determination is made.

6. Using a socket wrench with 1.25" socket, remove the 24 lid closure bolts. Set aside.

7. Utilizing appropriately rated lifting equipment, locate lifting ring at top-center of Lid Assembly. Remove Lid Assembly and set aside.

8. Utilizing a lifting eye (1/2") and appropriately rated lifting equipment, remove the Shoring Assembly.

9. Utilizing appropriately rated lifting equipment carefully lift the Shielded Liner from the BU650B package and place onto a pallet or other safe surface.

10. Move the Shielded Liner to a safe location within the facility.

11. Inspect the package interior for damage. Move package to a designated holding area for empty packages.

7.3 Preparation of Empty Package for Transport

This section describes how empty BU650B packages are prepared for transport. The instructions contained herein provide the necessary operating instructions, inspections, and tests required by 49 CFR 173.428 "Empty Class 7 Radioactive Materials Packaging".

Equipment Required:	*Radioactive materials contamination detector,* *Radiation survey meter.* *15,000 lb capacity forklift* *Optional overhead crane capable of lifting payload contents*

1. Verify the interior of the package is empty.

2. Visually inspect the BU650B package interior and exterior components for physical damage and cleanliness. If physical damage is detected, notify JLS&A Quality Assurance immediately. Remove from service in accordance with appropriate JLS&A Quality Assurance Procedures.

3. Perform a contamination survey of the external surfaces of the BU650B package to ensure any unfixed or removable contamination is at or below 300 dpm/300 cm^2 by taking a 300 cm^2 swipe and reading the swipe using radioactive materials contamination detection equipment. If the non-fixed surface contamination exceeds local requirements for empty package shipment, decontaminate using appropriate facility defined methods.

4. If applicable, install an empty Shielded Liner into the BU650B utilizing appropriately rated lifting equipment as follows:

   a. Install appropriate lifting equipment onto the Shielded Liner.
   b. Install appropriately rated shackles and straps into lifting eyes.
   c. Lift and lower into BU650B package center.

5. Install the Shielded Liner Impact Plate on top the lid of the Shielded Liner. Ensure the impact plate registers over the lifting ears of the Shielded Liner.

6. Install the Shoring Assembly utilizing appropriately rated lifting equipment.

7. Install the BU650B Lid Assembly using appropriately rated lifting equipment. Use the lifting ring provided at the lid center. (Note: closure flanges should be clean of any foreign matter and allow a surface-to-surface fit between the BU650B Closing Flange and Lid Assembly).

8. Inspect and Install 24 ea ¾"-10UNC x 2.0" grade 316 Stainless Steel Bolts using a calibrated torque wrench. Working in a criss-cross pattern, torque each bolt to 50 (+/-10) ft/lbs. If any bolt is damaged, do not install. Initiate appropriate Quality Assurance procedures to obtain replacement item(s).

9. Inspect Impact Limiter pins and clips. If any pin or clip is damaged or determined to be unusable, initiate Quality Assurance procedures to obtain replacement item(s).

10. Utilizing an appropriate lifting means, at a minimum of two points, attach lifting eyes (1/4" diameter) and straps, then Lift the Impact Limiter Assembly into position and install the four pins and clips necessary to retain the impact limiter

11. Complete and affix an "EMPTY" label on opposite sides of the BU650B. Affix the proper UN number and cover any inappropriate markings in accordance with 49 CFR 173.428.

12. Review BU650B loading/closure documentation for completeness.

13. Prepare Routine Determinations Quality Assurance form, Shipping Document and Bill of Lading in accordance with 49 CFR 173.428.

14. Utilizing a 15,000 lb capacity forklift, transfer the empty BU650B to the conveyance for transport to the consignee.

15. Ensure carrier properly blocks, braces or restrains the BU650B as necessary to prevent movement during transport.

16. Provide consignee copies of the BU650B Certificate of Conformance, Drawings, and procedures for opening, unloading, and shipping a loaded or unloaded BU650B as appropriate.

17. Release carrier.

7.4 Other Operations

7.4.1 Notifications and Security Measures.

JLS&A Quality Assurance, Security Measures, and Operational Instructions identify required notifications to be made when transporting radioactive materials in packages. These instructions, while considered "safeguarded" provide for protection of the shipment during loading, transit, and unloading at destinations. Information necessary to evidence support of these activities is contained within records relative to each category. Documented records are retained for three years from last date of package use.

7.5 Appendix

None.

Section 8

Acceptance Tests and Maintenance Programs

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Abbreviations Used

JLS&A	J.L. Shepherd & Associates
QA	Quality Assurance
QAPP	Quality Assurance Program Plan
NDT	Non-Destructive Testing
kg	Kilogram
lbs	Pounds
mR/hr	milli-Roentgen/hr. Unit of radioactive output measurement

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAMS

This section of the application describes the acceptance tests and maintenance program intended to be used for the BU650B, prior to first use of the package, in compliance with Subpart G of 10 CFR Part 71 and the J.L. Shepherd & Associates Quality Assurance Program Plan [8.1].

8.1 Acceptance Tests

This paragraph describes in detail the tests to be performed before the first use of each packaging. Each test and its acceptance criteria are identified and described. The initial acceptance tests will confirm that each packaging is fabricated as approved.

8.1.1 Visual Inspections and Measurements

The procurement of parts, components, goods, and services necessary to begin fabrication of the BU650B is controlled by the JLS&A Quality Assurance Program. Prior to issuance of purchase orders to support package fabrication, procurement of parts, components, goods, or services, potential vendors are qualified in accordance with the relevant JLS&A QA Procedures. Qualification of vendors may require audit of the potential vendor's QA Program prior to approval. Once approved, vendors are monitored to ensure compliance with purchase requirements.

All BU650B parts, components, goods and services are controlled by the JLS&A QA program to ensure that items ordered are in accordance with engineering approved bills of materials and meet the specifications of performance prescribed on drawings. All certificates of conformance, test results, vendor certifications are verified in accordance with receiving inspection instructions found within the JLS&A QA Program. Additionally, all ordered goods, parts, and components visually inspected to ensure compliance to drawings. Non-conforming items are segregated and returned to vendors or otherwise processed in accordance with specific JLS&A QA instructions.

As BU650B parts, components, goods and services are received, each is identified, visually inspected to drawing specification(s) and controlled to ensure integrity of the item (no comingling with unapproved items) and that only approved items are installed onto the BU650B.

As each major sub-assembly of the BU650B (excluding Shielded Liner, Sealed Sources, and shoring) is fabricated, there are hold points established in the Manufacturing Operations, Assembly and Inspection

Record Instructions identified in Section 2.12 which specify the type of inspection necessary before continuation of the fabrication process related to the specific item or sub-assembly. Criteria for acceptance is clearly identified within these documents. Also contained within these instructions are instructions for processing non-conforming items and re-work deemed necessary. All documents are clearly identified as unique to the BU650B package and are controlled by document control process to ensure only the most recent instructions for procurement, fabrication, and inspection are issued to organizations or operators performing work on the package. All documents require release to organizations or operators by Quality Assurance in order to ensure integrity of processes.

Inspections required for use of the package are detailed in Section 7.

8.1.2 Weld Examinations

This section will address how the evaluation of welds occurs within the BU650B manufacturing process. Sealed Sources are evaluated separately in accordance with the criteria found in 49 CFR 173.469. In conjunction with Manufacturing Operations, Assembly and Inspection Record Instructions and drawings, appropriate instructions are provided for the types, dimensions, and quality of welds to be made during fabrication of the BU650B. Included in these instructions is information relating to the type of weld inspection to be performed on each individual weld and the remedial action to take in the event a weld does not meet specified criteria. Non-Destructive Testing (NDT) is performed in accordance with the JLS&A QA Program, following the NDT kit manufacturer's instructions, if appropriate to the type of NDT used.

As a minimum, all package welds shall be examined to the requirements specified in drawings found in Section 1.3.2. Nonconforming welds shall be reworked or rejected in accordance with manufacturing Assembly and Inspection Record Instructions. Nonconforming conditions require specific identification as such and result in segregation of the involved component, part, or sub-assembly until resolved by JLS&A Engineering Personnel.

There are no brazed joints within the BU650B package.

8.1.3 Structural and Pressure Tests

The BU650B package does not have any seals or structural appliances that require testing or operational tests. Therefore these tests are not required or addressed in operating or maintaining the BU650B package. Prior to use visible welds and mating surfaces are inspected for damage,

cracks, pin holes or defects which may cause a reduction in the effectiveness of the package assembly.

8.1.4 Leakage Tests

The BU650B does not have a primary containment boundary. Secondary and tertiary containment boundaries are not sealed and do not require leakage tests. The primary containment feature is the radioactive sealed source which is fabricated and inspected in accordance with 49 CFR 173.469 and 10 CFR 71.75. Periodic leakage tests of sealed sources are performed by licensees as a condition of their authorization to possess the sealed source. Prior to loading, these leakage tests are reviewed or verified, as appropriate. Typically these periodic inspections are performed at six month intervals. Information relative to the validity of current leakage tests is recorded on JLS&A Shipping Documents and becomes a permanent package record item.

8.1.5 Component and Material Tests

This section will identify the appropriate tests and acceptance criteria for the principal package components that affect package performance. Those principal components are: The Lower Package Assembly, Lid Assembly, Impact Limiter, Shielded Liner(s), and Radioactive Sealed Source(s).

8.1.5.1 Package Weight

The packaging, when complete, shall be weighed to determine that it does not exceed 5,682 kg. Nonconforming packages shall be reworked or rejected.

8.1.5.2 Shielded Liners

Shielded Liners are verified in accordance with drawings and/or Assembly Operations and Inspection Record Instructions specific to the type of Shielded Liner required to transport the sealed source(s). All shielded liners are to be manufactured from a minimum of ¼" carbon steel plate, lead (held in fully welded containment); or tungsten shielding, and a cavity core with minimum 1/8" carbon steel wall, shielded plug at cavity top and bottom, and a bolted closure having a minimum number of bolts/washers or studs/nuts with washers as defined in Table 5-1. All features of Shielded Liners are verified prior to use within the BU650B package. Radiological evaluations are performed prior to

and upon completion of loading of the Shielded Liner with radioactive sealed sources.

Shielded Liners are inspected prior to use, checked for removable and/or fixed contamination, and then inspected for radiological emission as a condition of use. Radiation levels emitted from Liners are checked to determine that they are not in excess of 200 mR/hr from the surface of the loaded Shielded Liner and at one meter from the BU650B exterior do not exceed 10 mR/hr. Any measurement of radiation in excess of the above will require additional determinations for possible "Exclusive Use" shipment. If levels exceed those authorized for "Exclusive Use" then the Shielded Liner will be rejected. Shielded Liners are visually inspected for weld integrity, bolt closure, and overall condition prior to placement into the BU650B package. Information is recorded on Shipping Documents identified in Section 7.5.

Raw materials, components, parts, goods or services procured for fabrication, maintenance or repair of Shielded Liners are obtained from approved vendors as identified in Section 8.1.1.

Records supporting Shielded Liners are maintained in accordance with the JLS&A QA program for a period of three years beyond the date of last use of the Shielded Liner.

8.1.5.3 Impact Limiter Foam and Impact Limiter Assembly

Each batch of Impact Limiter foam shall be tested for the following attributes prior to pour into Impact Limiter shell bodies:

- Average density
- Static crush strength
- Flame retardancy
- Intumescence

Foam not meeting the acceptance criteria specified in J.L. Shepherd & Associates Engineering Specification ES-002 shall be rejected. Once poured, the Impact Limiter is sealed by weld. Further inspection of the foam component is not possible without damage to the stainless steel wall of the Impact Limiter.

Procurement of Impact Limiter parts, components, services, materials and hardware is governed by the JLS&A QA Program. All components and services used to fabricate an Impact Limiter

assembly are included within the JLS&A QA Program. As Impact Limiter assemblies are fabricated, the materials of construction are verified in accordance with the JLS&A QA Program and instructions contained in Manufacturing Operations Assembly and Inspection Records relative to each serialized BU650B Impact Limiter Set. Impact Limiter components and subassemblies are visually inspected prior to fabrication, and once complete, prior to each package use to ensure the integrity and performance of the impact limiter. Damage resulting in punctures in excess of 6" deep, large deformations (depressions of 4" or more), or tears in the sheet metal surfaces of the Impact Limiter shell result in rejection of the Impact Limiter.

8.1.5.4 Lid Assembly

The BU650B Lid Assembly is fabricated from grade 304 stainless steel plate which is procured from approved vendors in accordance with the JLS&A QA Program. Drawing BU650B-LA is used to determine the specific material, manufacturing processes, welding methods, welding inspections, dimensional inspections, and acceptance criteria important to the proper form, fit, and function of the Lid Assembly. These items are further defined in JLS&A Manufacturing Operations and Assembly Instructions relative to the Lid Assembly and can be found at Section 8.3.2.

Lid Assembly component items, sub-assemblies, or processes not meeting defined acceptance criteria are segregated from acceptable product, identified as unacceptable, and processed in accordance with JLS&A QA Procedures governing nonconforming conditions.

All documents relative to Lid Assembly procurement, inspection, tests, maintenance and use are maintained as permanent JLS&A QA records and remain available until 3 years beyond the date of last use of the BU650B package.

8.1.5.5 Lower Package Assembly

The BU650B Lower Package Assembly is fabricated from grade 304 stainless steel plate and Kaolite 1600 which are procured from approved vendors in accordance with the JLS&A QA Program. Drawing BU650B-LP is used to determine the specific material, manufacturing processes, welding methods, welding inspections, dimensional inspections, and acceptance criteria important to the

proper form, fit, and function of the Lower Package Assembly. These items are further defined in JLS&A Manufacturing Operations and Assembly Instructions relative to the Lid Assembly and can be found at Section 8.3.2.

Lower Package Assembly component items, sub-assemblies, or processes not meeting defined acceptance criteria are segregated from acceptable product, identified as unacceptable, and processed in accordance with JLS&A QA Procedures governing nonconforming conditions.

All documents relative to Lower Package Assembly procurement, inspection, tests, maintenance and use are maintained as permanent JLS&A QA records and remain available until 3 years beyond the date of last use of the BU650B package.

8.1.5.6 Kaolite 1600

Kaolite 1600 is a thermal barrier material that is found within the annular space of the BU650B Inner and Outer Shell walls, and the bottom of the Lower Package Assembly. Kaolite 1600 is also included in the 4" space at the bottom of the Lid Assembly.

The product is a castable, concrete-vermiculite slurry that is poured or gunned in accordance with the manufacturer's instructions by manufacturer-licensed organizations. Those organizations licensed to dispense Kaolite 1600 must pass the product manufacturer's QA requirements. Vendors selected to provide the Kaolite 1600 product to JLS&A will be audited for conformance to manufacturer installation instructions as well as for general Quality Assurance criteria in accordance with JLS&A QA requirements.

Once tested and found acceptable to manufacturer specifications, the Kaolite 1600 is a permanent component of the BU650B and does not require replacement over the normal operating life of the package. The thermal barrier capabilities of the Kaolite 1600 remain effective to 1" of thickness.

8.1.6 Shielding Tests

Section 8.1.5 discusses the tests to be taken for verification of shielding. The tests and assessments made are generally performed upon loading of the Shielded Liner which is governed by the facility radiation safety program.

8.1.7 Thermal Tests

Section 8.1.5.3 discusses the material tests for the Impact Limiter foam and Section 8.1.5.6 discusses the material tests for the Kaolite 1600. The material tests provide assurance that the material will perform under NCT and HAC conditions.

Because of the package's low heat load (450 watts or less) and the large design margins on allowable material temperatures, no additional thermal tests are deemed necessary.

8.1.8 Miscellaneous Tests

There are no miscellaneous tests beyond those identified of package components necessary as a condition of operation, maintenance, or repair of the BU650B.

8.2 Maintenance Program

The BU650B package is designed and manufactured in order to reduce the need for maintenance cycles and simplify the maintenance process. There are no valves or other attachments to the package that will wear or fatigue to the point of failure. Welds are generally visible and can be inspected with routine use. Those welds (4) that are not visible can be inspected by process performed annually as described in paragraph 8.2.5.

8.2.1 Structural and Pressure Tests

There are no structural tests required for use of maintenance of the package. Visual inspections of package features are conducted prior to use and at least annually. There are no pressure tests required as the package is designed for transport of sealed sources in special form which are leak tested under requirements contained in 49 CFR 173.469 and 10 CFR 71.75.

8.2.2 Leakage Tests

The BU650B does not use a sealing mechanism. Containment is achieved through the use of sealed sources in special form described above. Therefore, operational leakage tests are not considered or addressed.

8.2.3 Component and Material Tests

Other than component procurement certifications and initial acceptance tests, the BU650B package does not have any component or part required to be replaced during its anticipated 20 year life-cycle. There is no process that can be accomplished using the packaging that would deteriorate the integrity of the package, unless the package was subjected to accident necessitating major repair. Loss of a component part, such as a BU650B closure bolt, necessitates replacement of that part as it is identified on the particular bill of materials and is controlled by the licensee's quality assurance program.

8.2.4 Thermal Tests

The BU650B has no requirement for ensuring heat transfer capability, beyond that of natural convection addressed in Section 3.0. Therefore this section is not addressed.

8.2.5 Miscellaneous Test

Annually, the package is visually and mechanically inspected to ensure continued viability. Inspections include a pressure test to verify the continued integrity of the welds used to attach the inner liner bottom to the Inner Shell wall. Instructions for that pressure test are attached at Appendix 8.3.

8.2.5.1 Post repair.

JLS&A Quality Assurance Procedures identify specific steps to be taken in obtaining repair instructions and the tests and/or inspections necessary to assure integrity of the repair condition. These instructions take into consideration the effect of repairs upon related package components/systems and ensure the continued viability of all package components/systems as well as continued package compliance with the design approval.

8.2.5.2 Annual Inspection

At the first anniversary of the issuance of the Certificate of Conformance and each year thereafter, each package shall undergo a visual and mechanical inspection to insure the continued viability and operational integrity of the package. Annual inspections shall include an internal pressure test in order to verify the continued integrity of non-vislble welds made during package

fabrication. Upon satisfactory completion of annual inspections the Quality Assurance activity will issue a Certificate of Inspection which reflects the package continues to meet the conditions of the Certificate of Compliance as issued.

8.3 Appendix

8.3.1 References

[8.1] J.L. Shepherd & Associates Quality Assurance Program Plan, number 71-0122.

8.3.2 Work Instructions.

Manufacturing Operations, Assembly, and Inspections Instructions, BU650B Radioactive Materials Transport Package.

NRC FORM 311
(5-2000)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

QUALITY ASSURANCE PROGRAM APPROVAL
FOR RADIOACTIVE MATERIAL PACKAGES

1. APPROVAL NUMBER: 0122
REVISION NUMBER: 9

Pursuant to the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and Title 10, Code of Federal Regulations, Chapter 1, Part 71, and in reliance on statements and representations heretofore made in Item 5 by the organization named in Item 2, the Quality Assurance Program identified in Item 5 is hereby approved. This approval is issued to satisfy the requirements of Section 71.101 of 10 CFR Part 71. This approval is subject to all applicable rules, regulations, and orders of the Nuclear Regulatory Commission now or hereafter in effect and to any conditions specified below.

2. NAME: ~~J.L. Shepherd & Associates~~
STREET ADDRESS: 1010 Arroyo Ave.
CITY: San Fernando
STATE: CA
ZIP CODE: 91340-1822

3. EXPIRATION DATE: November 30, 2016

4. DOCKET NUMBER: 71-0122

5. QUALITY ASSURANCE PROGRAM APPLICATION DATE(S)
September 4, 2001, September 13, 2001 and October 23, 2006

6. CONDITIONS

1. Activities authorized by this approval: procurement, maintenance, repair, and use are to be executed with regard to transportation packagings. All other activities (i.e., design, fabrication, assembly, testing, and modification) shall be satisfied by obtaining certifications from packaging suppliers that these activities were conducted in accordance with an NRC-approved Quality Assurance Program. It shall remain the responsibility of the Quality Assurance Program holder that all transportation activities meet the requirements of 10 CFR 71.101.

2. Records shall be maintained in accordance with the provisions of 10 CFR Part 71. Specifically:

   a. Records of each shipment of licensed material shall be maintained for 3 years after that shipment [10 CFR 71.91(a)].

   b. Records providing evidence of packaging quality shall be maintained for 3 years after the life of the packaging [10 CFR 71.91(d)].

   c. Records describing activities affecting packaging quality shall be maintained for 3 years after this Quality Assurance Program Approval is terminated [10 CFR 71.135].

3. Planned and periodic audits of all aspects of the Quality Assurance Program shall be conducted in accordance with written procedures or checklists, by appropriately trained personnel not having direct responsibility in the areas being audited, in accordance with 10 CFR 71.137.

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

SIGNATURE: [signature]

DATE: 22 Dec 2006

ROBERT LEWIS, CHIEF
RULES, INSPECTIONS AND OPERATIONS BRANCH
DIVISION OF SPENT FUEL STORAGE AND TRANSPORTATION
OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS

1.0 QUALITY ASSURANCE ORGANIZATION.

1.1 Regulatory Reference.

71.103 Quality Assurance Organization.

The J.L. Shepherd & Associates (hereinafter referred to as JLS&A) quality assurance organization is formulated in accordance with the requirements found in paragraphs (a) through (f) of 10CFR71, Subpart H. JLS&A is a small business and the functional quality assurance elements (persons or organizations) of the quality program are structured in accordance with the provisions of 10CFR71.103(e), which provides for variables in program implementation, provided that these persons or organizations are assigned and have the required authority, responsibility and organizational freedom, irrespective of organizational structure, with direct access to management. The authority, responsibilities and duties of those persons or organizations that perform important to safety related activities, including but not limited to either performing activities associated with accomplishing quality missions or performance of quality assurance functions, are clearly established and depicted in appropriate work instructions. JLS&A's quality assurance organization, in conjunction with management staff, is responsible for the execution, effective implementation and verification of this quality assurance program. JLS&A's quality organization, including management members, has been provided with the appropriate training, authority and freedom to identify problems, to initiate, suggest or provide solutions, and to verify the implementation of solutions.

JLS&A's QAPP implementing procedures establish criteria to specify that adequate, continued and verifiable quality control is maintained over the quality missions contained in this program.

1.2 Statement of Responsibility

JLS&A implements a graded approach to the applicable important to safety quality control aspects of this Quality Assurance Program, for the design, testing, manufacture, procurement, use maintenance and repair of Type B quantity radioactive materials packages, for its own use, the use of other 10CFRPart 71 Program Licensees, and for licensed packages owned by others.

It is the corporate policy of JLS&A that the company perform any applicable important to safety activities on Type B packages in accordance with applicable requirements of 10CFR71, Subpart H, as described in this Quality Assurance Program Plan (QAPP), the Quality Assurance Manual (QAM) and related implementing procedures (QP's). A written policy statement signed by the President has been established and is contained in the top level series of administrative procedures of the QAPP. The Quality Assurance Policy Statement addresses major program elements such as authorities, responsibilities, commitment to resources, equipment, training and qualifications of quality personnel.

1.0 Quality Assurance Organization, continued.

1.2 Statement of Responsibility, continued.

The management of JLS&A not only endorses the Quality Assurance Program, but also maintains oversight, performs specific assigned QA/QC responsibilities, as they also have the required authority, responsibility and organizational freedom, irrespective of organizational structure, with direct access to other management members, and are responsible for the continued commitment to and implementation of this Quality Assurance Program.

1.3 Structure and Authority

JLS&A maintains a formally established functional organizational arrangement, depicted in Section 1.6 of this QAPP, which ensures that:

The assignment and responsibility for the execution of specified QA/QC areas are performed by appropriately qualified and trained personnel, who have sufficient and written authority, responsibility and organizational freedom to identify problems, stop work, suggest or provide corrections, and to verify corrections, by various procedures such as inspections, checks or audits.

The assignment of the overall authority and responsibility for the QA/QC Program is delegated to the QA/QC Manager/Administrator, who is appropriately qualified and trained, and has sufficient, written authority, responsibility and organizational freedom to verify conformance in the execution of the QAPP.

QA/QC personnel have direct access to the QA/QC Manager/Administrator and to JLS&A upper management.

Conformance or verification to requirements is verified by individuals not directly performing the work.

QA/QC functions relative to verifying that quality requirements are being implemented and maintained are controlled using established procedures and instructions by only those individuals who have been authorized by the Quality Assurance Department.

All personnel involved with QA/QC have the authority and responsibility, in writing, to stop at any time the further processing of any nonconforming material, work, shipment or delivery, with direct recourse to upper management. This authority and responsibility is internally documented through written procedures, and extends to effectivity of corrective actions and implementation of corrective action processes.

The JLS&A Organizational Chart, found within this plan, clearly defines Quality Assurance function.

1. Quality Assurance Organization, continued.

1.3 Structure and Authority, continued.

Abridged management responsibilities and authorities are as follows:

President and Chief Executive Officer. Chief Executive Officer, having ultimate responsibility for the success or failure of the organization. Has responsibility for the supervision of QA/QC department management, and overall responsibility for implementation of the Quality Assurance Program. Supervision and final decision maker (in case of impasse) for the final approval for resuming or correcting any item or procedure which has been stopped by QA/QC personnel. Determination of and reporting of 10CFR21 and 71 defects or nonconformances. Serves as a member of the Engineering Committee.

QA/QC Program Manager/Administrator. Reports to President. Provides overall responsibility and authority for the oversight, continued implementation and verification for all eighteen areas of the quality assurance program, including reviews and evaluations of QA/QC document control and record keeping as performed by various departments, as applicable. Is an observer of the Engineering Committee.

Vice President & General Manager. (Provisional – May be filled at discretion of management). Reports to the President on areas of operational importance. General Manager is responsible for overall management activities of the organization to include, research and development, engineering, finance, operations, sales and service. Has the direct supervision of Vice President Business Development and Vice President Operations, with the responsibility and authority to act on the President's behalf, either when delegated or during absence or unavailability. If unfilled, then responsibilities are assumed by the President and/or Vice President(s). Is a member of the Engineering Committee.

Vice President, Special Projects & Business Development. Has the responsibility for supervision of sales and serviced activities as well as Radiological Safety Program for the organization. Works with the Vice President Operations in providing senior management personnel with recommendations for compliance with regulatory issues. Maintains responsibility for implementation of Quality Assurance Program Plan within areas of operation, as directed by the President and/or General Manager. Is a member of the Engineering Committee.

Vice President, Electronics & Operations. Has responsibility for supervision of Engineering and Shop Operations activities. Works with Vice President, Business Development and senior management personnel on matters of regulatory compliance. Maintains responsibility for implementation of Quality Assurance Program Plan within areas of responsibility, as directed by the President, and/or General Manager. Chairs Engineering Committee in absence of staff engineer.

Engineer. Reports to Vice President, Operations. Responsible for the supervision of all engineering functions, from initial calculations and prototype testing for package approvals, approval of engineering drawing and procurement packages prior to release for fabrication, including but not limited to vendor selection and qualification, vendor QA/QC programs, drawing or procurement document revisions and/or change control and instructions or procedures and engineering document control and record

1.0 Quality Assurance Organization, continued.

1.3 Structure and Authority, continued.

keeping as applicable. Functions may be performed by an Engineering Committee and designated members, when position is unfilled.

Production/Operations Manager. Reports to Vice President, Operations, responsible for the supervision of all phases of product manufacturing and submittals to QA/QC for inspection processes, procurement of outside materials, stock withdrawals, instructions, procedures and drawing distribution and allocation, review of bills of materials, job package preparation, production scheduling and material rejection determination and segregation. Supervision of the maintenance, handling, storage, repair and preparation of packages for shipment in conjunction with radiological department, production and purchasing document control, and record keeping as applicable.

Procurement Specialist. Responsible for writing and placing purchase orders to qualified vendors in conformance with specifications as called out in the procurement documents, contacting vendors regarding rejected items and their return, checking that proper certifications accompany the shipment and follow-up on late deliveries as needed. In concert with production/operations, maintains procurement documents as applicable.

Radiological Safety Control / Radiation Safety Officer. Responsible for the supervision of health physics aspects of final inspections, involving verification and release of transportation packages relative to DOT and NRC shipment compliance with contamination control for packages as required by 10CFR71.87, the applicable DOT and Agreement State requirements and industry practice. Responsibilities include oversight of radiological QA/QC implementing documents such as package shipment, required radiological documentation and record keeping, as applicable. Is a member of the Engineering Committee.

The following are JLS&A QA/QC implementing documents concerning JLS&A's quality organization:

The organizational chart, which identifies QA/QC departments, personnel, positions, and functional infrastructure within the company.

Job Descriptions which detail QA/QC personnel functions and responsibilities.

Training and qualification criteria for each QA/QC position are identified to demonstrate competence.

1.0 Quality Assurance Organization, continued.

1.4 QA/QC Position Qualifications.

JLS&A maintains a formally established in-house training program for all new employees and employees assuming additional responsibilities.

All employees receive an overview of the administration of the QA/QC Program. A more in-depth QA/QC orientation is provided to those personnel assigned to quality assurance/quality control overview activities, commensurate with their levels of responsibility.

QA/QC employee training includes specific instructions, training and review of pertinent sections of the QA/QC Program and how the employee functions under the manager within the QA/QC program.

Audit personnel qualifications, including the QA/QC Program Administrator, principal QA/QC management positions, designated lead auditors and inspectors, are applied to and are commensurate with the applicable auditor qualification criteria of ANSI/ASME NQA-1-1989 "Quality Assurance Program Requirements for Nuclear Facilities". Basic Requirement 2 will be used as the primary qualification for audit personnel, with the incorporation of Supplement 2S-3. "Supplementary Requirements for the Qualification of Quality Assurance Program Audit Personnel", is used as a formulation guideline. Lead auditors and auditing personnel are qualified in accordance with formally established and approved procedures.

In addition to ANSI/ASME qualification, the QA/QC Program Manager/Administrator experience qualifications are to include five (5) years (minimum) working with ISO 9000, ISO 9001, ANSI, ASME, SAE, military or aerospace quality assurance programs in a management capacity.

Applicable qualification and training records are maintained as necessary. Training methodology, minimum experience requirements and certification protocols are established consistent with recognized industry guidance and standards for comparable positions. Proficiency re-evaluations are performed and documented, when applicable renewal of qualification measures are implemented.

JLS&A reserves the right to use appropriate QA/QC management discretion in determining the qualifications of audit personnel, using a combination of technical, educational, and experience factors specific to the type of audit to be performed, if and when situations arise where an auditor candidate may not definitively meet the qualification criteria specified in the applicable ANSI qualification criteria set forth in this section of the QAPP. Formally documented provisions will address these special circumstances, if a potential candidate does not specifically meet specification criteria, as written.

Areas of assigned responsibilities and authority are delineated, and are agreed upon and understood at the completion of the training and qualification program.

Training is kept current, with additional training classes performed as required and appropriately documented.

1.0 Quality Assurance Organization, continued.

1.4 QA/QC Position Qualifications, continued.

In the situations where an employee is not performing adequately, they are subject to re-training and re-qualification. If this is not successful, the employee will be removed from the function or process. Employment may be terminated after the appropriate notices and legal responsibilities are fulfilled.

1.5 Statement of Verification of Resolution of Disputes.

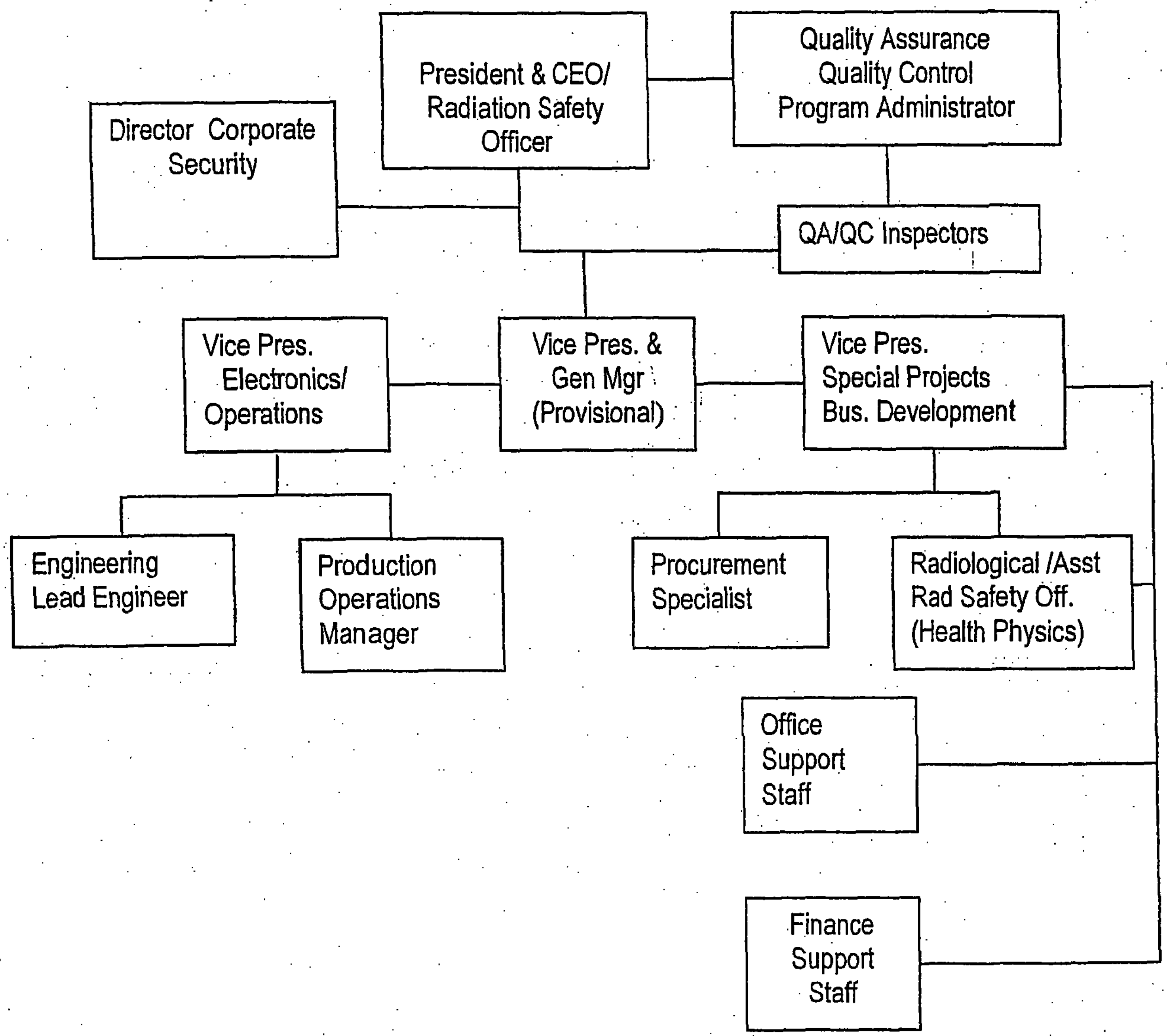
If disputes arise, either internally or by an outside entity, a review of the dispute and any applicable regulatory criteria is performed by JLS&A. Resolutions are subject to review by upper JLS&A management for final approval.

1.0 QUALITY ASSURANCE ORGANIZATION, continued.

1.6 JLS&A QA/QC Organizational Chart, representational showing functional organizational arrangement

CONDUCT OF OPERATIONS

Representational Functional Arrangement



2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM

2.1 Regulatory References for Quality Assurance Program Plan

This JLS&A Quality Assurance Program Plan (QAPP) is formulated in a graded approach in accordance with the requirements found in 10CFR71 – Packaging and Transportation of Radioactive Material, Subparts A, B, C, D, E, F, G and H, which are applicable to JLS&A Type B package quality, safety and transportation related activities.

2.2 10CFR Subpart A – General Provisions

71.0 Purpose and Scope

This Subpart establishes the requirements for the packaging, shipment preparation and transportation of Type B quantity radioactive materials and the procedures and standards for US Nuclear Regulatory Commission (NRC) approval of packaging and shipping procedures. Packaging and transport are also subject to the regulations of the U.S. Department of Transportation (DOT), U.S. Postal Service (USPS), and U.S. Coast Guard in addition to 71.0.

Provisions in Subpart A apply for JLS&A. An NRC general license is required. JLS&A is a Type B quantity radioactive materials packaging approval holder. JLS&A applications for NRC certificates of compliance for packages are to be prepared in accordance with Subpart D, which includes having an NRC approved Quality Assurance Program, to demonstrate that the package design satisfies standards found in Subpart E and test criteria found in Subpart F. For the transport or delivery to a carrier for transport, operating controls and procedure requirements are found in Subpart G, quality assurance requirements in Subpart H, general provisions of Subpart A; and DOT regulations referenced in 71.5.

JLS&A is a small business operating primarily as a discrete, made to order, manufacturer of irradiation and calibration facilities (devices) and the sealed radioactive sources contained therein. JLS&A procures or uses Type B packages manufactured by others and/or manufactures and uses Type B packages to facilitate the safe shipment of Type B quantity sealed sources in devices or for transfer into devices, which is the primary scope and focus of this Quality Assurance Program. JLS&A does not design, manufacture or contract for Type B packaging for the shipment of radioactive waste, radioactive liquids or nuclear fuel.

JLS&A was founded on January 9, 1967. Since its inception, the company mission has been to provide and ship the safest, most reliable possible gamma, beta and neutron irradiation and calibration sources and devices, and to provide the associated cradle to grave services and activities required for their safe use, relocation, or decommissioning. Concern for the radiological safety of staff, clients, and public is the fundamental basis of JLS&A's corporate policy and management's commitments and convictions.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.3 10 CFR Subpart B – Exemptions

71.12 Specific Exemptions

JLS&A may request specific transportation exemptions from the NRC.

71.13 Exemption of Physicians – not applicable for JLS&A.

71.14 Exemption for Low Level Material.

JLS&A is exempt from the requirements of this part if shipping packages of radioactive materials does not exceed 10 times the values specified in Appendix A, Table A-2 (activity concentration) for natural materials and ores, materials for which the activity concentration is not greater than the activity concentration or consignment values as found in Appendix A, Table A-2, Type A quantity radioactive materials, or special form americium or plutonium sources with an aggregate activity not exceeding 20 Curies with no fissile material or exemption standards thereof are met, in accordance with 71.5 and 71.88.

71.15 Exemption from Classification as Fissile Material.

Fissile material meeting the requirements of at least one of the paragraphs (a) through (f) of this section are exempt from classification as fissile material and from the fissile material package standards of §§ 71.55 and 71.59, but are subject to all other requirements of this part, except as noted.

(a) Individual package containing 2 grams or less fissile material.

(b) Individual or bulk packaging containing 15 grams or less of fissile material provided the package has at least 200 grams of solid non-fissile material for every gram of fissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass for solid non-fissile material.

(c)(1) Low concentrations of solid fissile material commingled with solid non-fissile material, provided that:

(i) There is at least 2000 grams of solid non-fissile material for every gram of fissile material, and

(ii) There is no more than 180 grams of fissile material distributed within 360 kg of contiguous non-fissile material.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.3 10 CFR Subpart B – Exemptions (continued)

(2) Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass of solid non-fissile material.

(d) Uranium enriched in uranium-235 to a maximum of 1 percent by weight, and with total plutonium and uranium-233 content of up to 1 percent of the mass of uranium-235, provided that the mass of any beryllium, graphite, and hydrogenous material enriched in deuterium constitutes less than 5 percent of the uranium mass.

(e) Liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2 percent by mass, with a total plutonium and uranium-233 content not exceeding 0.002 percent of the mass of uranium, and with a minimum nitrogen to uranium atomic ratio (N/U) of 2. The material must be contained in at least a DOT Type A package.

(f) Packages containing, individually, a total plutonium mass of not more than 1000 grams, of which not more than 20 percent by mass may consist of plutonium-239, plutonium-241, or any combination of these radionuclides.

2.4 10CFR Subpart C – General Licenses

71.17 General Licenses: NRC approved package.

This subchapter is applicable to JLS&A activities for either transporting or delivering to a carrier for transport, licensed materials in NRC certificate of compliance packages, or for other approvals issued by the NRC.

- This general license is applicable for JLS&A, which maintains an NRC-approved quality assurance program, satisfying a graded approach to 10CFR71, Subpart H criteria.

- This general license is only applicable when JLS&A has the following:

  (1) Has a copy of the CoC, or other approval of the package, and has the drawings and other documents referenced in the approval relating to the use and maintenance of the packaging and to the actions to be taken before shipment;

  (2) Complies with the terms and conditions of the license, certificate, or other approval, as applicable, and the applicable requirements of subparts A, G, and H of this part; and

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.4 10CFR Subpart C – General Licenses, continued.

(3) Before the licensee's first use of the package, submits in writing to: ATTN: Document Control Desk, Director, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, using an appropriate method listed in § 71.1(a), the licensee's name and license number and the package identification number specified in the package approval.

(4) This general license applies only when the package approval authorizes use of the package under this general license.

(5) For a Type B or fissile material package, the design of which was approved by NRC before April 1, 1996, the general license is subject to the additional restrictions of § 71.19.

71.19 Previously Approved Type B Package.

JLS&A can use previously NRC approved Type B packages without a B(U) or B(M) designation with limitations as follows, until October 1, 2008:

Per paragraph a). Fabrication must have been completed before August 31, 1986, as demonstrated by application of its model number in accordance with 71.85.

A serial number that uniquely identifies each package which conforms to the approved design is assigned to, and legibly and durably marked on, the outside of each package.

Per paragraph b). For packages not designated as "-85", fabrication must have been completed by April 1, 1999, as demonstrated by application of its model number in accordance with 71.85.

A serial number that uniquely identifies each package which conforms to the approved design is assigned to, and legibly and durably marked on, the outside of each package.

The package cannot be used outside the US without obtaining a DOT multilateral approval as defined in 49CFR173.403.

Per paragraph c). For packages bearing the designation "-85" fabrication must have been completed by December 31, 2006, as demonstrated by application of its model number in accordance with 71.85.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.4 10CFR Subpart C – General Licenses, continued.

A serial number that uniquely identifies each package which conforms to the approved design is assigned to, and legibly and durably marked on, the outside of each package.

The package cannot be used outside the US without obtaining a DOT multilateral approval as defined in 49CFR173.403.

JLS&A must submit modification plans for these packages to the NRC for approval and identification number revision or changes must not be significant to the design, operation, or safety when the package is tested per 71.71 and 71.73.

71.20 General License: DOT Specification Container.

JLS&A either transports, or delivers to a carrier for transport, licensed material for Type B quantity radioactive material packages as specified by the DOT in 49 CFR173 and 178.

This general license is applicable for JLS&A which maintains an NRC approved quality assurance program, satisfying a graded approach to 10CFR71, Subpart H criteria.

This general license is only applicable when JLS&A has the following:

Has a copy of the specification;

complies with the terms and conditions of the specification;

complies with the applicable requirements of 10CFR71, Subparts A, G, and H;

the package cannot be used outside the US without obtaining a DOT special arrangement per 49CFR173.471 or 49CFR173.403, as appropriate.

This provision expires October 1, 2008, unless a DOT exemption or special permit is granted for continued use.

71.21 General License: Use of Foreign-Approved Package.

JLS&A either transports or delivers to carriers for transport licensed material in packages approved by certificate by foreign national competent authorities with DOT re-validation.

JLS&A uses these packages solely for transport made to or from locations outside the US.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.4 10CFR Subpart C – General Licenses, continued.

This general license is applicable for JLS&A when:

A copy of the specific license, certificate of compliance and revalidation or other package approval, with the drawings and other documents referenced in these documents relating to maintenance and use and actions to be taken prior to shipment compliance with the terms and conditions of these documents, and with the applicable requirements of 10CFR71 Subparts A, G, and H, with quality assurance program exemptions from design, construction and fabrication considerations.

71.22 General license: Fissile material.

A general license is issued to any licensee of the Commission to transport fissile material, or to deliver fissile material to a carrier for transport, if the material is shipped in accordance with this section. The fissile material need not be contained in a package which meets the standards of subparts E and F of this part; however, the material must be contained in a Type A package and contains no more than a Type A quantity of radioactive material. The Type A package must also meet the DOT requirements of 49 CFR 173.417(a). At present, JLS&A does not package, ship, or receive fissile materials in excess of those quantities identified in Table 71-2, Mass Limits for General License Packages Containing Uranium-235 of Known Enrichment per § 71.22(e).

71.23 General license: Plutonium-beryllium special form material.

A general license is issued to any licensee of the Commission to transport fissile material in the form of plutonium-beryllium (Pu-Be) special form sealed sources, or to deliver Pu-Be sealed sources to a carrier for transport, if the material is shipped in accordance with this section. This material need not be contained in a package which meets the standards of subparts E and F of this part; however, the material must be contained in a Type A package, contains no more than a Type A quantity of radioactive material and contains less than 1000 g of plutonium, provided that Pu-239, Pu-241 or and combination of these radionuclides constitutes less than 240 g of the total quantity of plutonium on the package. The Type A package must also meet the DOT requirements of 49 CFR 173.417(a). For shipment of multiple packages, the sum of CSIs must be less than or equal to 50 (for shipment on a nonexclusive use conveyance) and less than or equal to 100 CSIs (for shipment on an exclusive use conveyance). JLS&A is a shipper of Pu-Be in licensed quantities permitted by this section.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.5 10CFR Subpart D – Application for Package Approval.

71.31 Contents of Application

JLS&A's quality assurance program description per 10CFR71.37 must be submitted as part of the application, and design, planning, and execution of such packages will fall under Subpart D criteria.

71.33 Package description.

The application must include a description of the proposed package in sufficient detail to identify the package accurately and provide a sufficient basis for evaluation of the package. At a minimum package description must include all information as called out in (1) through (8) of this paragraph. JLS&A's Quality Assurance Program and related Quality Assurance Procedures provide detailed instructions for package description requirements.

71.35 Package evaluation.

JLS&A's Quality Assurance Program and related Quality Assurance Procedures provide adequate instructions for inclusion of package evaluation criteria in any package certificate application. Specifically, instructions include the following:

(a) A demonstration that the package satisfies the standards specified in subparts E and F of this part;

(b) For a fissile material package, the allowable number of packages that may be transported in the same vehicle in accordance with § 71.59; and

(c) For a fissile material shipment, any proposed special controls and precautions for transport, loading, unloading, and handling and any proposed special controls in case of an accident or delay.

Note: JLS&A does not package, load, unload or handle fissile materials as part of normal business operations.

71.37 Quality Assurance.

JLS&A's quality assurance program, per 10CFR71, Subpart H, will describe the design, fabrication, assembly, testing, maintenance and use of proposed packages, including identification of applicable standards and codes or specific quality assurance provisions.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.5 10CFR Subpart D – Application for Package Approval, continued.

Applicable standards for packages may be found in 10CFR71, Subpart E, and prototype testing criteria are found in 10CFR71, Subpart F.

71.38 Renewal of a certificate of compliance or quality assurance program approval.

(a) JLS&A shall apply for renewal of any Certificate of Compliance or Quality Assurance Program in accordance with this paragraph. Each Certificate of Compliance or Quality Assurance Program Approval expires at the end of the day, in the month and year stated in the approval.

(b) In any case in which a person, not less than 30 days before the expiration of an existing Certificate of Compliance or Quality Assurance Program Approval issued pursuant to the part, has filed an application in proper form for renewal of either of those approvals, the existing Certificate of Compliance or Quality Assurance Program Approval for which the renewal application was filed shall not be deemed to have expired until final action on the application for renewal has been taken by the Commission.

(c) In applying for renewal of an existing Certificate of Compliance or Quality Assurance Program Approval, an applicant may be required to submit a consolidated application that incorporates all changes to its program that, are incorporated by reference in the existing approval or certificate, into as few referenced documents as reasonably achievable.

71.39 Requirement for additional information.

The Commission may at any time require additional information in order to enable it to determine whether a license, certificate of compliance, or other approval should be granted, renewed, denied, modified, suspended, or revoked. Such requests will be formally addressed by the JLS&A Quality Assurance Program with appropriate document controls applied.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.6 Subpart G – Operating Controls and Procedures.

71.81 Applicability of Operating Controls and Procedures.

JLS&A is bound by this Sub-Chapter as a general licensee, by either transporting or delivering to a carrier for transport, licensed materials in NRC certificate of compliance packages and is required to comply with the quality assurance requirements of 10CFR71, Subpart H, and general provisions of Subpart A.

71.83 Assumptions As To Unknown Properties.

Not applicable. JLS&A does not ship fissile materials.

71.85 Preliminary Determinations.

As part of the Subpart H Quality Assurance Program, JLS&A shall determine prior to the first use of any package that there are no defects which could significantly reduce the effectiveness of the package, the maximum normal operating pressure requirements (if applicable), that the package has been manufactured in conformance with the design approved by the NRC before appropriately marking the package in a conspicuous and durable manner; i.e., model number, serial number, gross weight, and package identification number.

71.87 Routine Determinations.

As part of the Subpart H Quality Assurance Program, JLS&A determines prior to each Type B radioactive materials package shipment that the following applicable criteria are satisfied:

The package is correct for the contents being shipped;

The package is in good physical condition, except for uncritical marks or dents;

The package closure, including any gaskets, is properly installed secured and free of defects (as applicable);

Any system for containing liquids is adequately sealed with provision for expansion. Normally, JLS&A does not ship liquids;

Any pressure relief valve (if installed) is operable and set in accordance with written procedures;

The package has been loaded and closed in accordance with written procedures;

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.6 Subpart G – Operating Controls, continued.

Determinations for fissile materials are not applicable for JLS&A;

Package lifting fixtures or tie downs are made inoperable for shipment unless part of package approval, unless it meets the design requirements of 71.45;

The level of removable contamination is as low as achievable and within DOT permissible levels per 49CFR173.443; and,

The package surface temperature will not exceed permissible levels per 10CFR71.43(g).

71.88 Air Transportation of Plutonium.

JLS&A will not ship plutonium by air in any form, either domestically or, import/export, unless the criteria found in paragraphs (1) through (4) is applicable.

71.89 Opening Instructions.

JLS&A will make available to the consignee, prior to transport, any special instructions needed to safely open the package, for consignees use per 10CFR20.1906(e).

71.91 Records.

JLS&A shall maintain the applicable records called out in this section for each shipment for a period of three years after the shipment.

71.93 Inspection and Tests.

JLS&A shall notify the commission 45 days in advance of beginning fabrication of the first packaging under a Certificate of Compliance in accordance with paragraph (c) of this part. Additionally, JLS&A shall permit the NRC to inspect JLS&A facilities and activities in accordance with this paragraph. Further, JLS&A shall perform, and permit the commission to perform any inspections and/or tests the commission deems necessary or appropriate for the administration of this section.

71.95 Reports.

(a) JLS&A, after requesting the certificate holder's input, shall submit a written report to the Commission of–

(1) Instances in which there is a significant reduction in the effectiveness of any NRC-approved Type B or Type AF packaging during use; or

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.6 Subpart G – Operating Controls, continued.

(2) Details of any defects with safety significance in any NRC-approved Type B or fissile material packaging, after first use.

(3) Instances in which the conditions of approval in the Certificate of Compliance were not observed in making a shipment.

(b) JLS&A shall submit a written report to the Commission of instances in which the conditions in the certificate of compliance were not followed during a shipment.

(c) JLS&A shall submit, in accordance with § 71.1, a written report required by paragraph (a) or (b) of this section within 60 days of the event or discovery of the event. JLS&A shall also provide a copy of each report submitted to the NRC to the applicable certificate holder. Written reports prepared under other regulations may be submitted to fulfill this requirement if the reports contain all the necessary information, and the appropriate distribution is made. Using an appropriate method listed in § 71.1(a), JLS&A shall report to: ATTN: Document Control Desk, Director, Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards. The reports will include the following:

(1) A brief abstract describing the major occurrences during the event, including all component or system failures that contributed to the event and significant corrective action taken or planned to prevent recurrence.

(2) A clear, specific, narrative description of the event that occurred so that knowledgeable readers conversant with the requirements of part 71, but not familiar with the design of the packaging, can understand the complete event. The narrative description will include the following specific information as appropriate for the particular event.

(i) Status of components or systems that were inoperable at the start of the event and that contributed to the event;

(ii) Dates and approximate times of occurrences;

(iii) The cause of each component or system failure or personnel error, if known;

(iv) The failure mode, mechanism, and effect of each failed component, if known;

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.6 Subpart G – Operating Controls, continued.

(v) A list of systems or secondary functions that were also affected for failures of components with multiple functions;

(vi) The method of discovery of each component or system failure or procedural error;

(vii) For each human performance-related root cause, a discussion of the cause(s) and circumstances;

(viii) The manufacturer and model number (or other identification) of each component that failed during the event; and

(ix) For events occurring during use of a packaging, the quantities and chemical and physical form(s) of the package contents.

(3) An assessment of the safety consequences and implications of the event. This assessment must include the availability of other systems or components that could have performed the same function as the components and systems that failed during the event.

(4) A description of any corrective actions planned as a result of the event, including the means employed to repair any defects, and actions taken to reduce the probability of similar events occurring in the future.

(5) Reference to any previous similar events involving the same packaging that are known to the licensee or certificate holder.

(6) The name and telephone number of a person within JLS&A's organization who is knowledgeable about the event and can provide additional information.

(7) The extent of exposure of individuals to radiation or to radioactive materials without identification of individuals by name.

(d) Report legibility. JLS&A shall provide reports of sufficient clarity and content so as to facilitate reproduction and/or microfilming.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.7 Subpart H – Quality Assurance

71.97 Advance Notification of Shipment of Nuclear Waste.

For purposes of this paragraph, JLS&A does not ship nuclear waste, as defined. In the event of a future need to ship nuclear waste, the requirements of this paragraph will be fulfilled.

71.101 Quality Assurance Requirements

This JLS&A Quality Assurance Program Plan, with implementing documents (i.e., written procedures, contained in quality assurance/quality control manuals, as approved by appropriate levels of JLS&A management), describes JLS&A's commitments to a graded approach (i.e., to an extent consistent with important to safety) quality assurance program in order to provide quality control over all important to safety activities, as applicable to the design, purchase, fabrication, handling, shipping, storage, cleaning, assembly, inspection, testing, operation, maintenance, repair and modifications of Type B radioactive materials packages.

JLS&A utilizes existing package designs and packages owned by others, per (d) and (e) of this paragraph.

JLS&A has established criterion with management reviews for distinguishing, identifying and controlling the important to safety components, structures and systems to be incorporated into the quality assurance program, and for verifying that any applicable components, structures and systems meet the design parameters. These criterion include pertinent documentation that important to safety activities are accomplished under controlled conditions using specified and applicable M&TE equipment, environmental conditions, special processes, codes standards and work instructions, and that these activities are performed by trained, qualified and knowledgeable personnel.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.8 Implementing Procedures, 71.101 – 71.137.

Implementing Document	Subject Matter	10CFR71 Subpart H Criteria 18 Pts	Description
QAM/QP 1.0	Quality Assurance Program Plan	1	Describes established procedures for JLS&A's documented QA/QC program, originally implemented in 1979, under 10CFR71, Appendix E, currently Subpart H. Status: Complete 5/9/2003
	Job Descriptions	1	Identifies individual QA/QC job functions within organization structure, responsibilities, authority and duties. Status: Complete, 5/9/2003.
QAM/QP 2.0	Organization and Staffing	2	Identifies JLS&A internal organizational structure& relationships in performance of activities affecting quality. Defines training requirements, auditor qualifications, and inspection qualification. Other organizational functions described in sub procedures. Status: Complete 5/9/2003
QAM/QP 3.0	Design Control	3	Describes established procedures for control of design process, input and verification, directly related to NRC issued "Certificate of Compliance for Radioactive Materials Package Design", and USDOT "Certificate of Competent Authority" for Type B Quantity (Specification) Packages or DOT re-validated foreign Type B packages, including standards and prototype test criteria. Other relevant design functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 4.0	Procurement Document Control	4	Describes established procedures for control of procurement document (purchase order) preparation, reviews, concurrences, and approvals, including but not limited to technical requirements, documentation, access to supplier facilities for audits, certifications and change orders. Other relevant functions described in sub procedures as necessary. Status: Complete 5/9/2003.
QAM/QP 5.0	Instructions, Procedures and Drawings	5	Describes established procedures for documented instructions, procedures, drawings, and acceptance criteria for important to safety activities. Also provides writing and style guide, definition of terms used within procedures. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 6.0	Document Control	6	Describes established procedures for document generation, issuance and changes, to include drawings and specifications, design changes, procurement documents, QA/QC manuals, inspection & test procedures, nonconformance reports, corrective action reports, and others. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.

2.8 Implementing Procedures, 71.101 – 71.137, continued.

Implementing Document	Subject Matter	10CFR71 Subpart H Criteria 18 Pts	Description
QAM/QP 7.0	Control of Purchased Materials, Parts, Components, Equipment and Services	7	Describes procedures for procurement document planning, selection of procurement sources, supplier conformance control, verification activities, controlling nonconformances, deviations, and corrective action. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003
QAM/QP 8.0	Identification of Materials, Parts, and Components	8	Describes procedures for the identification, control & conditional releases of materials, parts & components including limited shelf-life items. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 9.0	Control of Special Processes	9	Describes procedures for the control of special processes, including qualifications of procedures, equipment, personnel, operations and records. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 10.0	Inspection	10	Describes procedures for inspections, inspection records and qualification of inspection personnel. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 11.0	Test Control	11	Describes requirements, defines procedures for establishment and evaluation of test criteria, result documentation and evaluation of test activities. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 12.0	Control of Measuring and Test Equipment	12	Describes procedures for M&TE selection, calibration requirements and records. Further defines process of recall in event of significant out of tolerance condition. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 13.0	Handling, Storage, and Shipping	13	Describes procedures for handling, storage & shipping, including preservation, release and delivery in accordance with regulatory guidelines, licenses, approvals & Certificates of Competent Authorities. Other relevant functions described in sub procedures as necessary. Status: Complete 5/9/2003.
QAM/QP 14.0	Inspection, Test and Operating Status	14	Describes procedures for inspection, test and operating status. Further defines inspection process. Other relevant functions described in sub procedures as necessary. Status: Complete 5/9/2003

2.0 PURPOSE AND SCOPE OF QUALITY ASSURANCE PROGRAM, continued.
2.8 Implementing Procedures, 71.101 – 71.137, continued.

Implementing Document	Subject Matter	10CFR71 Subpart H Criteria 18 Pts	Description
QAM/QP 15.0	Control of Nonconforming Items	15	Describes established procedures for control of nonconforming materials, parts, components and services, including identification, segregation, disposition and evaluation thereof. Other relevant functions described in sub procedures as necessary. Status: Completed 5/9/2003.
QAM/QP 16.0	Corrective Action	16	Describes established procedures for implementing corrective action, including root cause analysis, inspection, monitoring and closeout. Further defines process of 10CFR21 reporting of significant safety related nonconforming items. Other relevant functions described in sub procedures as necessary Status: Completed 5/9/2003.
QAM/QP 17.0	Quality Records	17	Describes established procedure for maintenance of QA records, including design, procurement, manufacturing, installation, process evaluations, employee evaluations, nonconformance reports, inspection records, test reports, audits, analysis, as-built drawings and specifications, personnel qualifications procedures, equipment calibration procedures, training records, corrective action reports; includes record generation, indexing and classification, receipt, retrieval, disposition, storage, preservation and safekeeping thereof. Other relevant functions described in sub procedures as necessary Status: Completed 5/9/2003.
QAM/QP 18.0	Audits	18	Establishes an audit program designed to fairly evaluate effectiveness of implementation of QA/QC program and program controls. Includes guidance on scheduling, audit team structure, documentation, pre and post audit conferencing, reporting and corrective action. Other relevant functions described in sub procedures as necessary Status: Completed 5/9/2003.

3.0 DESIGN CONTROL

3.1 Regulatory Reference.

71.107 Package Design Control

JLS&A shall use applicable regulatory requirements for design control per 10CFR71, including this paragraph, Subpart D – Application for Package Approval, 71.31 through 71.39, Subpart E – Package Approval Standards, 71.41 through 71.51, Subpart F – Package and Special Form Tests, 71.21 through 71.77, and Subpart G – Operating Controls and Procedures, in a graded, important to safety approach for package designs.

JLS&A's engineering organization, in conjunction with management, quality assurance and production, is responsible for the oversight and implementation of this part of the quality assurance program. JLS&A's implementing documents establish criterion to assure that:

Applicable regulatory requirements pertinent to a package design are established, interpreted, and translated into specifications, drawings, procedures and instructions;

Measures are established regarding selection and review of the applicability and suitability for safety related functions of materials, parts, and components;

Measures are established for the identification and control of design interfaces and for coordination among design organizations, including written procedures for review, release, distribution and revision to interfaces;

Measures are established for verification or checking of design adequacy, by review, calculations, or prototype test programs which may employ use of outside agencies meeting vendor approval criteria;

Design control measures are established for other applicable safety related areas such as radiation shielding, stress, thermal limitations or considerations, accident analysis, compatibility of materials, accessibility for in-use inspections, maintenance, repair, decontamination and acceptance criteria for inspections and tests;

Design control measures are established for design changes, which are subject to the original design criteria, including those changes requiring re-application to the NRC for review and package approval amendments, in a graded approach to safety, consistent with each element's important to safety.

3.0 DESIGN CONTROL, continued.

3.2 Statement of Verification of Package Design Process Control

JLS&A has drafting/drawing standards, with provisions for drawing checks, review and approval protocols, issuance and distribution. Protocols are established for the development of a graded approach to the classification of important to safety package characteristics, with reviews to determine compliance with prototype test and inspection criteria.

JLS&A's revisions to drawings are controlled in the same manner as the originals. Any package drawing changes are documented, incorporating the current design and/or specifications. Package drawing changes require certificate of conformance review and approval, and transmittal of this information to the appropriate departments or licensing authorities, as appropriate, prior to release for production.

JLS&A's original, obsolete drawings or specifications are so marked and copies are removed from production points, as necessary.

JLS&A's central drawing list is maintained according to Quality Assurance Procedures.

JLS&A's specification (regulatory) references, codes and standards, are maintained in various locations at JLS&A facilities and are utilized as necessary by respective JLS&A organizations.

3.3 Statement of Verification of Responsible Package Design Input and Compliance with Regulatory Certificates and Requirements.

JLS&A's design procedures for packages require that designs are approved by the appropriate licensing/regulatory authority after prototype testing or calculation analysis.

JLS&A's prototype designs for certificate packages shall have any required regulatory approvals pending. The initial design of a package requires providing licensing authorities with all pertinent information as required by the approval criteria; i.e., prototype testing or calculations, design review, drawings, instructions or procedures as applicable. New designs will be formulated in accordance with package design and use criteria, with any applicable standards or regulatory guides, or sections thereof, and references used as required.

New certificate package designs and implementing documents or changes requiring approval to existing certificate package designs, will use a graded approach to safety or quality classification of systems, reflecting the applicable parts of the NRC's Classification of Transportation Packaging and Dry Spent Fuel Storage Systems Components, NUREG/CR6407.

3.0 DESIGN CONTROL, continued.

3.3 Statement of Verification of Responsible Package Design Input and Compliance with Regulatory Certificates and Requirements, continued.

After licensing authority approval is granted to JLS&A and prior to release for production of new packages, drawings are to be reviewed for conformance to the approval specifications.
The standards used by JLS&A in this graded safety and quality approach QA/QC Program are contained within the provisions of 10CFR71, Subpart H, and pertain to applicable criteria consistent with each style or type of package design, manufacture, and use.

3.4 Statement of Verification of Adequacy of Package Design and, That Quality Standards Are Maintained.

JLS&A ensures the verification of adequate design for packages by means of prototype testing, modeling or calculation, which are allowed in licensing applications and approvals. Actual prototypes may be tested and inspected in the appropriate stages to verify that they meet all licensing authority criteria and design specifications. Inspection and test criteria are documented. Each package design is reviewed to assure that the design characteristics are such that components can be readily inspected and tested, and that maintenance, handling, storage and cleaning requirements, as required can be achieved.

JLS&A's design verification is performed in accordance with approved procedures that define responsibilities, methods, and documentation requirements. Design verification is performed by qualified independent personnel, other than the original designer.

4.0 PROCUREMENT DOCUMENT CONTROL

4.1 Regulatory Reference.

71.109 Procurement Document Control.

JLS&A has procedures to ensure that quality control of procured safety-related material, equipment, and services for Type B quantity radioactive material packages, vendors who maintain quality assurance programs, as applicable, and specifies the rights of access, inspection and document retention on purchasing documents issued.

JLS&A's quality assurance organization, in conjunction with management, engineering and production, is responsible for the oversight and implementation of this part of the quality assurance program.

JLS&A's QAPP implementing documents establish criterion to assure adequate quality control is maintained over purchasing documents and processes.

4.2 Statement of Verification of Purchasing Department Procedure for Packages.

JLS&A has established procedures which control the preparation, review concurrence and/or approval for the preparation of bills of materials which are the guidance documents for the purchasing department. These procedures define a sequence of actions for the conduct of purchasing operations.

4.3 Statement of Verification That the Scope of Work is included on Purchase Orders for Packages.

JLS&A's purchase requisition documents provide the purchasing department with purchase order information and instructions pertinent to the scope of work to be performed by the vendor.

4.4. Statement of Verification That Appropriate Reference of Specifications Appear on Purchase Orders.

JLS&A's purchase requisition documents provide purchasing activities with the appropriate package references regarding technical requirements; i.e., regulatory requirements, material and component identification requirements, drawings, specifications, codes and/or industrial standards, test and inspection requirements and special process instructions, to be included on purchase orders when applicable.

4.0 PROCUREMENT DOCUMENT CONTROL, continued

4.5 Statement of Verification That Subpart H Criteria and Appropriate Reference of Documentation Appear on Purchase Orders.

JLS&A's purchasing activity in coordination with licensing and engineering identifies 10CFR71 Subpart H criteria, when applicable, as provided by bill of materials instruction, per 4.2 above, for packages. The following items will also be required, as applicable: certification of model and serial number; NRC approved QA/QC Program for manufacturing, use and maintenance instructions, and verification procedures; Certificates of Compliance; use and maintenance manuals; drawings and photographs, or sketches.

4.6 Statement of Verification That Package Purchase Orders Contain a "Right of Access" Clause.

JLS&A's purchase orders contain an agreement clause covering JLS&A's right of access to the supplier's facilities and records for inspections or audits, when applicable.

4.7 Statement of Verification That Appropriate Documents Are Retained by Vendor and/or Delivered to Purchaser for Packages.

JLS&A's bill of materials provides the appropriate references of records, certification or test reports to be retained, controlled and maintained by the supplier and for those which are to accompany delivery to JLS&A, to be included with the purchase order when applicable. When possible, these items are specified in supplemental instructions to vendors.

4.8 Statement of Verification That NonConformances are Reported and Dispositioned.

JLS&A implements and maintains procedures which are used to identify, report and disposition nonconforming information, features, processes, or specification deviation from purchase documents.

4.9 Statement of Verification That Package Purchase Order Revision is Subject to Review and Approval.

JLS&A's purchasing department has instructions that require revisions or changes to purchase requisition documents, or specifications contained therein, made by purchasing, the vendor or subcontractor, are to be subjected to the same review and approval by the issuing department as were the original documents.

5.0 INSTRUCTIONS, PROCEDURES, AND DRAWINGS.

5.1 Regulatory Reference.

71.111 Instructions, Procedures, and Drawings.

JLS&A has procedures to ensure that control of package quality and important to safety affected activities are documented. Documentation is administered through the use of instructions, procedures or drawings as appropriate to the activity, and includes quantitative or qualitative acceptance criteria.

JLS&A's quality assurance organization, in conjunction with management, engineering and production is responsible for the oversight and implementation of this part of the quality assurance program.

5.2 Statement of Verification that Package Important-to-Safety Activities Are Accomplished In Accordance With Specifications.

Important to safety activities affecting the quality of packages, are accomplished by JLS&A according to documented instructions, procedures, and/or drawings.

5.3 Statement of Verification of Compliance per 10CFR71, Subpart H Criteria.

JLS&A's QAPP administrative and implementing procedures contain adequate instructions, procedures and drawings, to demonstrate compliance with applicable sections of 10CFR71, Subpart H, relative to package parts, materials, and components.

5.4 Statement of Verification that Package Safety-Related Activities are Satisfactorily Accomplished.

JLS&A's implementing procedures for packages include requirements for dimensions, tolerances, operating limits and specifications, as applicable, for safety related activities to determine that inspection and acceptance criteria verify that these have been satisfactorily accomplished.

5.5 Statement of Verification of Quality Assurance Responsibility.

JLS&A's quality organization is arranged, such that particular departments are assigned authority and responsibility for implementing various elements of the quality related activities under the auspices of the QAPP. As described above, certain staff members have been trained, certified and authorized to perform verifications of safety related activities. In all cases these individuals are restricted from performing any type of direct work activity relative to the respective verification processes for which they are assigned. The QA/QC department reviews

5.0 INSTRUCTIONS, PROCEDURES, AND DRAWINGS, continued.

5.5 Statement of Verification of Quality Assurance Responsibility, continued.

these activities to ensure that procedures, instructions and applicable regulations of NRC and DOT are being implemented and followed.

5.6 Statement of Verification that Packages Are Prepared for Use.

JLS&A's QA/QC instructions and procedures are designed and established to meet the applicable routine determination requirements of 10CFR71.87, for placing packages in use and/or for inspection before re-use as part of the QA/QC program.

5.7 Statement of Verification that Package Repair, Rework and Maintenance Instructions are Established.

JLS&A's procedures ensure that routine or major repair, rework, and/or maintenance instructions for packages are prescribed before that work begins. Important to safety activities are required to be reviewed by the quality assurance staff and are included in instructions and procedures as applicable. These activities have prescribed QA/QC hold points for QA/QC inspections and are coordinated with the Quality Assurance Department.

5.8 Statement of Verification of Package Storage, Packaging and Delivery Instructions.

JLS&A has procedures and/or instructions for package storage, packaging and delivery. DOT and/or NRC shipping regulations are documented and implemented in accordance with the formally approved procedures for all packages.

5.9 Statement of Verification of Package Loading/Unloading Procedures.

JLS&A's receiving procedures ensure that loading/unloading of radioactive materials packages meets regulatory requirements, including but not limited to radiation surveys, contamination wipe surveys, and rigging, for packages, as applicable.

5.10 Statement of Verification of Proper DOT Transport of Package.

JLS&A's outgoing shipments of packages are controlled using procedures that ensure the packages are in compliance, in good operating condition, meet external contamination levels and are properly identified and labeled in accordance with all pertinent DOT and NRC regulations.

6.0 DOCUMENT CONTROL

6.1 Regulatory Reference

71.113 Document Control

JLS&A has procedures to ensure that issuance of quality and important to safety related documents for Type B radioactive materials packages, such as instructions, procedures and/or drawings, and the changes thereto, are controlled and maintained. These procedures also ensure that this documentation and any changes thereto are reviewed for adequacy, approved for release by authorized personnel and that they are used and maintained in the locations where the activity is performed.

JLS&A's quality assurance organization, in conjunction with management, engineering and production, is responsible for the oversight and implementation of this part of the quality assurance program.

6.2 Statement of Verification of Controlled Documents for Packages

JLS&A's QA/QC procedures, implementing documents, and revisions thereto are controlled, utilizing methods such as computer password, by distribution or in controlled QA/QC files, as applicable. These documents may include, but are not limited to drawings, specifications, purchase orders, QA/QC manuals, change order reports, inspection reports, test reports, conformance reports, nonconformance reports, operating and maintenance procedures, loading and unloading procedures, repair and maintenance procedures, packaging for transport procedures, design change requests and corrective action reports.

6.3 Statement of Verification That the Issuance of Package Documents is Procedurally Controlled.

JLS&A has procedural controls to check, review, approve and/or change documents and/or procedures prior to issuance.

Each JLS&A department head retains a controlled copy of the QA/QC Manual and is provided changes and updates as applicable. The master copy of the QA program procedure documents is kept by the QA/QC Department under the control of the Document Coordinator, who is responsible for distributing approved revisions to all controlled copies of the QA/QC Manual and associated implementing procedures. Employees, customers, and/or outside auditors may receive uncontrolled copies of procedures or documents for specific programs, but do not receive changes or updates unless specifically requested.

6.0 DOCUMENT CONTROL, continued.

6.4 Statement of Verification That Changes to Package Documents Are Made By the Original Department That Prepared The Initial Document.

Any JLS&A department initiating QA/QC documents, when notified of the need for change or modification, approves revisions to the original documents. Major changes are reviewed and approved using the same process as the original document. Minor changes such as inconsequential editorial corrections, do not require the same level of review as the original document. Formally approved procedures define the types of changes considered minor and the process for requesting changes.

6.5 Statement of Verification that All Pertinent Package Documents Are Available At the Site Where They Are to Be Implemented.

Pertinent JLS&A procedural documents are available at the site where they are to be implemented, prior to starting work, whether at JLS&A's facility or temporary job sites. JLS&A has established formal procedures to control document distribution and to ensure that the most current documents are distributed.

6.6 Statement of Verification that Master Lists, Including Revisions, Are Current and Appear on Appropriate Package Documents.

JLS&A keeps a master index of QA/QC instructions and procedures which reflects the overall current status of the QP/QAM, with revisions. Revisions are identifiable, appear on the current appropriate documents and are distributed.

7.0 CONTROL OF PURCHASED MATERIALS, PARTS, COMPONENTS, EQUIPMENT AND SERVICES.

7.1 Regulatory Reference.

71.115 Control of Purchased Material, Equipment and Services.

JLS&A has inspection procedures to ensure that purchased materials, parts, components, equipment and/or services, important to safety/quality for Type B radioactive materials packages, comply with the purchase documents and the provisions contained therein.

JLS&A has established procedures for vendor evaluation and selection, including quality program evaluation as applicable and appropriate using a graded approach for the purchase of materials, parts, components, equipment and/or services.

JLS&A has established controls so that documentary evidence of receiving inspections and records showing conformance to the purchase orders is maintained for the life of the package.

JLS&A's quality assurance organization, in conjunction with management, engineering and production, is responsible for the oversight and implementation of this part of the quality assurance program.

7.2 Statement of Verification of Evaluation of Package Vendors (Selection of Procurement Sources).

JLS&A's QA/QC procedures provide necessary control over the selection of quality vendors, using a graded approach to evaluate the safety significance assigned to the item or vendor.

JLS&A's personnel responsible for determining bill of materials and/or purchase requisition documents (purchase order planning), vendor selection or for qualifying vendors' QA/QC programs, are trained and possess sufficient experience to establish vendor acceptability to meet specifications applicable for the purchase order.

JLS&A's vendor selection for materials, parts, components, equipment and/or services for packages is discretionary, is used in those situations as a function of the relative importance, complexity, quality and within an important to safety graded approach of the item or service procured, along with vendor performance history and may be made by using all or part of the following criteria, as applicable:

7.0 CONTROL OF PURCHASED MATERIALS, PARTS, COMPONENTS, EQUIPMENT AND SERVICES, continued.

7.2 Statement of Verification of Evaluation of Package Vendors (Selection of Procurement Sources) continued.

The vendor's capability to comply with the appropriate elements of 10CFR71, Subpart H, or 10CFR21 and/or NRC approved QA/QC program (or equivalent), which are applicable to the type of material, part, component, equipment or service for the package being procured.

Continuous satisfactory performance of current vendors.

A review of previous records and performances of past vendors who have provided similar articles of the type being procured.

A survey or audit of the vendor's facility and QA/QC program is performed, when applicable, to determine capability to supply a product which meets the design, manufacturing and quality requirements. Notes: audit results and approvals by approved vendors, or a copy of the QA/QC Manual and/or NRC or DOE approval, are acceptable in lieu of a formal JLS&A survey or audit, or on a case by case basis as determined by the QA/QC Program Administrator. The evaluation and acceptance of professional services is performed by engineering activity. Catalog item providers are exempt from QA/QC audits or surveys.

7.3 Statement of Verification of Package Contract Evaluation and Award Procedures. (Bid Evaluation and Award).

Currently not applicable. JLS&A does not use the bid evaluation and awards process due to the nature of the materials or services provided, although they may be required by outside contractual obligations. JLS&A implements and maintains established procedures that ensure the appropriate departments evaluate prospective bidders, when required.

7.4 Statement of Verification that Inspection and/or Supervision of a Package Vendor is Performed. (Vendor Performance Control).

JLS&A performs receipt inspections, utilizing established inspection criteria to determine that items are properly identified and correspond to the specifications contained within purchasing documents.

JLS&A does not currently use items that are contingent on tests after installation on packages, but has procedures to establish inspection and conformance criteria for such activities.

If required, and as applicable, a JLS&A QA/QC Inspector will be present at the vendor's site during fabrication, testing and/or shipment of a package to assure conformance with purchase order specifications. Inspection and/or supervision requirements are transmitted to the purchasing staff using a bill of materials for inclusion in the purchase order.

7.0 CONTROL OF PURCHASED MATERIALS, PARTS, COMPONENTS, EQUIPMENT AND SERVICES, continued.

7.5 Statement of Verification of Minimum Records to be Supplied by Purchaser for Packages. (Verification Activities).

JLS&A requires as a minimum from all package vendors the following documentation:

Documentation that identifies the purchased materials, parts, components, equipment or service and documented evidence that specific procurement requirements (e.g., codes standards and specifications) are met by the item;

Documentation that identifies any procurement requirements which have not been met together with a description of those nonconformances. Contingent on acceptance by JLS&A, all nonconforming items must be repaired or replaced and certification thereof provided by the vendor;

QA/QC inspection reports and documentation from vendor's facility, when applicable by contract terms or specifically requested by JLS&A management.

7.6 Statement of Verification of QA/QC Inspector Acceptability Criteria and Responsibility for Package Inspections (Controlling Nonconformances).

JLS&A's inspectors are responsible for and will not accept packages or package components that do not meet the following criteria:

The material, component or equipment is properly identified and corresponds with the requirement or specifications contained in receiving documentation, including verification of any documentation required by the purchase document.

In those instances of nonconforming items, the issuance of the following type documents is procedurally controlled:

Material Rejection Forms and/or tags for nonconforming parts, assemblies, etc.
In-House nonconformance report for nonconforming procedures etc.
NRC Part 21 or Part 71 nonconformance reporting, as appropriate.

When a commercial grade item identified in a design document is substituted with an alternate commercial grade item or if an item is recommended/considered to be "use as is" or "repaired", the supplier's design organization verifies that the substitute or "use as is" or "repaired" item will perform to the intended function satisfactorily, when appropriate justification documentation provided to JLS&A.

Records of certificates of conformance attesting to the acceptance of material and components, when applicable.

8.0 IDENTIFICATION AND CONTROL OF MATERIALS, PARTS AND COMPONENTS

8.1 Regulatory Reference

71.117 Identification and control of material, parts, and components.

JLS&A has procedures to ensure that the identification and control of materials, parts and components relating to quality or important to safety items for Type B radioactive materials packages is achieved in order to prevent the use of the wrong or defective item.

JLS&A has procedures for identifying items in an appropriate and nondestructive manner, or by traceable documentary records during fabrication, installation or use phases.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production is responsible for the oversight and implementation of this part of the quality assurance program.

8.2 Statement of Verification that Established Procedures are Used for Identifying and Controlling Materials, Parts, or Components for Packages.

JLS&A has procedures for identification of package materials, parts, and/or components received or fabricated as part of the QA/QC program.

8.3 Statement of Verification that Package Materials, Parts, or Components are Identified Properly.

As part of JLS&A's receiving procedures, all incoming quality or safety related materials, parts and /or components are inspected for conformance to the purchase order. They are then identified and marked to be directly traceable to specific jobs, or alternately placed into general inventory by the appropriate department. Non-inspected parts or components are held in separate inventory locations as applicable for the item. Non-conforming materials, parts, or components are placed in separate locations as applicable for those items.

8.4 Statement of Verification that the Location and Method of Identifying Package Materials, Parts, and/or Components is not Harmful to Them.

JLS&A's receiving areas and methods of identification (several methods are used as appropriate to the item) do not in any way interfere with the fit, function or quality of the package.

8.0 IDENTIFICATION AND CONTROL OF MATERIALS, PARTS, AND COMPONENTS, continued.

8.5 Statement of Verification that Identification Numbers for Packages are Verified Before Release.

Any item taken from JLS&A's general or dedicated inventory is verified to be the proper item for the job before release for fabrication, assembly or installation. Completed packages have discrete serial numbers which are verified before release for shipment.

8.6 Statement of Verification that Limited Life Items are Controlled.

Currently not applicable for the type of packages utilized by JLS&A. JLS&A implements and maintains established procedures that ensure the appropriate implementing controls are in place for the replacement of limited life items, whose shelf life has expired or the prescribed operation time has expired, as applicable.

8.7 Statement of Verification that Conditional Releases for Packages, Materials, Parts and Components are Controlled.

In those instances where required inspections and/or tests of package materials, parts, or components have not been completed, JLS&A has established controls to facilitate the continued processing activity. Identification by an appropriate tagging type method and control by segregation or by status indicators as appropriate of such items is procedurally maintained at all times. Conditional release of completed NRC or DOT approved Type B packages is not permitted under any circumstances. JLS&A has established provisions for identification, control and surveillance for prototype Type B packages slated for destructive testing before such testing occurs.

9.0 CONTROL OF SPECIAL PROCESSES

9.1 Regulatory Reference

71.119 Control of Special Processes.

JLS&A has established procedures to assure that applicable special processes, including but not limited to, welding and non-destructive testing activities relating to quality or important to safety items for Type B radioactive materials packages are controlled and accomplished by qualified personnel using procedures which include applicable or appropriate codes, standards, specifications, criteria or other special requirements.

JLS&A's quality assurance organization, in conjunction with management, engineering and production is responsible for the oversight and implementation of this part of the quality assurance program.

9.2 Statement of Verification that Special Processes for Packages are Procedurally Controlled.

JLS&A has established procedural controls for packages which may be determined to require special processes, such as certified welding. Procedures for establishing controls for other special processes such as heat treating, non-destructive testing and/or cleaning are developed and controlled by work instructions as required for the package. Special processes are defined by JLS&A as those processes requiring specific standards outside the normal scope of operations.

9.3 Statement of Verification that Package Procedures, Equipment and Personnel Meet Applicable Specifications, Codes and Standards.

JLS&A has procedures and equipment, personnel training and qualifications programs which allow for the application of codes, standards, and/or specifications, required documentation and records as appropriate, for special processes. JLS&A has in place provisions for establishing additional qualified procedures, equipment and personnel training and qualifications for future applications.

9.4 Statement of Verification that Qualification Records Concerning Special Processes for Packages are Established and Current.

JLS&A has procedures that govern the conduct of special process operations and the retention requirements for qualification records associated with the special process. The qualification records for current processes and qualifications of personnel are kept current, with administrative controls to ensure that personnel and equipment qualifications are retained and current.

10.0 INSPECTION CONTROL.

10.1 Regulatory Reference

71.121 Internal Inspection

JLS&A has established measures for planning and accomplishing quality or important to safety inspections and/or for verifying conformance with documented instructions, procedures, and drawings for those activities. Receiving, in-process and/or final inspections are performed by individuals not performing the activity being inspected or, in cases where this is not practical or possible, by indirect control and conformance review. Specific hold points, when applicable, are incorporated into the appropriate documents. These inspections and reviews are designed to ensure that each activity affecting quality or safety is adequately identified, evaluated and documented in accordance with established procedures.

JLS&A's quality assurance organization, in conjunction with management, engineering and production, is responsible for the oversight and implementation of this part of the quality assurance program.

10.2 Statement of Verification that the Package Inspection Program Verifies Conformity of Items in Accordance with Established Procedures.

JLS&A's conformance inspections on packages are performed in accordance with established procedures, instructions, and/or checklists and are documented.

10.3 Statement of Verification that Package Receiving Inspections Verify the Integrity of Important to Safety Items.

JLS&A's receiving inspections for important to safety items are designed to verify integrity of such items. In the cases of re-usable packages, an inspection is performed, identifying maintenance and/or repair items, as required to assure package integrity and/or to prevent or mitigate the release of the radioactive materials or contamination. Receiving inspections also have provisions for purchase order conformance inspections, when applicable, and for physical control and disposition of accepted or rejected items.

10.4 Statement of Verification that Package In-Process Inspections are Established.

When appropriate and applicable to important to safety items, JLS&A has established procedures to ensure that in-process inspections are performed on packages, with the appropriate documentation maintained. JLS&A has provisions for establishing additional in-process inspection procedures, as required for future applications.

10.0 INSPECTION CONTROL, continued.

10.5 Statement of Verification that Package Final Inspections Verify Item Integrity.

JLS&A's final inspection verifies the package integrity. As a minimum, items are inspected for completeness, markings, calibration, adjustments, and protection from damage. The acceptance of the item will be documented and approved by authorized personnel. Modification, repair or replacement requires re-inspection or re-testing, as appropriate to verify acceptability.

10.6 Statement of Verification of Package Inspection Activity.

JLS&A's receiving inspections of materials, components, parts, equipment and services, as applicable, are performed by qualified QA/QC inspectors, not performing the activity being inspected. For in-house outgoing, loaded package inspections, QA/QC inspection personnel may have performed the activity being inspected and quality assurance or management personnel either supervise or perform final conformance verification of the activity, depending upon the safety aspects of the activity. For those situations involving remote site inspections for shipment activities, package preparation and inspections activities are performed by authorized and trained QA/QC personnel and quality assurance or management personnel either supervise or perform final conformance verification of the activity, depending upon the safety aspects of the activity.

The QA/QC Department audits these types of activities to ensure that the quality program is being implemented and maintained in accordance with established procedures and that the program is effective.

10.7 Statement of Verification that Package Inspectors are Qualified per A Training Program and that Qualifications Are Current.

JLS&A maintains in-house qualified QA/QC inspectors and their certifications and qualifications are on file. QA/QC personnel who verify conformance of work or activities for acceptance are qualified to perform QA/QC inspections in accordance with established procedures. These qualifications reference applicable standards or codes related to the safety aspects of the inspections to be performed. Personnel at temporary job sites require certification, training is provided and those records are also kept on file.

Training and qualification of inspectors is implemented and maintained in accordance with the criterion and processes defined in the appropriate procedures and specifications.

The QA/QC Manager/Administrator reviews these training activities to ensure that the quality program training is being implemented and maintained in accordance with established procedures and to verify the program is effective.

11.0 TEST CONTROL

11.1 Regulatory Reference.

71.123 Test Control.

JLS&A currently uses packages manufactured before August 31, 1986, and DOT specification packages or foreign approved packages with DOT revalidation. JLS&A has the capability to establish procedural protocols for initiating a formal prototype test or calculation review program in accordance with 10CFR71, Subpart G criteria; or, production tests, proof tests, operational tests, structural integrity, leak-tightness (if applicable), shielding integrity and thermal integrity testing is performed to current standards when either modifications requiring NRC review and approval or packages are tested to meet new standards, including the the graded approach to importance to safety protocols . These protocols will call out the determination of any applicable test to pre-determined standard and suitable environmental conditions; and, then documentation reviews, and evaluations assure that the test requirements have been met. The current types of packages used by JLS&A do not require production, proof or operational tests; however, procedure protocols will be established if and when these tests are required.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production, is responsible for the oversight and implementation of this part of the quality assurance program.

11.2 Statement of Verification that Package Test Programs and Procedures Are Established, Documented and Performed Accordingly.

JLS&A has protocols to establish a prototype test program and procedures pursuant to 10CFR71 Subpart G criteria, or to other current standards for packages when needed, i.e., when either modifications requiring NRC review and approval or packages are tested to meet new standards.

11.3 Statement of Verification that Packages Meet Test Acceptance Criteria Prior to Shipment

JLS&A has procedure protocols for package test programs which provide for the evaluation and verification of acceptance criteria prior to shipment and are implemented when required, which are package specific. Packages are identified both by serial number and DOT or NRC Certificate identification. Newly manufactured packages must pass a complete physical design and fabrication compliance inspection, including inspection of purchased parts and/or components, along with a review of conformance with the package's individual type of certificate and procedures, with a conformance verification before release for initial shipment. The compliance inspection for JLS&A packages includes structural integrity and shielding integrity (for the applicable package component). Repaired packages must pass a physical inspection including review of purchased parts and/or components.

11.0 TEST CONTROL, continued.

11.3 Statement of Verification that Packages Meet Test Acceptance Criteria Prior to Shipment, continued

Leak tightness, component performance and thermal integrity testing are not applicable for the types of packages used by JLS&A to ship sealed sources. Acceptance protocols are implemented prior to shipment, as described under Section 13, Handling, Shipping and Storage, to this QAPP, by implementing procedures, including instructions and inspections which contain acceptance or nonconformance criteria.

12.0 CONTORL OF MEASURING AND TEST EQUIPMENT (M&TE).

12.1 Regulatory Reference

71.125 Control of Measuring and Test Equipment.

JLS&A has procedures to assure that the applicable tools, gauges, instruments or other measuring and testing equipment related to quality or important to safety activities are properly controlled and calibrated.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production, is responsible for the oversight and implementation of this part of the quality assurance program.

12.2 Statement of Verification that Measuring and Test Equipment are Properly Calibrated.

JLS&A maintains calibrated measuring and test equipment, based upon required accuracy, purpose, and degree of usage, stability characteristics or other conditions affecting the measurement of salient characteristics of a particular item, calibration requirements and frequency. Measuring and test calibration frequencies/intervals are established and implemented consistent with industry guidance and recommendations as applicable. Records of calibration history are maintained. Vendors are required to submit standards used and certifications, as required.

12.3 Statement of Verification that Measuring and Test Equipment are Identified and Traceable to Calibration Test Data.

JLS&A requires and maintains serial or unique identification numbers on all measuring and test equipment and requires all calibration test data to reference the instrument's serial number(s) or identification number(s). All measuring and test equipment is labeled or tagged to indicate the date of the next calibration.

12.4 Statement of Verification that Calibration of Measuring and Test Equipment Meets Appropriate Standards.

JLS&A maintains requirements and procedures to ensure that package M&TE is calibrated to National Institute of Standards and Technology (NIST, formerly NBS), or other appropriate nationally recognized standard used for calibration. The parameters for that calibration procedure will be documented.

12.0 CONTORL OF MEASURING AND TEST EQUIPMENT (M&TE), continued.

12.5 Statement of Verification that Measurements Are Taken, Documented, and Validated, Against Previous Measurements When an Instrument Is Found To Be Out of Conformance During Calibration.

JLS&A requires that new measurements be taken to validate previous inspections in the event that an instrument is found to be out of conformance during calibration. The appropriate parties are notified, as applicable. Any measuring equipment which is consistently out of tolerance will be removed from service, then repaired or replaced.

13.0 HANDLING, STORAGE AND SHIPPING

13.1 Regulatory Reference

71.127 Handling, Storage and Shipping Control

JLS&A has instructions and procedures to control the handling, shipping, storage, cleaning, and preservation of packages to prevent their damage and/or degradation. Special protective environments are not required for the packages currently used by JLS&A. However, procedural controls are formally established to apply this protective system when situations call for such control.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production, is responsible for the oversight and implementation of this part of the quality assurance program.

13.2 Statement of Verification that Handling, Storage, Cleaning and Routing Preservation Requirements for Packages are Accomplished in Accordance with Work and Inspection Instructions.

JLS&A has procedures that ensure the unloading, handling, storage, cleaning and preservation activities are performed in accordance with work and/or inspection instructions in order to prevent damage or degradation.

13.3 Statement of Verification that Special Requirements for Package Environments are Accomplished by Qualified Individuals in Accordance with Work and Inspection Instructions.

Currently there are no special requirements for special preservation associated with packages utilized or operated by JLS&A. In the future, if the scope of package operations or requirements change criteria for special inspection instructions and qualification of employees exists in current Quality Assurance Procedures for performing work related to special handling , preservation, storage, cleaning, packaging and shipping requirements, in order to preclude physical or environmental damage, as required for that package.

13.4 Statement of Verification that Packages Meet Acceptance Criteria Prior to Shipment.

JLS&A has established a shipment preparation program, which includes a clear sequence of actions for inspections covering package acceptance criteria and/or documentation, prior to shipment of radioactive materials. Acceptance criteria will be based upon: Certificates of Compliance and compliance certifications thereof; drawings, operating and maintenance instructions or manuals; physical inspections based upon package criteria for integrity, or other documentation that may become applicable.

13.0 HANDLING, STORAGE, AND SHIPPING, continued.

13.5 Statement of Verification that Conditions of the NRC and DOT Shipping Regulations are Satisfied Before Shipment.

JLS&A performs package inspections before shipment of radioactive materials and documents all items pertinent to NRC (10CFR71, Subpart G) and DOT shipping regulations applicable to the package, package certificate of compliance, and for the shipment itself. Items must pass all criteria, including cumulative results of previous sections contained therein, all of which is documented, before shipment is made. Empty packages are screened for surface contamination, proper closure and general condition prior to shipment as an exempted empty package.

13.6 Statement of Verification that Inspections and Procedures are Established, Documented and Performed Accordingly on Packages.

JLS&A's quality assurance organization in conjunction with the health physics radiological inspection program ensures that packages remain in conformance, usable and free of excessive radiation and contamination, through a series of inspections, documented wipe tests and radiation surveys, which are reviewed and approved in advance of shipments and in accordance with established procedures.

13.7 Statement of Verification that Package Shipping Papers Are Properly Prepared.

All necessary shipping papers are prepared by JLS&A for shipment of loaded packages in accordance with NRC, DOT and/or other regulatory agency requirements with validation and control implemented utilizing JLS&A approved procedures. Shipping papers for radioactive shipments are reviewed and approved by specifically trained and authorized personnel.

13.8 Statement of Verification that 10CFR21.6 Posting Requirements Have been Established.

"Notification to Comply or Existence of A defect – Explanation of Notification Procedures and Proper Authorities", along with Section 206 of the Energy Reduction Act of 1974, Noncompliance, is posted in the prescribed manner according to 10CFR21.6. JLS&A implements periodic surveillance of the postings to ensure that the information depicted remains current and is conclusive.

JLS&A has procedures that contain specific instructions for reporting and handling of concerns required to be reported and dispositioned in accordance with the requirements of 10CFR Part 21. In addition to the actual posting of the 10CFR Part 21 document, JLS&A maintains in the same general area, and in clear sight, specific instructions to employees regarding the protocols for reporting any 10CFR or Part 21 type concerns.

14.0 INSPECTION, TEST AND OPERATING STATUS.

14.1 Regulatory Reference.

71.129 Inspection, Test, and Operating Status.

JLS&A has instructions and procedures to control the applicable inspection indicators for packages or individual items of packages, by using markings, such as stamps, tags, labels, or other suitable means of tracking to prevent inadvertent by-passing of required inspections and/or tests. Critical operating status parameters are required for the transport of the packaging shipped by JLS&A and include items such as structural and thermal criteria.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production is responsible for the oversight and implementation of this part of the quality assurance program.

14.2 Statement of Verification that Package Inspection Results are Documented and Reviewed by Appropriate Departments.

JLS&A's package operation and maintenance inspection program results are documented by appropriately trained personnel working within responsible departments.

14.3 Statement of Verification that Status of Packages is Provided to Affected Departments or Organizations.

JLS&A's procedures contain provisions for determining the status of packages through the use of acceptance or rejection media, such as tags or other markings. Affected internal departments or outside organizations are notified as to package status changes as required.

14.4 Statement of Verification that Removal of Package Inspection Indicators are Procedurally Controlled.

JLS&A's mechanism for identifying a nonconforming package inspection status is achieved through a method of utilizing a rejection "tag" or other marking process. Rejection tag or marking application and removal procedures are established and controlled, with management oversight provided as necessary. The removal of any other inspection or other status indicator is performed by responsible QA/QC inspection personnel and is procedurally controlled.

14.5 Statement of Verification that By-Passing of Package Inspections or Tests is Controlled.

The by-passing of JLS&A's inspections or tests is procedurally controlled by means of JLS&A's documentation, work structure, procedures, inspection checklists and daily communications as applicable. The QA/QC Program Manager/Administrator has overall responsibility for the adequacy of effectiveness relative to the implementation of this important program.

15.0 Nonconformances.

15.1 Regulatory Reference.

71.131 Nonconforming materials, parts, or components

JLS&A has instructions and procedures to control adverse conditions applicable to quality and safety related procedures, processes, materials, parts, components or complete packages. These procedures include provisions for the identification, documentation, segregation, disposition, and notification to affected departments or organizations. Nonconforming items are rejected, segregated, evaluated, repaired, re-worked or reviewed and accepted, as applicable, and the disposition status is documented. Nonconformance implementing procedures also provide for management notification to the NRC when nonconforming conditions warrant regulatory notification.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production is responsible for the oversight and implementation of this part of the quality assurance program.

15.2 Statement of Verification that Nonconforming Package Items or Procedures are Identified and Procedurally Controlled.

JLS&A implements and maintains material rejection procedures, and nonconformance reports for: 1) nonconforming parts, assemblies, etc.; 2) nonconforming Type B radioactive materials packages; 3) nonconforming procedures, etc.; and 4) NRC Part 21 or Part 71 Nonconformance Reporting, as appropriate.

These JLS&A procedures have provisions to assure that the identification, documentation segregation, review disposition of nonconforming items or procedures are implemented and that affected departments are appropriately notified.

15.3 Statement of Verification that Nonconforming Package Items are Segregated from Accepted Items.

JLS&A maintains separate locations for nonconforming items, as appropriate for the item, and those items are identified and controlled as nonconforming, until the necessary corrective actions are taken by designated department personnel.

15.4 Statement of Verification That Repaired or Re-worked Package Items are Subjected to Original Inspection or Testing Criteria.

Replaced, re-worked, or repaired items are subjected to the same documentation, original inspection, and/or test procedures, as applicable, by JLS&A.

15.0 Nonconformances (continued)

15.5 Statement of Verification That Package Nonconformance Reports are Evaluated.

JLS&A management and the QA/QC Program Manager/Administrator perform evaluations of nonconformance reports to determine quality trends, identify problem areas requiring further management review and assessment for regulatory reporting, as applicable.

15.6 Statement of Verification that 10CFR21.6 Posting Requirements Have Been Established.

"Notification to Comply or Existence of a Defect – Explanation of Notification Procedures and Proper Authorities", along with Section 206 of the Energy Reduction Act of 1974, Noncompliance, is posted in areas of the JLS&A facility in the prescribed manner, in accordance with 10CFR21.6.

Formal administration of this facet of the program is carried out in accordance with established JLS&A implementing procedures. Also, auditing is performed by JLS&A management, as necessary, to ensure current and appropriate postings are maintained.

JLS&A has procedures that contain specific instructions for reporting and handling of concerns required to be reported and dispositioned in accordance with requirements of 10CFR21. In addition to the actual posting of the 10CFR Part 21 documents, JLS&A maintains in the same general area, in clear sight, specific instructions to employees regarding the protocols for reporting concerns to upper management, as well as directions on utilizing and formally reporting any 10CFR Part 21 type concerns.

16.0 CORRECTIVE ACTION.

16.1 Regulatory Reference.

71.133 Corrective Action

JLS&A has instructions and procedures to control and identify adverse conditions applicable to quality and safety related corrective actions regarding nonconforming procedures, materials, parts, components, or complete packages. These procedures contain provisions for the identification, documentation, segregation, disposition, and notification to affected departments or organizations of conditions adverse to quality. For conditions adverse to quality, corrective action procedures include determination of the cause of the nonconformance, and a corrective action sequence to prevent recurrence of the nonconforming condition. Corrective action procedures also provide for reporting to JLS&A management and management's response to NRC when nonconforming conditions warrant regulatory notification.

JLS&A's quality assurance organization, in conjunction with management, engineering, and production, is responsible for the oversight and implementation of this part of the quality assurance program.

JLS&A's QAPP implementing documents establish appropriate criterion to assure that adequate control and documentation is maintained over corrective actions related to nonconformances.

16.2 Statement of Verification That Package Corrective Actions are Implemented.

JLS&A's internal program for corrective action processing is implemented and documented.

Each JLS&A corrective action processed contains provisions for:

The reason for corrective action(s), including an analysis of methods and procedures, if required;

Statement of work for the corrective actions to be taken;

Re-inspection of the non-conforming condition, as corrected;

Implementation of improvements, if required;_and, monitoring and evaluation of corrective actions to assure effectiveness and NRC Part 21 and 71 reporting, as appropriate.

If an external or internal JLS&A\ inspection determines a nonconforming condition exists, resulting in an internal corrective action, it is documented and reported to the appropriate JLS&A department managers. The nonconformance is subsequently evaluated by the department manager(s) with the corrective action proposed and closeout protocols established.

16.0 Corrective Action, continued

16.2 Statement of Verification That Package Corrective Actions Are Implemented (continued).

External notifications of noncompliance or JLS&A internal noncompliance notification and corrective actions are reviewed by JLS&A management to determine it is also reportable to applicable regulatory authorities. In the event that a nonconformance or corrective action is reportable to a regulatory authority under Part 21, Part 71, or other regulation(s) the regulations call out a sequence of actions for JLS&A management reporting, and is implemented in accordance with formally established procedures.

16.3 Statement of Verification That Package Corrective Action Proceedings are Completed.

In the event of a non-regulatory reportable corrective action, the cognizant personnel of the applicable JLS&A department, in accordance with established procedures, will evaluate the nonconformance, determine the course of the corrective action to prevent recurrence and establish a completion date.

JLS&A's QA/QC Program Administrator is responsible for reviewing and monitoring this process, including closure.

In the event that an adverse condition requiring corrective action is reportable to a regulatory authority, JLS&A management will present a sequence of actions to be taken for completion and close-out.

17.0 QUALITY ASURANCE RECORDS.

17.1 Regulatory Reference.

71.135 Quality Assurance Records.

JLS&A has instructions and procedures for the management and administration of quality records relative to the area of safety related design, fabrication, assembly, procurement, modification, use, repair, maintenance, transportation and testing of Type B radioactive materials packaging manufactured and used by JLS&A. These quality records furnish documentary evidence related to requirements for classification, legibility, identification, receipt, indexing, filing, storage, transmittal, retention, retrieval and disposition.

JLS&A's quality records include, but are not limited to, applicable Type B package instructions and procedures, drawings, and specifications, procurement, inspection, test and audit results, non-conformance/corrective action reports, and qualifications of personnel, procedures and equipment, and personnel training and re-training records.

JLS&A's quality assurance organization, in conjunction with engineering, production and operations management team is responsible for maintaining oversight and administration of this part of the quality assurance program.

JLS&A's QA implementing documents establish criterion to assure adequate control and documentation is maintained over these instructions and procedures for record retention, changes and safekeeping.

17.2 Statement of Verification That Package Records Documentation Furnishes Evidence of Activities Affecting Quality or Safety.

JLS&A shall maintain sufficient written records describing the activities affecting quality. These records will include the instructions, procedures and drawings required by 10CFR71.111 to prescribe quality assurance activities and include closely related specifications such as required qualifications of personnel, procedures and equipment. These records include the instructions or procedures which establish the records retention program which is consistent with applicable regulations and designates factors such as duration, location, and assigned responsibility. These records shall be retained for three years beyond the date when JLS&A last engages in the activity for which the QA/QC Program was developed along with other records as required by law, regulatory authority and good manufacturing practices. If any portion of the written procedures or instructions is superseded, JLS&A shall retain the superseded material for three years after it is superseded.

JLS&A'S QA/QC records are indexed and retained in appropriate locations and contain sufficient information for determining the identification between the record and item(s) or activities to which they are applicable.

17.0 QUALITY ASSURANCE RECORDS, continued.

17.2 Statement of Verification that Package Records Documentation Furnishes Evidence of Activities Affecting Quality or Safety, continued.

JLS&A's QA/QC inspection and prototype test records include the following criteria, as applicable:

A description of the activity;

Evidence of completion or verification of a manufacturing inspection or test operation;

Data and results of the inspection or tests;

Information related to conditions adverse to quality;

Inspector(s) identification;

Evidence as to the acceptability of the results.

17.3 Statement of Verification that Package Records are Legible and Completed.

All of the JLS&A quality departments that are required to implement quality measures commensurate with their functional responsibilities have authority and accountability for maintaining legible and completed quality records.

17.4 Statement of Verification that Package Records are Identifiable and Retrievable.

JLS&A maintains master listings of locations where quality records are maintained within the quality records system. Identification of records is implemented using control methods, such as, numerical, alphabetical and/or alpha-numerical means, with cross-referencing to other records as applicable.

JLS&A'S records are designated as "lifetime", "permanent", or "non-permanent/temporary", as applicable. Permanent records pertain to the package fabrication, storage, safe operation, repair, re-work, replacement, modification, instructions for use, inspections, nonconformances and corrective actions, and also include qualifications for packages, equipment and personnel. Temporary records which do not meet the protocols for permanent records shall be kept for a minimum of two years after the last shipment.

JLS&A implements and maintains formally established procedures that require prior review and approval of any record designated for destruction.

17.0 QUALITY ASSURANCE RECORDS, continued.

17.5 Statement of Verification that Package Records are Subject to Storage, Preservation and Safe Keeping.

JLS&A'S quality records, when not in use, are stored in approved areas to minimize risk of elemental, zoological or botanical damage. All current and completed records are retained for safe keeping and are kept in file cabinets when not in use or upon completion of a project. Measures are established for replacement, if at all possible, for lost or damaged records, including daily computer back-ups. Computer programs are password protected, with view and/or write access protected, as applicable. JLS&A office and storage area access is controlled to prevent unauthorized access by members of the public.

JLS&A has a program to duplicate some critical (pre-computer) QA/QC records, especially drawings, for storage in either multiple internal files or at other locations if they are not on the computer back-up. The latest computer back-up is removed from the JLS&A premises. Critical corporate records (as defined by JLS&A) are kept in fire-proof file cabinets, when not in use.

18.0 INTERNAL AUDITS.

18.1 Audits Program Administration.

71.137 Quality Assurance Records

JLS&A implements and maintains instructions and procedures for ensuring that a comprehensive system of periodic and planned QA/QC audits is implemented. These internal and external audits are designed to verify contract and/or specification compliance, procedure adherence and effectiveness of the overall Quality Assurance Program. This audit program includes provisions for internal program audits, as well as for external audits and surveillance of suppliers (as appropriate).

JLS&A's trained and qualified personnel perform audits using appropriate checklists or procedures. Audit results are documented and reviewed by JLS&A management personnel.

JLS&A's QA/QC Program Administrator, in conjunction with the quality organization, management, engineering, and production personnel is responsible for the oversight and implementation of this part of the quality assurance program.

18.2 Statement of Verification that Internal Audits are Conducted in a Prescribed Manner.

Internal JLS&A company audits are conducted on a three year cycle, or an "as needed" basis depending upon frequency and trending of nonconformances, using a graded approach for evaluating quality areas of the program, which are considered to be of major importance to safety. Emphasis is placed on package certification compliance and effectiveness of the program's implementation. Audits of the balance of the program criteria, not covered by frequency, will be conducted over cycle intervals not to exceed three years.

JLS&A's scheduled and planned audits are conducted using approved audit plans and formally established procedures and/or checklists. Audits of the general program are performed by qualified employees, who do not have direct responsibility for the area being audited, with provisions for timely access to documents and facilities. Individuals who have received appropriate training and who have been certified by management as being qualified, perform the required audits of certificate of compliance for Type B packages.

JLS&A's nonconformance follow-up actions, based on audit results, are subject to re-audit.

Alternatively, JLS&A management reserves the right to retain the services of qualified outside consultants to perform these audits.

18.0 INTERNAL AUDITS, continued.

18.3 Statement of Verification that Audits are Scheduled.

Internal audits and management assessments are scheduled and planned by the JLS&A QA/QC Program Administrator with approval of executive management. Management provides the necessary resources to ensure that the important to safety elements of the program are identified, receive priority and are evaluated in a timely and appropriate manner. Additional internal audits or re-audits may be performed more frequently if circumstances arise relative to nonconformances or negative audit finding trends.

JLS&A has provisions in place to control audit and surveillance activities for the approval of and contract oversight of package vendors and suppliers. Audits and surveillance are defined and implemented on an as needed basis, dependent upon the frequency of purchasing activities and based upon the safety significance applicable to the quality related service or activity needed. After initial JLS&A qualification, acceptance and approval of vendors or suppliers, continued audit and surveillance frequency will not exceed three year intervals, as applicable for high safety significant items. Some vendors or suppliers may receive more or less frequent surveillance and oversight due to the degree of safety significance applied to their activities and frequency of purchasing activities. JLS&A management provides oversight and reviews audits of applicable vendors or suppliers providing important to safety items or activities and these evaluations will be documented. Vendors who provide commercial grade parts, materials and components may require less stringent and frequent audits or oversight, as deemed appropriate by the Quality Assurance Manager/Administrator. JLS&A uses other entities audit results as justification for limiting the extent and scope of vendor audit surveillance.

18.4 Statement of Verification of Qualifications of Audit Personnel.

Audit personnel qualifications, including the QA/QC Program Administrator, principal QA/QC management positions, designated lead auditors and inspectors, are applied to and are commensurate with the applicable auditor qualification criteria of ANSI/ASME NQA-1-1989 "Quality Assurance Program Requirements for Nuclear Facilities". Basic requirement 2 is used as the primary qualification for audit personnel, with the incorporation of Supplement 2S-3, "Supplementary Requirements for the Qualification of Quality Assurance Program Audit Personnel", which is used as a formulation guideline. Lead auditors and auditing personnel are qualified in accordance with procedures and may serve at the discretion of the Quality Assurance Program Manager/Administrator with proper documentation.

Applicable qualification and training records are maintained as necessary. Training methodology, minimum experience requirements, and certification protocols are established and consistent with recognized industry guidance and standards for comparable positions. Proficiency re-evaluations are performed and documented when applicable renewal of qualification measures is warranted.

18.0 INTERNAL AUDITS, continued.

18.4 Statement of Verification of Qualifications of Audit Personnel (continued).

JLS&A may periodically utilize industry consultants for audits. Their individual qualifications will be reviewed and approved by JLS&A in accordance with formally established procedures.

18.5 Statement of Verification of Pre-Audit Conferences.

JLS&A's pre-audit conferences will be held either before, or at the beginning, of a scheduled audit. Completion dates for the conclusion of the audit will be established at this conference.

JLS&A's audits are implemented using a documented plan that includes the audit scope, requirements, audit personnel, activities to be audited, organizations to be notified, schedules, documents to be reviewed and applicable written check lists. Audit teams are formed prior to or at the beginning of a scheduled audit, utilizing personnel with no direct responsibility for the activity being evaluated.

18.6 Statement of Verification of Post-Audit Conferences.

JLS&A's post audit conferences are scheduled and conducted between management and audit team(s) to present and review audit results. During this conference the management of the organization audited is provided the opportunity to discuss the specific audit findings, in order to understand; clarify, provide additional records, etc.; resolve any audit findings disagreements, or misunderstandings prior to the issuance of the formal audit report.

18.7 Statement of Verification of Audit Reporting, Management Review, Response and Follow-up.

Upon completion of audit activities, JLS&A's audit team(s) formally compile and document audit results, including applicable follow-up corrective actions, with distribution to appropriate management. Management, in conjunction with audit team personnel, review the proposed corrective actions respective to the audit findings, to clarify and to resolve any and all concerns related to the corrective actions proposed by the organization being audited.

In the event a JLS&A corrective action can not be determined or implemented in a timely manner, a schedule for implementation and closure dates will be determined by management. Audit teams and management are responsible for the verification and accountability of timely responses and adequate audit reports, responses to findings, closure of corrective actions and the re-auditing of corrective activities taken and completed.