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3.0 THERMAL EVALUATION

This Section identifies, describes, discusses, and analyzes the principal thermal engineering design of the WMG 150B package. Compliance with the performance requirements of 10 CFR 71 (Reference 3-1) is demonstrated. The details of the thermal evaluation are presented in Reference 3-2 and summarized in this section.

3.1 Description of Thermal Design

Four components contribute to the thermal protection of the cask body. These components include (1) the impact limiters which provide thermal protection to the ends of the cask, (2) the secondary lid cover thermal barrier which provides thermal protection to the secondary lid seals, (3) the exterior fire shield which protects the side walls between the impact limiters, and (4) the insulating disk embedded in the bottom plate.

3.1.1 Design Features

Figure 3.1 shows the design features of the components contributing to the thermal protection of the cask. The fire shield is made of 7 gauge (3/16") 316 stainless steel sheet metal. In order to provide an air gap between the cask outer shell and the fire shield, 3/16" diameter carbon steel wires are helically wrapped around the cask outer shell. The fire shield is welded to the cask body at the two ends. Cut-outs are provided in the fire shield in order to wrap around the tie down lugs.

The impact limiters are 11 gauge 316 stainless sheet metal enclosures filled with rigid polyurethane foam which acts as insulation barrier to heat flow. The impact limiters are attached to the cask body with bolted fixtures. The impact limiters remain attached to the cask body during the HAC drop tests (see Section 2.7.1.6). Therefore, they provide thermal insulation to the cask during NCT events and the HAC fire test.

The thermal barrier for the secondary lid is comprised of an 11 gauge circular disc that is 4-7/8" thick with foam around its periphery. This barrier is attached to the top impact limiter and provides thermal insulation for the secondary lid seals during the NCT events and the HAC fire test.

There is also an optional Alumina insulating disk imbedded in the cask bottom plate between the steel outer layer and the lead shield to protect the bottom plate lead shield during the HAC fire test. This disk is 38 inches in diameter and ¼ inch thick.

3.1.2 Content's Decay Heat

The maximum decay heat of the packaged waste is 200 W. In the limiting case thermal analyses 100 W (max) and 0 W (min) are used.

3.1.3 Summary Tables of Temperatures

The maximum temperatures in various important components of the cask during the NCT events are summarized in Table 3-1. Table 3-2 summarizes the maximum temperature in these components during the HAC fire test. The time at which these components achieve the maximum temperature is also identified in Table 3-2.

3.1.4 Summary Table of Maximum Pressures

The summary of maximum pressures during the NCT and HAC fire test are provided in Table 3-3. The details of these pressure calculations are provided in Sections 3.3.2 and 3.4.3 for NCT and HAC fire test, respectively.

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

The material properties of the cask components used in the thermal analysis of the WMG 150B Cask are provided in Tables 3-4 through 3-7.

3.2.2 Component Specifications

The metallic components of the cask are made of different types of steel. Lead is specified to be ASTM B29 commercial grade, chemical lead. The melting temperature is T_m =621.5°F. Non-metallic components of the cask are specified as follows:

- The seals used in the package are GLTS Flouro-elastomer (Viton) compound with working temperature range of -49°F to 400°F.
- Polyurethane foam used in the impact limiters are specified to be 23 lb/ft^3 density General Plastic's FR-3700 or FR-6700 series foam. Glass Transition of foam is T_{GTr} =279°F (Reference 3-3).
- The insulating disk embedded in the cask bottom plate is high purity silica ZIRCAR Alumina Insulation Types ZAL-45 boards (Reference 3-6).

3.3 Thermal Evaluation under Normal Conditions of Transport

The NCT thermal analyses of the cask have been performed using finite element modeling techniques, ANSYS ver.14.0.3 code (Reference 3-7). The verification and validation of the software package is documented in Reference 3-8.

The thermal analysis of the cask is considered as a steady state heat transfer problem of solid body with given boundary conditions as shown in Figure 3-2. The 2D, axisymmetric finite element model consisting of 56,604 (excluding air gaps) elements (ANSYS PLANE55) with small average sizes of finite element, is shown in Figure 3-3 and in Figure 3-4 (for more information see Table 2.7 of Reference 3-2). This selection of the element size results in very fine finite element grids of all the components of the WMG 150B cask. It results in several elements through the thickness of the critical components. Therefore, the grid size used in the model is sensitive enough for computing the temperature distribution in the cask accurately.

The lead shielding in the cask body and the lid is not bonded to the steel, it is free to slide over the steel surface. Accordingly, the interface between the lead and the steel is modeled by pairs of 2-d 3-node thermal contact elements (CONTA172) and 2-d target segments (TARGE169). Heat transfer through contact pair is realized by only heat radiation, i.e. arbitrarily large value of contact resistance is assumed at these interfaces.

The mode of heat transfer into and out of the WMG 150B package is shown in Figure 3-2 for the normal conditions of transport load cases. Reference 3-2 provides complete details and theoretical basis for these heat transfer modes. They are summarized here as follows:

- Natural convection between all the exposed surfaces of the package to the ambient.
- Radiation between all the exposed surfaces of the package to the ambient.
- Radiation across the air-gap between the fire-shield inner surface and the outer shell.
- Solar insolation on the exposed surfaces of the package, as needed.
- Heat flux on the inside surfaces of the cask (cavity).

3.3.1 Heat and Cold

The finite element model described in Section 3.3 is analyzed for the following loading conditions:

- Hot Environment – This load case is based on the requirements of 10 CFR 71.71 (c) (1). The loading includes a 100°F ambient temperature, solar insolation, and maximum internal heat load. This loading is used as one of the extreme initial conditions for the normal conditions of transport (NCT) and hypothetical accident condition (HAC) test evaluation. The temperature distribution in the cask body under this loading condition is shown in Figure 3-5
- Cold Environment – This load case is based on the requirements of 10 CFR 71.71 (c) (2). The loading includes a -40° F ambient temperature, no solar insolation, and maximum internal heat load. This loading is used as one of the extreme initial conditions for the normal conditions of transport (NCT) and hypothetical accident condition (HAC) test evaluation. The temperature distribution in the cask body under this loading condition is shown in Figure 3-6.
- Normal Hot – This load case is based on the requirements of 10 CFR 71.71 (b). The loading includes a 100° F ambient temperature, no solar insolation, and maximum internal heat load. The temperature distribution in the cask body under this loading condition is shown in Figure 3-7.
- Normal Cold – This load case is based on the requirements of 10 CFR 71.71 (b). The loading includes a -20° F ambient temperature, no solar insolation, and maximum internal heat load. The temperature distribution in the cask body under this loading condition is shown in Figure 3-8.

The thermal analysis shows that under the normal conditions of transport there is no reduction in packaging effectiveness. The heat transfer capability of the components is not reduced under NCT and there are no changes in material properties that affect structural performance, containment, or shielding. It has also been demonstrated that the maximum temperature of the accessible portion of the cask body is 162.1°F which is less than 185°F, required by 10 CFR 71.43(g), for an exclusive use shipment.

3.3.2 Maximum Normal Operating Pressure

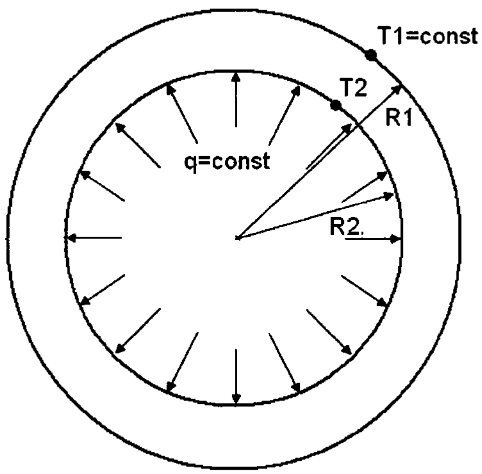
The maximum internal pressure of the cask is calculated assuming that the gas within the cask, a mixture of air, water vapor, oxygen, and hydrogen, behaves as an ideal gas. The maximum pressure is the sum of three components:

1. The pressure due to the increased temperature of the gas in the cavity;
2. The pressure due to water in the cask (vapor pressure of water);
3. The pressure due to generation of gas (hydrogen and oxygen) by radiolysis.

To determine the maximum internal pressure under normal conditions in the cask (MNOP) the temperature of the gas mixture within the cask is first calculated.

3.3.2.1 Estimation of the Cask Cavity Average Temperature

Cask cavity average temperature is calculated, assuming the internal surface temperature of cask is a constant value. To estimate the average air temperature inside the container surfaces, forming a gap between the container and the payload can be considered spherical as shown in the accompanying sketch.



The problem then reduces to a one-dimensional case of heat transfer through the gas gap. Following Reference 3-9 (Section 5, Page 5-5) the temperature of the payload can be written as:

$$T_2 = T_1 - \frac{q}{4\pi\lambda}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \qquad \text{..........Equation (1)}$$

Where, the equivalent thermal conductivity coefficient (λ) is calculated according to the radiation and convection heat transfer;

$$\lambda = \varepsilon_c \cdot \lambda_{air} + \varepsilon \cdot C_0 \cdot \frac{(T_1^4 - T_2^4)}{T_1 - T_2} \cdot (R_1 - R_2) \frac{R_2}{R_1}$$ ....Equation (2)

Where,

ε_c = convection factor (see Chapter 2.3 of Reference 3-9)

λ_{air} = air conductivity (see Table 2.5 of Reference 3-9)

ε = emissivity = 0.8

C_0 = Stefan-Boltzmann Constant = 3.3056×10^{-15} BTU/(in^2-R^4)

Assuming that the payload consists of a steel liner having a diameter of 60" and height of 73", and using the wall temperature of 152°F (corresponding hot environment), Equations (1) and (2) are iteratively solved.

The radius of cask cavity sphere $R_1 = \sqrt{\frac{32.9\cdot(32.9+75.8)}{2}} = 42.29$ in, and

The radius of liner $R_2 = \sqrt{\frac{30\cdot(30+73)}{2}} = 39.3$ in.

On the first iteration the thermal conductivity coefficient is set to $\lambda = \lambda_{air}$. Iteratively the new values of T_2 and λ are calculated. The calculation stops when a convergence of 1% on the previous value has been achieved. The air properties T = 0.5×(T_1+T_2) = 340.8 K are:

- ν_{air} =19.82e-6 m^2/s (0.031 in^2/s)
- λ_{air}=0.02933W/m-K (3.92e-07BTU/s-in-°F).

The resulting values of T_1 and T_2 are:

T_1 = 339.8 K (152°F)

T_2 = 341.8 K (155.5°F)

Cask cavity average volume temperature is defined as:

$$T_{AV} = \frac{\sum_i T_{R_i} V_i}{V},$$

Where,

$$T_{R_i} = T_1 - \frac{q}{4\pi\lambda}\left(\frac{1}{R_1} - \frac{1}{R_i}\right), V_i = \frac{4}{3}\pi(R_i^3 - R_{i-1}^3), V = \frac{4}{3}\pi(R_1^3 - R_2^3)$$

3.3.2.2 Estimation of Cask Cavity Average Pressure

The average temperature of the cask cavity under normal conditions is 153.5°F. The gas mixture temperature in the cavity is conservatively assumed to be 175°F. Initially, cask has an internal pressure equal to ambient pressure, assumed to be 1 atm absolute (14.7 psia) at 70 °F (294.3 K) and defined as P_1 in the equation below. Per the ideal gas law, the increased partial pressure of the air initially sealed in the fixed volume of the cask at the ambient temperature 175 °F (352.6 K) is:

$$P_2 = P_1 \frac{T_2}{T_1} = 14.7 \frac{352.6}{294.3} = 17.61\, psia$$

Since the cask cavity is assumed also to contain water, the vapor pressure of water must be added to the pressure in the cavity. The vapor pressure contributed by water (P_{H_2O}) in the cavity at 175°F (352.6K) is 6.77 psia (interpolated from the table "Saturated Steam Pressure vs. Temperature", (Reference 3-10). Adding the water vapor pressure at 175°F to the partial pressure of the initially-sealed air at this temperature gives:

$$P = 17.61 + 6.77 = 24.38\,psia$$

The cavity cask atmosphere is assumed to contain 5% (vol.) hydrogen gas† (H_2) due to radiolysis of the water. By stoichiometry of the water (H_2O), the cask atmosphere will also contain 2.5% (vol.) oxygen (O_2) gas produced by radiolysis. Noting that partial pressures in an ideal gas mixture are additive and behave the same as ideal gas volume fractions, the partial pressure of combination of hydrogen and oxygen is described by the following equation:

$$P_{H_2+O_2} = (0.05 + 0.025) \cdot \frac{\mathrm{P_{air+H_2O}}}{(1-(0.05+0.025))} = 0.075\frac{24.38}{0.925} = 1.98\,psia$$

Total pressure in the cask at 153.5°F is:

$$P = P_{H_2+O_2} + P_{air+H_2O} = 1.98 + 24.38 = 26.36\,psia$$

Therefore, the MNOP in gage pressure is calculated as:

$$MNOP = 26.36 - 14.7 = 11.66\,psig$$

Table 3-8 lists cask cavity averaged pressure for all NCT cases.

3.3.3 Thermal Stresses

The structural evaluation of the package under the normal condition of transport loading is performed in Section 2.6. All the stresses are within the design allowable values established for the WMG 150B package.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

The thermal analyses of the WMG 150B package under HAC fire conditions have been performed using the ANSYS finite element model, described above. A nonlinear thermal transient analysis was performed to obtain the time-history of the temperature in the package.

The temperature results from the thermal analyses have been used for performing the structural evaluation of the WMG 150B Cask under HAC fire. The volume-average temperature of the cavity during the entire transient has been used for calculating the cask pressure during the HAC fire.

The impact limiters of the WMG 150B package have been shown to remain attached to the cask body during the free drop tests. The effect of these drop tests is a local crushing of the foam, and possible rupture of the impact limiter skin. The puncture drop on the impact limiters will also crush the foam and may also rupture the skin in the vicinity of the impact location.

The rupture of the impact limiter skin after the drop and puncture tests may expose the

† The contents of the WMG 150B Package are limited in such a way that the maximum hydrogen generation during the shipping period will not exceed 5% of the internal volume. The operating procedure in Section 7 includes an evaluation, based on NUREG-6673, to ensure that the 5% limit on the hydrogen generation is satisfied.

polyurethane foam material to the fire. However, the polyurethane fire retardant characteristics will mitigate the effect of the direct exposure to fire due to formation of intumescent char. The intumescent char has the ability to seal large voids which could be caused by the impact damage. The char also provides a secondary thermal barrier which breaks down very slowly at 2000 to 2200°F.

General Plastics has performed tests with a 5 gallon bucket where the open face of the bucket is exposed to direct fire. These tests show the formation of the char that prevents the fire from extending into the underlying foam. These tests also indicate that for the 11¾" foam thickness in the test, the effect of 30-minute fire has a minimal effect on the end opposite the exposed end. These tests were performed for various density foams and it was shown that the effectiveness of the foam is enhanced with the increasing foam density. With 23 lb/ft^3 foam density and a minimum foam thickness of 11¼" the 150B cask package, the effect of exposure of a small portion of foam due to rupture during the drop and puncture test will not have a significant effect on the impact limiter performance during the fire. Therefore, the same boundary conditions at the interface between the cask and the impact limiter as those under the NCT have been used for the HAC fire test analyses.

The direct impact of the puncture bar on the sidewall of the cask will remove the air gap provided between the fire-shield and the cask body. The fire shield may come in contact with the cask body near the impact location. During the HAC fire test extra heat will be input to the cask body locally near the impact point. Analyses have also been performed to evaluate the conditions in which the fire-shield is damaged during the puncture drop test. The fire is assumed to hit the area directly where the puncture bar damages the fire shield.

The details of the analyses, including the assumptions, modeling details, boundary conditions, and input and output data are included in Reference 3-2 for the analyses without the puncture-bar damage and in Reference 3-11 for the analyses with puncture-bar damage.

3.4.1 Initial Conditions

The initial temperature condition, used for the HAC fire test analysis is obtained by running the finite element model with the following boundary conditions:

- Internal heat load – 200 W
- Solar insolation – yes
- Heat Transfer to the ambient by radiation – yes
- Heat transfer to the ambient by natural convection – yes
- Ambient air temperature - 100°F

Since the HAC fire test precedes the free drop test, the impact limiters will undergo some deformation during the drop test. A very conservative assumption on the amount of deformation of the foam is made for the fire test analysis. The largest deformation obtained from the end, side and corner drop analyses, as shown in Figure 3-9, are assumed to have been lost from the impact limiters. Furthermore, this deformation is assumed to be axisymmetric rather than limited to the impact region. With these assumptions considerably more foam volume has been assumed to be crushed during the drop test than will actually happen. The finite element model of the crushed impact limiter is shown in Figure 3-10. The initial temperature distribution in the package,

obtained from analyzing the finite element model, described in Section 3.0, is shown in Figure 3-11.

3.4.2 Fire Test Conditions

The fire transient is run with the body temperature resulting from the above initial conditions. The fire transient is run for 30 minutes (1,800 sec) with the following boundary conditions:

- Internal heat load – 200 W
- Solar insolation – no
- Heat Transfer to the ambient by radiation – yes
- Heat transfer to the ambient by forced convection – yes
- Ambient air temperature – 1475°F

The end of fire analysis of the model is performed with the body temperature resulting from the above fire transient to 1801 sec with the following boundary conditions:

- Internal heat load – 200 W
- Solar insolation – no
- Heat Transfer to the ambient by radiation – yes
- Heat transfer to the ambient by natural convection – yes
- Ambient air temperature – 100°F

The cool-down analysis of the model is performed with the body temperature resulting from the above fire transient to 22,500 sec with the following boundary conditions:

- Internal heat load – 200 W
- Solar insolation – yes
- Heat Transfer to the ambient by radiation – yes
- Heat transfer to the ambient by natural convection – yes
- Ambient air temperature – 100°F

The applied loading on the package during the fire test analysis is shown in Figure 3-12. Figure 3-13 shows the load steps used during the fire transient analysis.

3.4.3 Maximum Temperatures and Pressure

From the analyses of the finite element model, the temperature time-history in various components of the cask is obtained. The fire shield, outer shell, inner shell, lead, and seal were considered as the critical components of the cask. The temperatures at representative locations in these components are monitored during the entire fire and cool down transient analysis.

The time dependent temperatures for the steel components are shown in Figure 3-14. This presents the time-history data at the representative steel nodes of the cask components. The maximum temperature occurs in the fire-shield (wire wrap) ½ hour after fire initiation. The temperatures achieved have no adverse effect on cask integrity.

The time dependent temperatures for the lead shielding are shown in Figure 3-15. This presents the time-history data at the representative lead nodes of the cask components. These temperatures do not include the scenario in which the fire-shield has been damaged during the puncture drop test. This scenario is separately analyzed in Reference 3-11. Figure 3-16 shows the time-history plot of the lead maximum temperature during the fire test of the package in which the fire-shield has been damaged during the preceding puncture drop test. Figure 3-17 shows the temperature distribution in the lead elements at the time when the lead attains the maximum temperature. The maximum temperature of lead (647.1°F), predicted by this model is slightly higher than the lead melting temperature of 621.5°F. It should be recognized that the model has the following conservatism built into it.

- Due to the axisymmetric nature of the model, the indentation of the puncture bar has been modeled as a cylindrical ring rather than a circle. This introduces a much larger amount of heat to the cask during the fire analysis than the actual case.
- The model does not account for the latent heat required for the phase-change of lead during melting. Therefore, the temperature distribution predicted by the model is higher than the actual case.

Additionally, the model predicts the temperature above the melting point over a small region and for a very short time duration.

For reasons described above it is, therefore, concluded that the lead-melting in the WMG cask in the post-puncture drop fire test is not a possibility. In an unlikely event, even if it were to happen, the amount of shielding loss during this drop scenario will be insignificant.

Figure 3-18 gives the temperature time-history data for the non-metal cask components that are not directly exposed to the fire. For these components the maximum temperature is achieved in the primary lid seal ring approximately 13 hours after the fire is initiated. These plots represent the fire test scenario in which the impact limiter has been damaged during the drop tests but no effect of puncture drop test has been included. The analyses in Reference 3-11 include cases in which it is conservatively assumed that the during the puncture drop test the puncture bar pierces through the impact limiter all the way to areas close to the primary and secondary lid seals (see Figure 3-19). For the evaluation of the seal temperature this is a very conservative assumption in which the fire is directly introduced to these areas. Figure 3-20 shows the time-history of the O-ring seal temperatures when the puncture drop damage is assumed to be near the primary lid seal area. The maximum temperature of 367.3°F is calculated in the primary lid O-rings. Figure 3-21 shows the time-history of the O-ring seal temperatures when the puncture drop damage is assumed to be near the secondary lid seal area. The maximum temperature of 361.1°F is calculated in the secondary lid O-rings. The O-ring material will be required to demonstrate no loss of sealing at 380°F for 10 hours (see Section 8 of this SAR). Therefore, the seal integrity will not be affected during the HAC fire test of the WMG 150B package.

The temperature distribution in the WMG 150B package at the end of 30 minute fire is shown in Figure 3-22. Figure 3-23 shows the temperature distribution in the cask at the end of the fire. The lead temperature distribution, when it attains the maximum value, is shown in Figure 3-24. The cask average cavity temperature distribution, when it attains the maximum value, is shown in Figure 3-25.

The HAC fire test analyses presented above have been performed, with the optional thermal insulation disk in the base of the cask, included in the model. In Reference 3-11 HAC fire analysis of the package was performed without including this disk. The time-history of the maximum lead temperature in absence of this disk is shown in Figure 3-26. The lead at the base of the cask attains a

maximum temperature of 610.7°F which is lower than the melting point of lead (621.5°F). Therefore, it is concluded that the option of not including the thermal insulation disk in the design will not have any significant effect on the analyses of this SAR.

The maximum internal pressure in the cask cavity under hypothetical accident conditions (HAC) is calculated assuming that the gas within the cask, a mixture of air, water vapor, oxygen, and hydrogen, behaves as an ideal gas.

The waste container temperature and the cavity average temperature are calculated following the method, and under the assumptions, described in Section 3.3.2.1. The maximum wall temperature of the waste container is calculated to be 220.6°F and the average cavity temperature is calculated to be 219°F.

To determine the maximum internal pressure in cavity the temperature of the gas mixture within the cask was evaluated.

The maximum value of the volume-averaged temperature in the cask cavity is 219°F. Assuming 26.36 psia (see Section 3.3.2.2) exists inside the cask at 175°F (352.6 K), the pressure in the cask at 219°F (377 K), may be calculated by the ideal gas relationship:

$$P_2 = P_1 \frac{T_2}{T_1} = 26.36 \frac{377.0}{352.6} = 28.18\ psia$$

The vapor pressure contributed by water in the cavity at 219°F is 17.37 psia (interpolated from the table Saturated Vapor Pressure vs. Temperature, (Reference 3-10, Page 321), and the partial pressure of combination of hydrogen and oxygen is

$$P_{H_2+O_2} = (0.05+0.025) \cdot \frac{P_{air+H_2O}}{(1-(0.05+0.025))} = 0.075 \cdot \frac{28.18+17.37}{0.925} = 3.69\ psia$$

Therefore, total pressure in the cask at HAC (maximum volume averaged cask cavity temperature243.7 °F) is:

$$P = P_{H_2+O_2} + P_{air+H_2O} = 3.69 + 28.18 + 17.37 = 49.24\ psia$$

and

$$P_{\max} = 49.24 - 14.7 = 34.54\ psig$$

3.4.4 Maximum Thermal Stresses

The structural evaluation of the package under the HAC fire test conditions is performed in Section 2.7.4.3. The maximum thermal stresses in the package with the corresponding allowable stresses are compared in Table 2-30 of this SAR. All the stresses are shown to be within the design limits established for the WMG 150B package.

3.4.5 Accident Conditions for Fissile Packages for Air Transport

Not applicable.

3.5 Appendix

3.5.1 List of References

3-1 Code of Federal Regulations, Title 10, Part 71, *Packaging and Transportation of Radioactive Material.*

3-2 WMG-150B-AR-123-P71, Rev.0, *WMG 150B Cask Thermal Evaluation.*

3-3 General Plastics Manufacturing Company, *Last-A-Foam FR-3700 for Crash & Fire Protection of Nuclear Material Shipping Containers*, June 2003.

3-4 *ASME Boiler & Pressure Vessel Code*, American Society of Mechanical Engineers, New York, NY, 2010 Edition.

3-5 J.P. Holman, *Heat Transfer*, Fifth Edition, McGraw Hill Publishing Company.

3-6 Web-page www.zircarceramics.com. Excerpt included as Attachment 1.

3-7 ANSYS Version 14.0.3, ANSYS Inc., Canonsburg, PA.

3-8 WMG-150B-AR-099-P71, Rev.1, SAEC ANSYS 14.0.3 Verification and Validation Report.

3-9 *Perry's Chemical Engineer's Handbook*, 8th Edition, McGraw-Hill Publishing Company, 2007.

3-10 Chirkin V.S., *Thermo-Physical Properties of Materials for Nuclear Engineering*, Atomizdat, Moscow, 1968, p. 321. Excerpt included as Attachment 2.

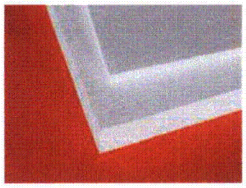
3-11 WMG-150B-AR-124-P71, Rev.0, *WMG 150B Cask Supplemental Thermal Analyses.*

3.5.2 Attachments

3.5.2.1 Attachment 1 - Excerpts from Reference 3-6

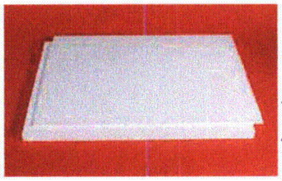
Alumina Insulation Type ZAL-45 & ZAL-45AA

GENERAL INFORMATION



ZIRCAR Alumina Insulations Types ZAL-45 and ZAL-45AA "All-Alumina" boards are high strength, uniform, rigid, refractory structures composed of alumina fibers and high purity inorganic binders. Both have an optimum fiber density of 45 lbs/ft³ (0.72 gm/cc), fine open pore structure and excellent thermal insulating properties. Type ZAL-45 has superior hot strength and dimensional stability to 1650°C (3000°F) and withstands intermittent use to 1700°C (3192°F). Type ZAL-45AA has superior resistance to chemical attack and dimensional stability to 1550°C (2822°F).

The homogeneous microstructure and consistent binder distribution allow these materials to be machined to tight exacting tolerances with ordinary shop tools and equipment. Their superior machineability and dimensional stability plus low heat capacity make them ideal for use as setters, supports and process fixtures in both continuous and batch firing furnaces.



High purity silica is the binder in Type ZAL-45. Silica's strong bond gives ZAL-45 excellent high temperature strength and dimensional stability. Type ZAL-45AA "All Alumina" has a high purity alumina bond making it well suited to use in high vacuum and reducing atmosphere applications where silica cannot be tolerated, such as in bright annealing furnaces with H_2 atmospheres. For more information see "Effects of Hydrogen Gas at 1450°C on Select Fibrous Alumina Insulation Products." They both have high electrical resistivity at elevated temperatures allowing them to be used in direct contact with many different resistance heating elements.

Type ZAL-45 and ZAL-45AA products are pre-fired, contain no organic binders and will produce no smoke or odors when heated. They show excellent resistance to chemical attack and are not affected by oil or water. They are, however, affected by hydrofluoric acid, phosphorous acid and strong alkalis.

CHARACTERISTICS & PROPERTIES

Type	ZAL-45	ZAL-45AA
Typical Composition, %		
Al_2O_3	85	97
SiO_2	15	3
Organic Content	0	0
Density, gm/cc (pcf)	0.72 (45)	
Maximum Use Temp.*, °C (°F)		
Continuous	1650 (3002)	1550 (2822)
Intermittent	1700⁺ (3192)	1600⁺ (2880)
Melting Point, °C (°F)	1870 (3392)	1870 (3392)
Color	White	
Open Porosity, %	70	
Specific Heat, BTU/lb °F (J/kg °K)	0.25 (1047)	
Linear Shrinkage ‡, %		
1 hr. at 1500°C (2732°F)	0	2
1 hr. at 1600°C (2912°F)	3	6
Thermal Conductivity**, (ASTM C177-76) W/m°K (BTU/hr ft² °F/in)		
250°C (482°F)	0.16 (1.10)	
525°C (977°F)	0.20 (1.40)	
800°C (1472°F)	0.23 (1.60)	
1075°C (1967°F)	0.29 (2.00)	
1350°C (2462°F)	0.36 (2.50)	
1650°C (3002°F)	0.43 (3.00)	
Thermal Expansion Coefficient, RT to 1000°C (1832°F)	5.0×10^{-6}/°C (2.8×10^{-6}/°F)	7.5×10^{-6}/°C (4.2×10^{-6}/°F)

3.5.2.2 Attachment 2 – Excerpt from Reference 3-10

В. С. ЧИРКИН

Chirkin V.S. Thermophysical properties of materials for nuclear engineering. Atomizdat, Moscow, 1968

ТЕПЛОФИЗИЧЕСКИЕ СВОЙСТВА МАТЕРИАЛОВ ЯДЕРНОЙ ТЕХНИКИ

СПРАВОЧНИК

АТОМИЗДАТ МОСКВА, 1968

Saturated Steam Pressure vs. Temperature

Таблица 9.15

Давление насыщенного пара воды в зависимости от температуры [291]

T, °K	*p*, *мм рт. ст.*	P, kg/cm2 *p*, *кГ/см²*	*T*, °K	*p*, *мм рт. ст.*	P, kg/cm2 *p*, *кГ/см²*
305	35,7	0,0485	358	434,0	0,5894
307	39,9	0,0542	363	526,0	0,7149
309	44,6	0,0606	368	634,0	0,8619
311	49,7	0,0676	373	760,0	1,0332
313	55,3	0,0752	383	1075,0	1,4609
318	71,9	0,0977	393	1491,0	2,0245
323	92,5	0,1258	403	2030,0	2,7544
328	118,0	0,1605	413	2718,0	3,685
333	149,4	0,2031	423	3581,0	4,854
338	187,5	0,2550	433	4652,0	6,302
343	233,7	0,3177	443	5962,0	8,076
348	289,0	0,3931	453	7545,0	10,225
353	355,0	0,4829	463	9443,0	12,800

Таблица 9.16

Table 3-1

Summary of Maximum NCT Temperatures(1)

Component	Maximum Calculated Temp.		Maximum Allowable Temperature (°F)
	Location(2) (Node Number)	Value (°F)	
Fire-Shield	51818	149.4	185(3)
Outer Shell	9670	149.3	N/A
Inner Shell	63391	153.0	N/A
Poured Lead	64859	151.4	622(4)
Bottom Plate – Outer	5680	149.8	N/A
Primary Lid	16632	150.9	N/A
Primary Lid O-Rings	9134	149.8	N/A
Secondary Lid	39213	152.1	N/A
Secondary Lid O-Rings	12880	150.8	N/A
Rigid Polyurethane Foam	28806	162.1	279(5)
Primary Lid Test Port Seal	30766	149.9	N/A
Secondary Lid Test Port Seal	17402	150.9	N/A
Pressurization Port Seal	27057	150.5	N/A
Cask Cavity	-	153.5	N/A
Waste Container	-	155.5	N/A

Notes:

(1) See Table 2.1 of Reference 3-2 for additional notes.

(2) Node numbers correspond to the FEM described in Reference 3-2.

(3) Based on the requirements of 10CFR71.43(g).

(4) Melting point of lead.

(5) Glass Transition of foam (Reference 3-3).

Table 3-2

Summary of Maximum HAC Temperatures[1]

Component	Maximum Calculated Temp.			Maximum Allowable Temperature (°F)
	Location[2] (Node Number)	Time (sec)	Value (°F)	
Fire-Shield	51595	1800.0	1264.8	N/A
Outer Shell	43718	2040	552.0	N/A
Inner Shell	21982	21258.8	238.3	N/A
Poured Lead	63605	4696.7	372.0	622 [3]
Bottom Plate – Outer	20581	1800.0	873.7	N/A
Primary Lid	16632	54258.8	190.5	N/A
Primary Lid O-Rings	9134	45258.8	189.3	400 [4]
Secondary Lid	39218	48858.8	193.7	N/A
Secondary Lid O-Rings	12880	57858.8	190.2	400[4]
Rigid Polyurethane Foam	24499	1800.0	1453.1	279[5]
Primary Lid Test Port Seal	30766	47058.8	189.2	400 [4]
Secondary Lid Test Port Seal	17402	57858.8	190.1	400 [4]
Pressurization Port Seal	27057	54258.8	189.9	400 [4]
Cask Cavity	-	22008.8	219	N/A
Waste Container	-	22008.8	220.6	250[6]

Notes:

(1) See Table 2.1 of Reference 3-2 for additional notes.

(2) Node numbers correspond to the FEM described in Reference 3-2.

(3) Melting point of lead.

(4) Specified temperature range of O-ring.

(5) Glass Transition of foam (Reference 3-3).

(6) The allowable temperature of 250°F is for the HDPE waste containers.

Table 3-3

Summary of Maximal Pressures during NCT and HAC

Condition	Maximum Pressure (psia)	Reference
NCT	26.36	Section 3.3.2.2
HAC Fire Test	49.24	Section 3.4.3

Table 3-4

Temperature Independent Material Physical/Thermal Properties

Material	Property	Value	Unit
Steel	Density, ρ	0.28[(1)]	lb/in^3
	Density, ρ	0.29[(1)]	lb/in^3
	Emissivity, ε	0.8[(2)]	-
	Emissivity, ε	0.15[(3)]	-
Lead	Density	0.4109[(4)]	lb/in^3
	Specific Heat, C_p	0.0311[(4)]	Btu/lb-°F
	Melting Point	621.5[(4)]	°F

Notes:

(1) From Reference 3-4.

(2) Emissivity of the outside surface of the cask is based on the requirements of 10CFR71.

(3) The emissivity of the steel surfaces can be anywhere between 0.15 and 0.8 depending on its condition. For conservatism both extreme values must be considered in the analyses.

(4) From Reference 3-5.

Table 3-5
Temperature Dependent Metal Thermal Properties

Temp. (°F)	**Thermal Conductivity** (Btu/sec-in-°F × 10^3)			
	ASTM A543 Type B Class 1 & 2(1)	ASTM A240 Type 316(2)	ASTM A540 Gr. B24(1)	ASTM B29 Lead(3)
70	0.549	0.190	0.486	0.465
100	0.546	0.192	0.486	0.461
150	0.544	0.199	0.491	0.455
200	0.544	0.204	0.493	0.448
250	0.542	0.211	0.495	0.441
300	0.542	0.215	0.498	0.434
350	0.539	0.220	0.498	0.427
400	0.535	0.227	0.498	0.420
450	0.532	0.231	0.498	0.414
500	0.525	0.236	0.495	0.408
550	0.521	0.243	0.493	0.401
600	0.514	0.248	0.488	0.395
650	0.507	0.252	0.484	0.392
700	0.500	0.259	0.479	0.392
750	0.493	0.264	0.475	0.392
800	0.486	0.269	0.468	0.392
900	0.470	0.280	0.456	-
1,000	0.456	0.289	0.442	-
1,100	0.442	0.301	0.428	-
1,200	0.424	0.310	0.417	-
1,300	0.384	0.319	0.400	-
1,400	0.354	0.331	0.361	-
1,500	0.350	0.340	0.354	-

Notes:

(1) From Reference 3-4, Table TCD.

(2) From Reference 3-4, Table TCD.

(3) From Reference 3-5, Table A-2.

Table 3-5 (contd.)

Temperature Dependent Metal Thermal Properties

Temp. (°F)	**Specific Heat** Btu/lb-°F		
	ASTM A543 Type B Class 1 & 2[(1)]	ASTM A240 Type 316[(2)]	ASTM A540 Gr. B24[(1)]
70	0.107	0.118	0.106
100	0.108	0.118	0.108
150	0.111	0.121	0.112
200	0.115	0.121	0.115
250	0.117	0.124	0.117
300	0.121	0.124	0.120
350	0.123	0.125	0.122
400	0.126	0.126	0.124
450	0.129	0.127	0.127
500	0.131	0.127	0.129
550	0.134	0.129	0.132
600	0.137	0.129	0.135
650	0.139	0.130	0.138
700	0.142	0.131	0.141
750	0.145	0.132	0.144
800	0.149	0.132	0.147
900	0.156	0.134	0.155
1,000	0.165	0.136	0.163
1,100	0.177	0.137	0.175
1,200	0.189	0.138	0.194
1,300	0.209	0.139	0.223
1,400	0.411	0.141	0.442
1,500	0.156	0.142	0.161

Notes:

(1) From Reference 3-4, Table TCD.

(2) From Reference 3-4, Table TCD.

Table 3-6
Temperature Dependent Air Thermal Properties

Temp ^0F	**Density** $lb/in^3 \times 10^5$	**Specific Heat** Btu/lb-°F	**Thermal Conductivity** $Btu/sec\text{-}in\text{-}°F \times 10^7$
70	4.354	0.2402	3.447
100	4.114	0.2404	3.619
150	3.754	0.2408	3.900
200	3.469	0.2414	4.175
250	3.238	0.2420	4.444
300	3.032	0.2429	4.701
350	2.832	0.2438	4.955
400	2.674	0.2449	5.201
450	2.523	0.2461	5.446
500	2.397	0.2474	5.685
550	2.278	0.2490	5.918
600	2.169	0.2511	6.140
650	2.071	0.2527	6.360
700	1.981	0.2538	6.578
750	1.898	0.2552	6.787
800	1.818	0.2568	6.993
900	1.690	0.2596	7.406
1000	1.572	0.2628	7.801
1100	1.473	0.2659	8.172
1200	1.385	0.2689	8.542
1300	1.304	0.2716	8.894
1400	1.235	0.2741	9.282
1500	1.171	0.2766	9.704

Notes:

(1) From Reference 3-5, Table A-5.

Table 3-7
Temperature Independent Physical/Thermal Properties of Insulation Ring

Material	Property	Value	Unit
Zircar ZAL-45[1]	Density, ρ	0.026	lb/in^3
	Thermal Conductivity, k	2.141×10^{-6}	Btu/sec-in-°F
	Specific Heat, C_p	0.25	Btu/lb-°F

Notes:

(1) From Zircar Ceramics web-page (Reference 3-6) included as Appendix 1 of Reference 3-2.

Table 3-8
Cask Cavity Averaged Pressure

Case	Maximum Calculated Temperature °F	Cask Cavity Average Volume Temperature °F	Total Pressure (absolute) psia
Hot Environment	155.5	153.5	26.36
Cold Environment			
max decay	-7.8	-11.6	13.43
zero decay	-40.0	-40.0	12.59
Normal Hot			
max decay	120.6	118.3	19.14
zero decay	70.0	70.0	15.89
Normal Cold			
max decay	9.9	6.3	13.98
zero decay	-20.0	-20.0	13.19

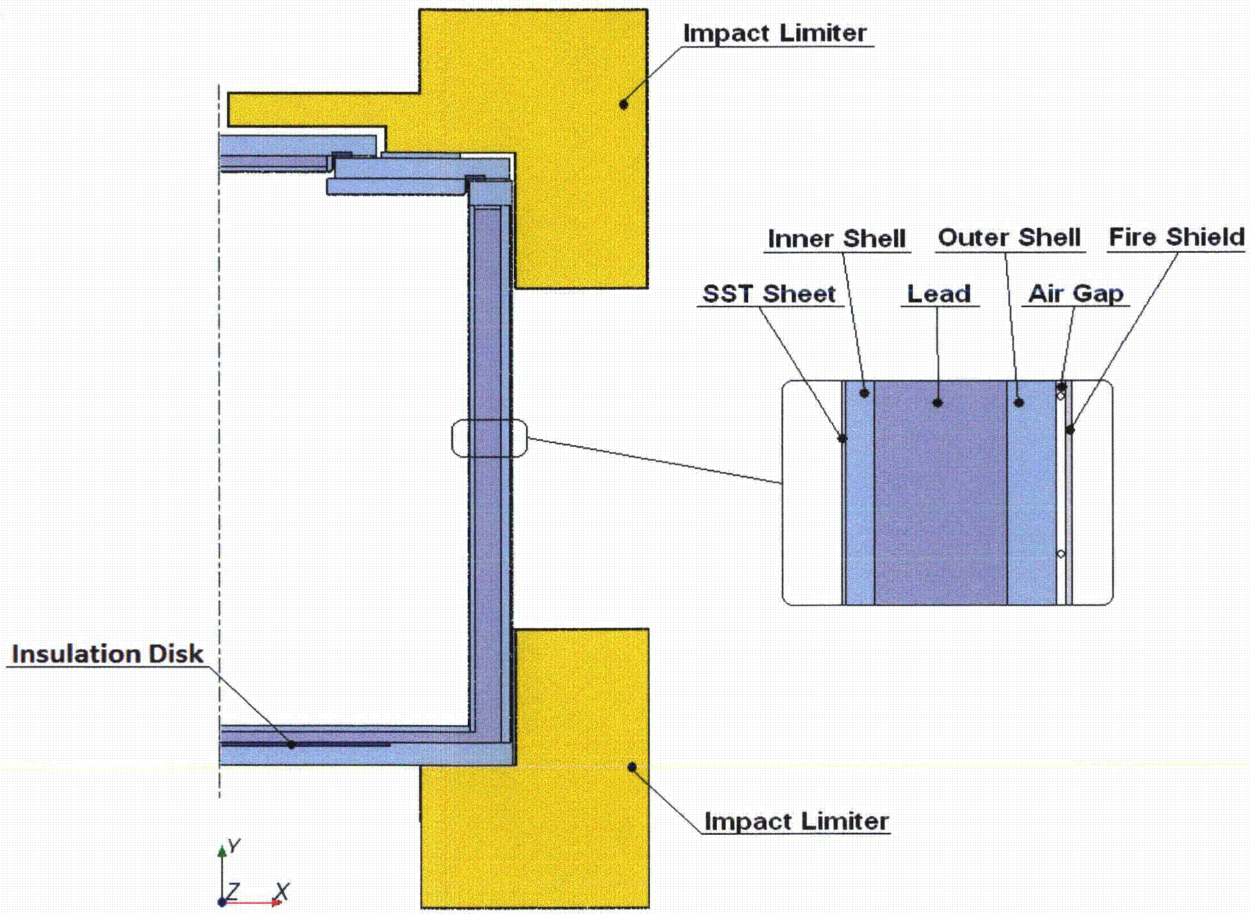


Figure 3-1 – WMG 150B Cask – Thermal Protecting Elements

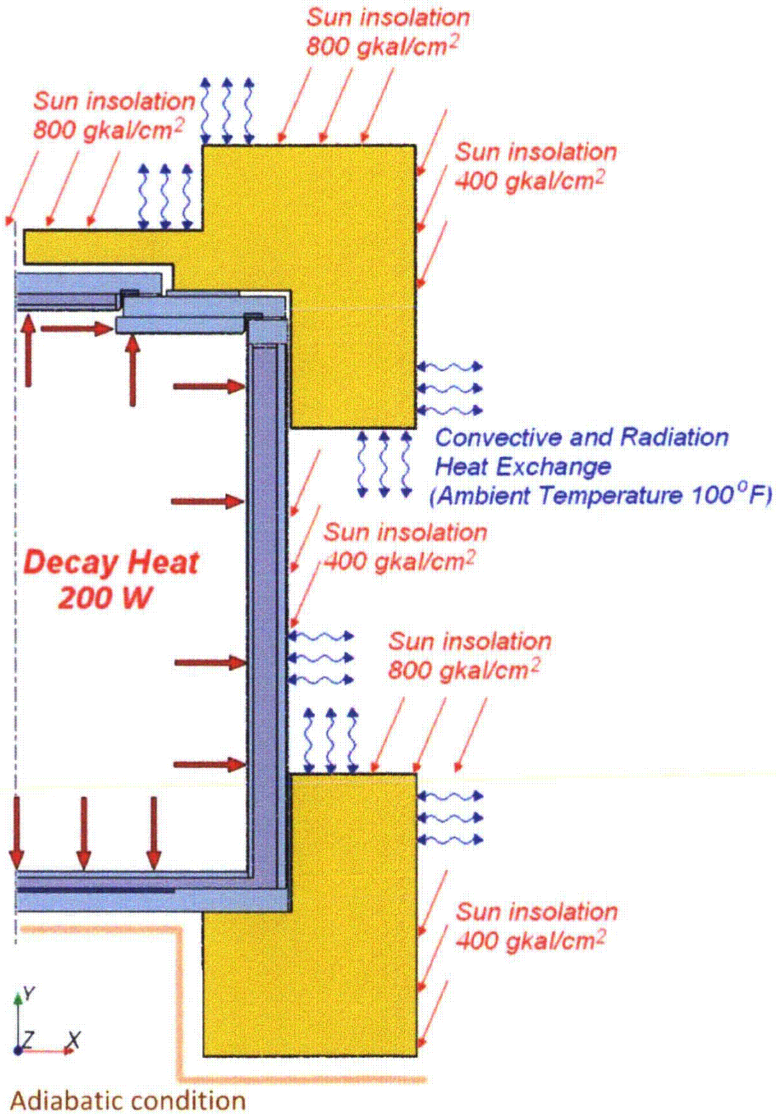


Figure 3-2 – Heat Transfer Modeling of the WMG 150B Package

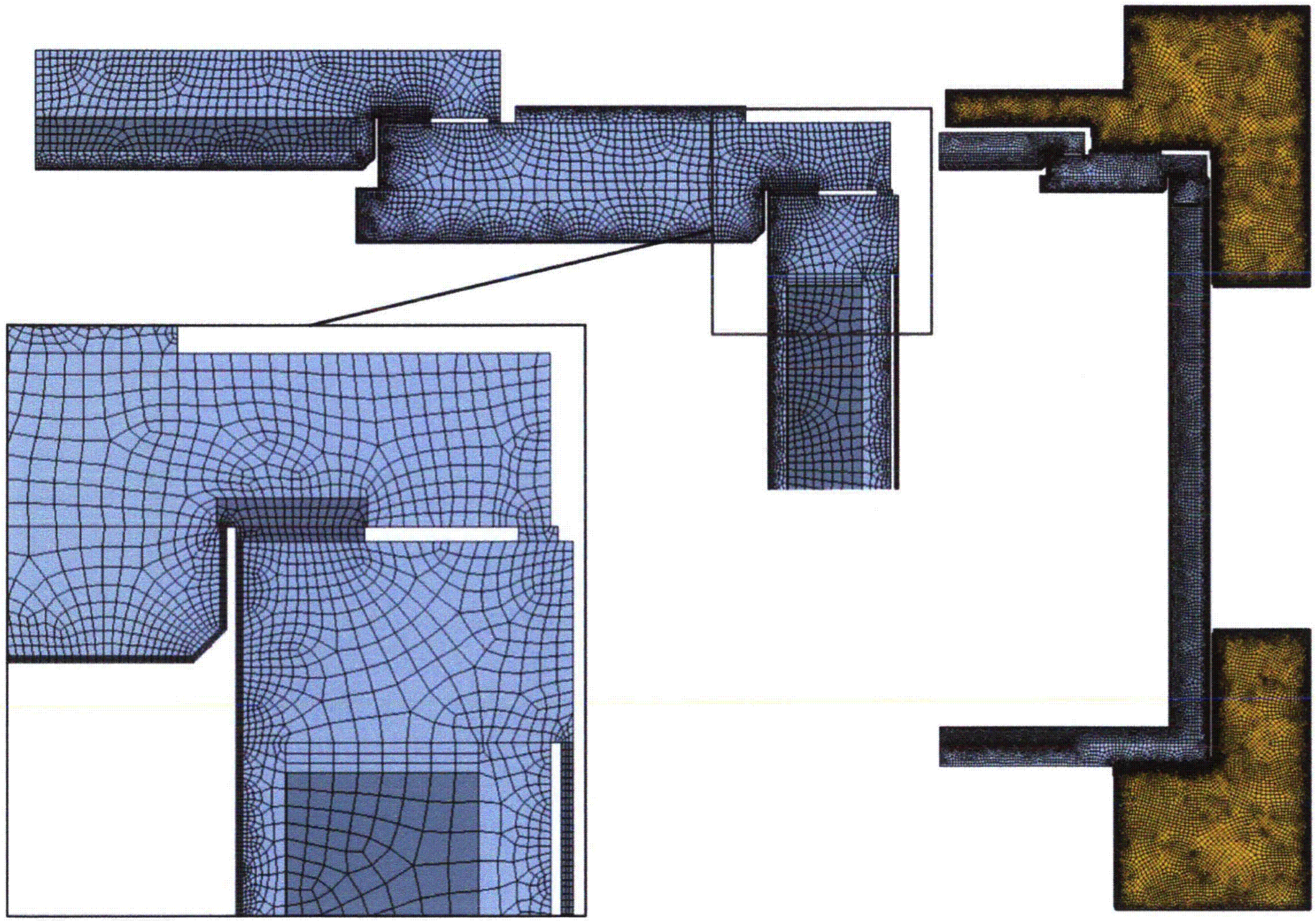


Figure 3-3 – WMG 150B Package - Finite Element Model

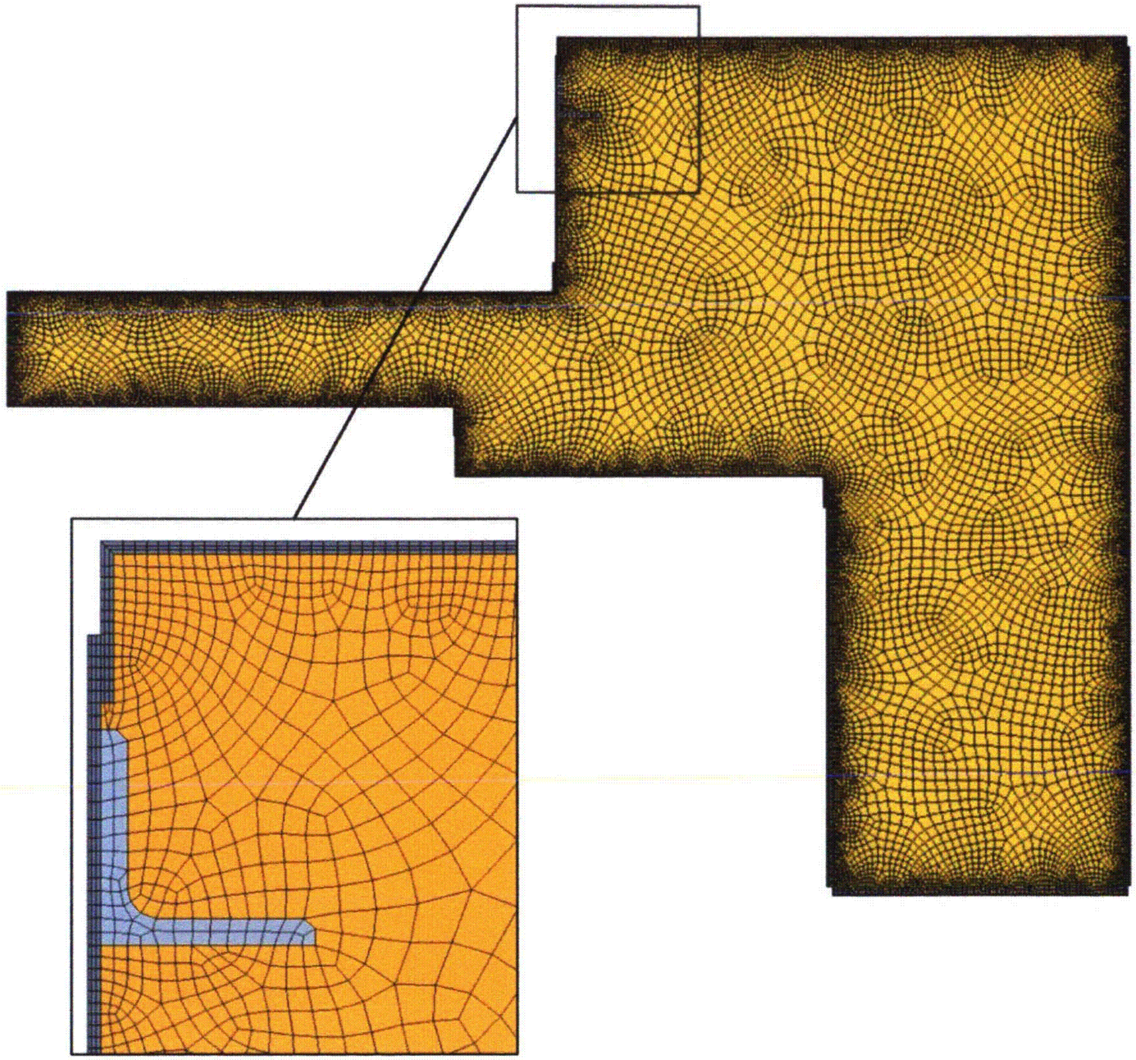


Figure 3-4 – WMG 150B Package – Impact Limiter FEM Detail

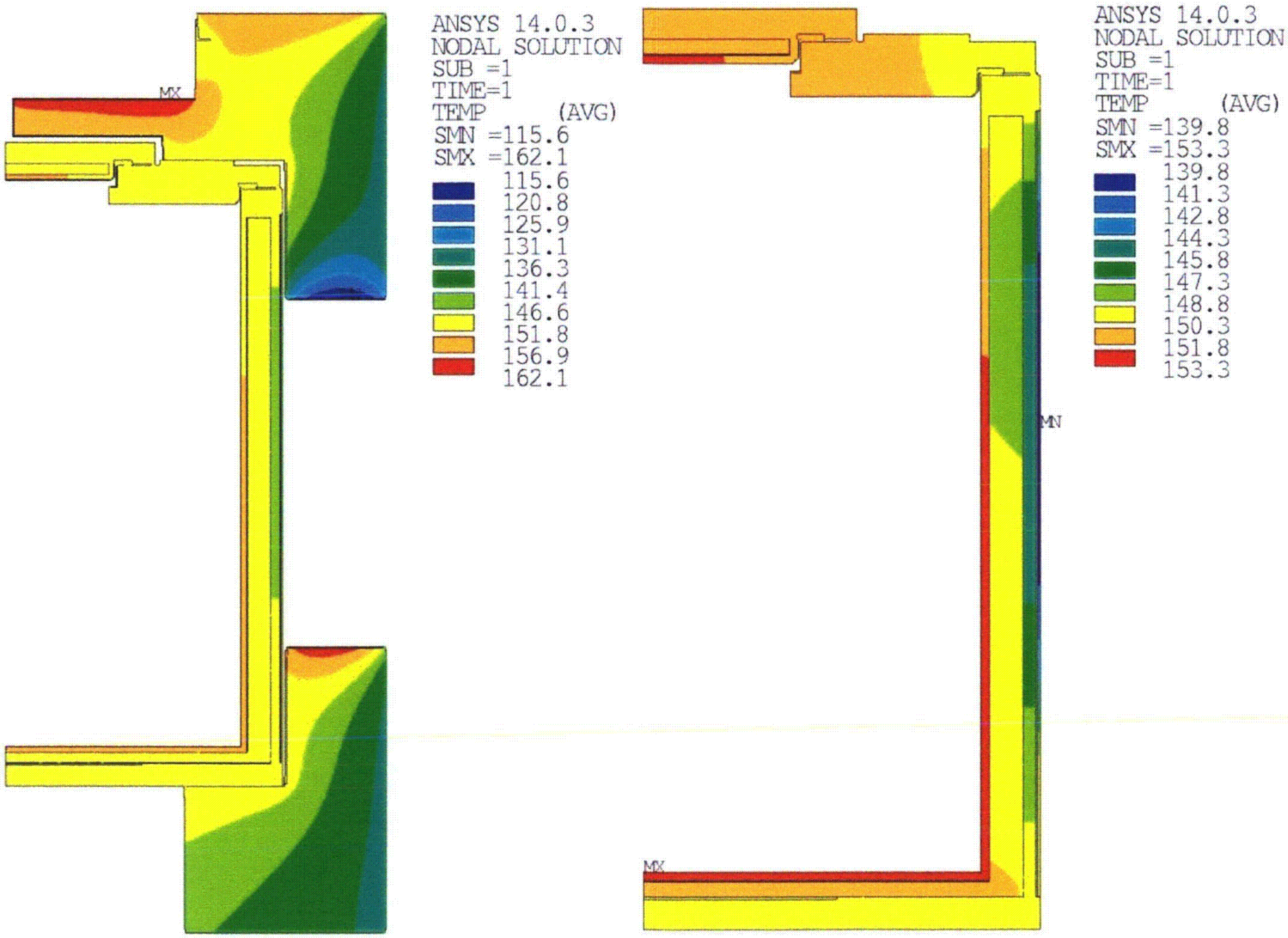


Figure 3-5 – WMG 150B Cask – Temperature Distribution - Hot Environment

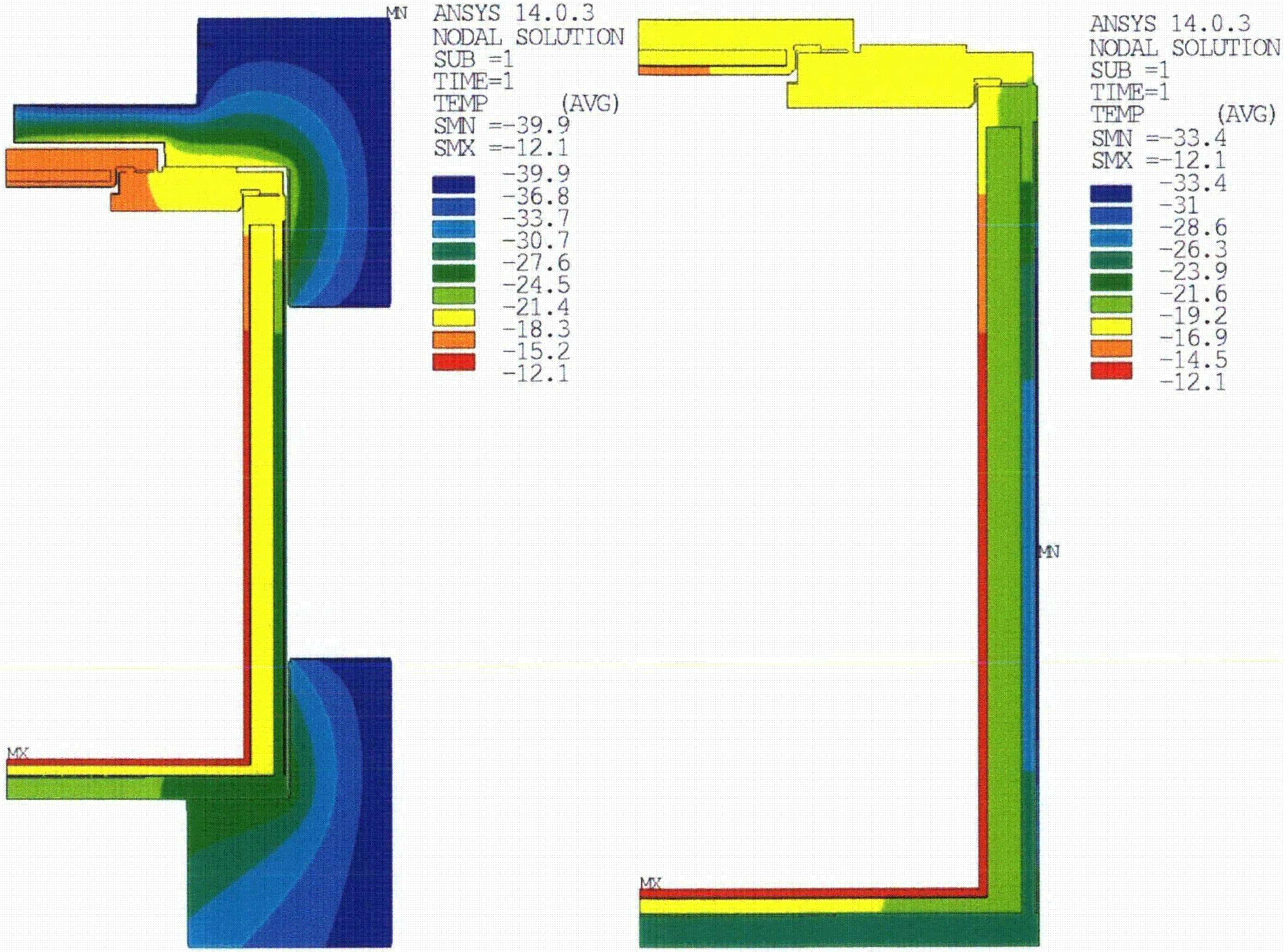


Figure 3-6 – WMG 150B Cask – Temperature Distribution - Cold Environment

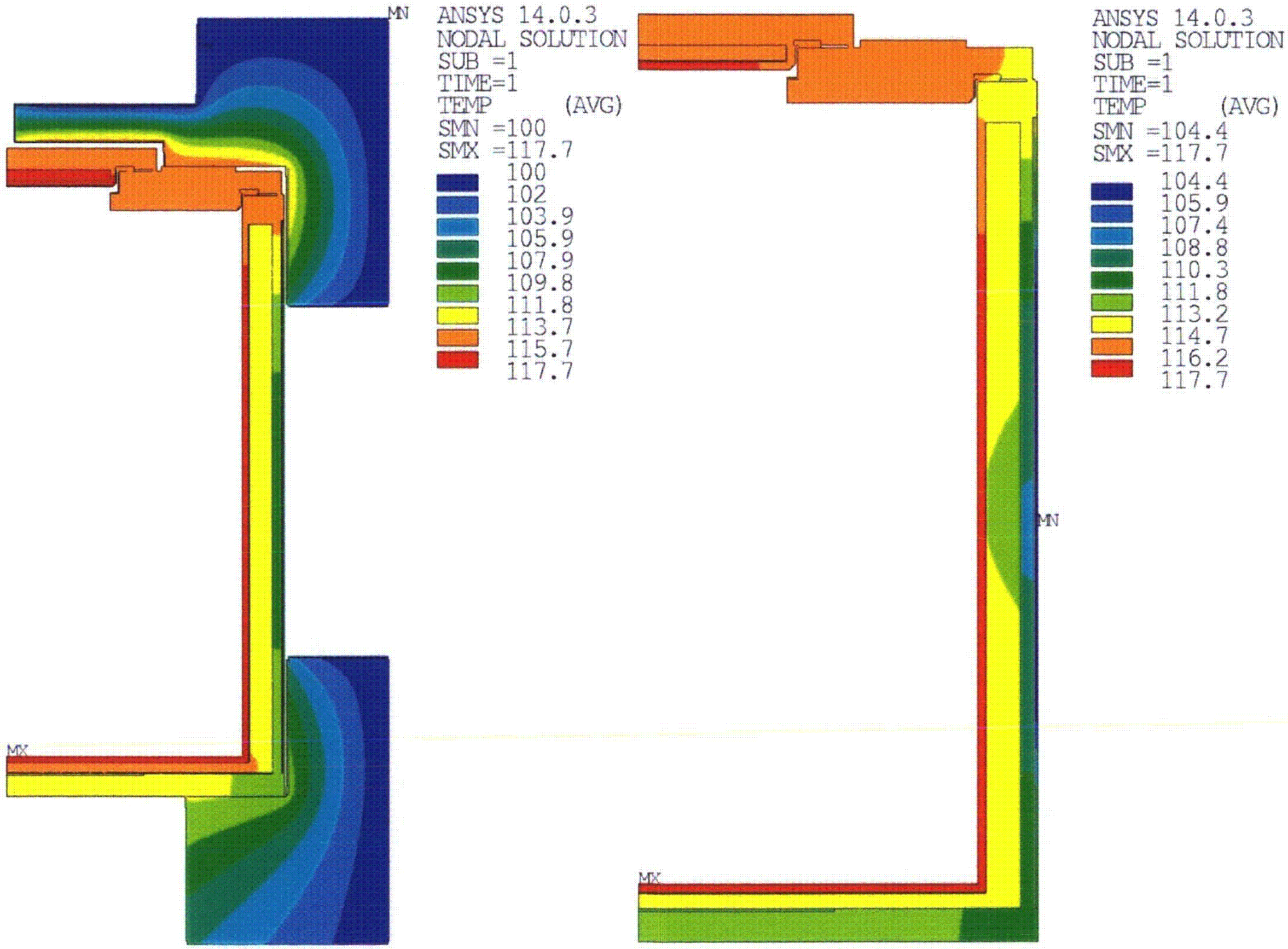


Figure 3-7 – WMG 150B Cask – Temperature Distribution – Normal Hot

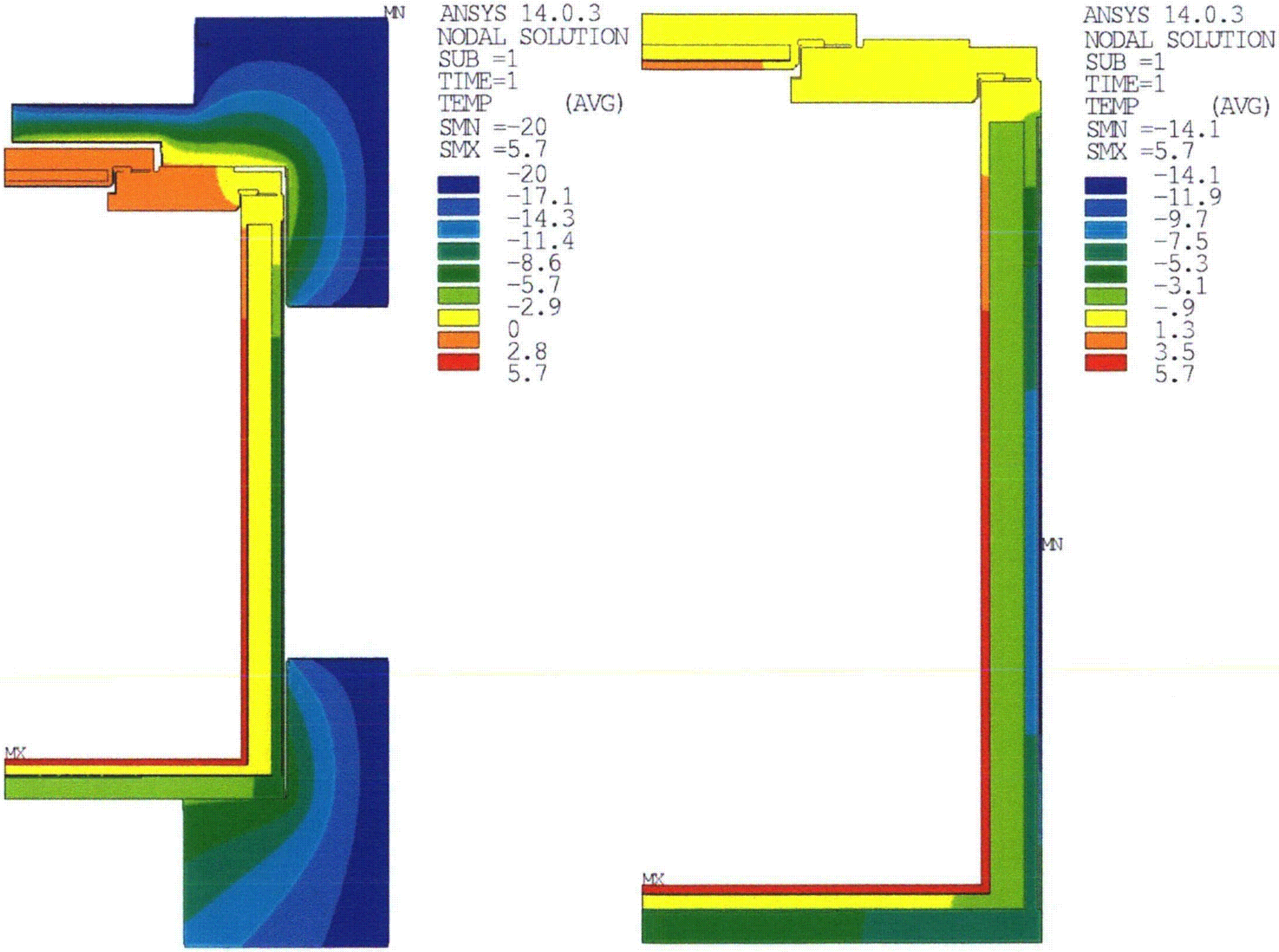


Figure 3-8 – WMG 150B Cask – Temperature Distribution – Normal Cold

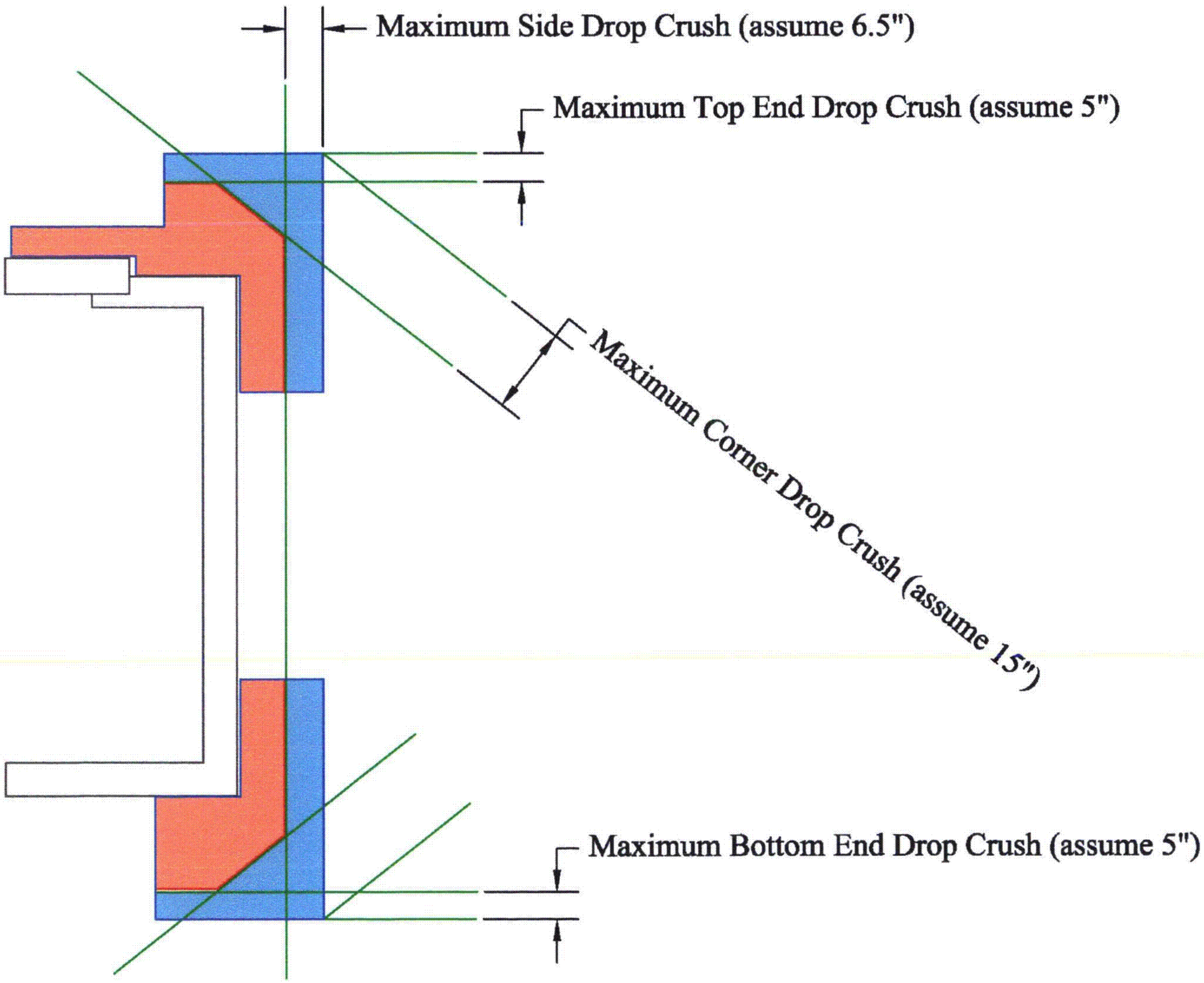


Figure 3-9 – Deformed Shape of the Impact Limiters after Drop Tests

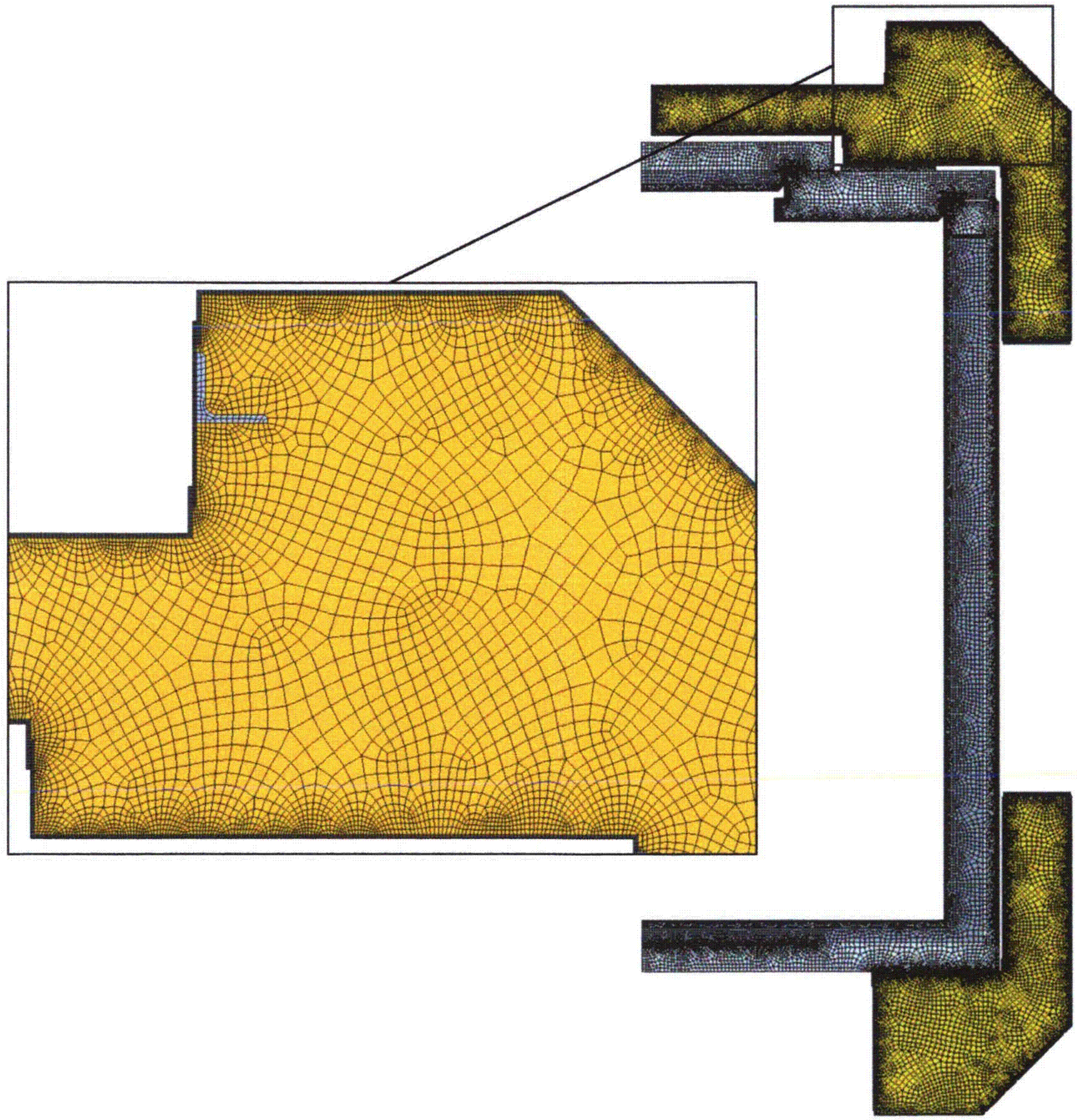


Figure 3-10 – Deformed Impact Limiters Finite Element Model

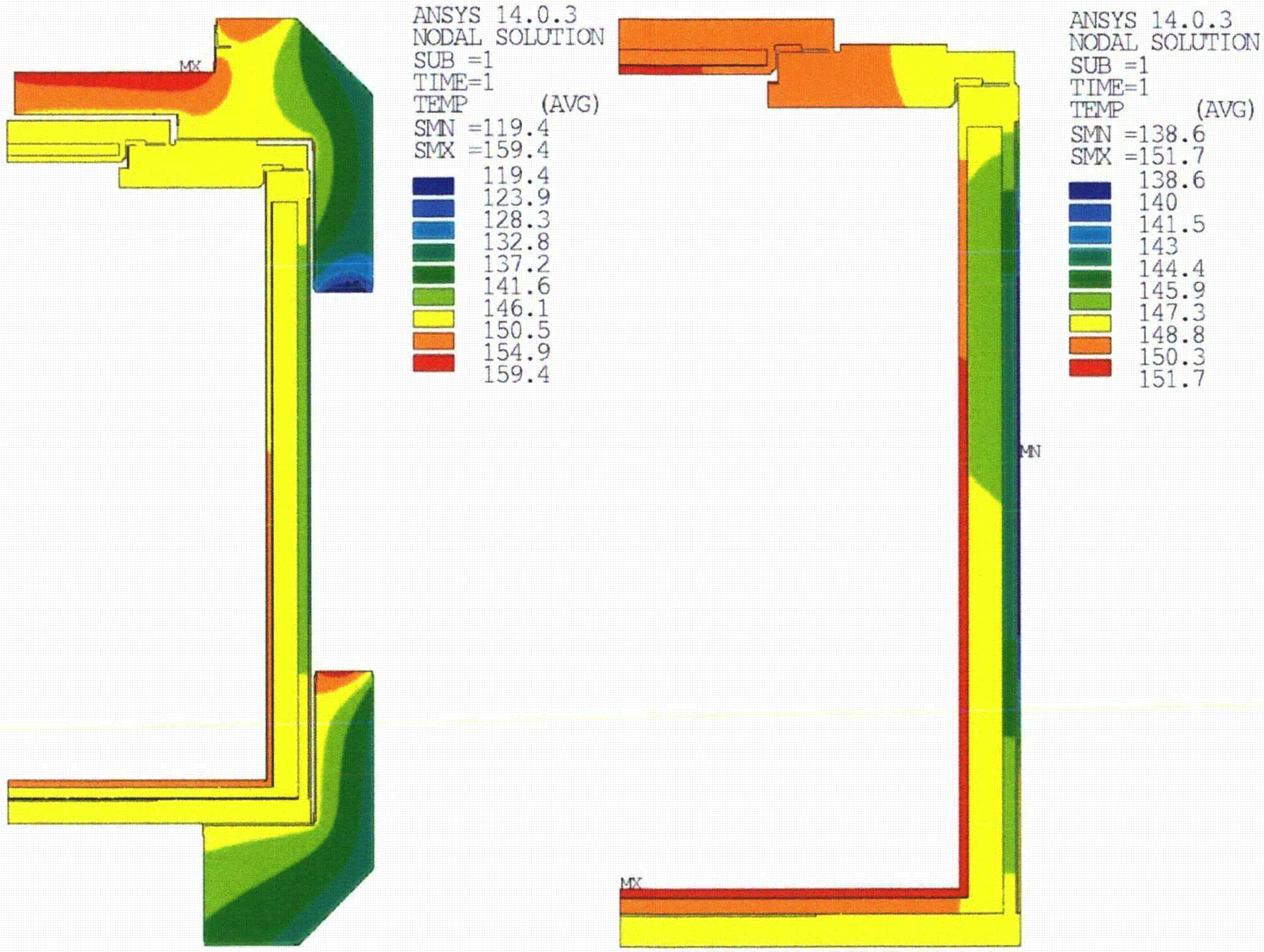


Figure 3-11 – Initial Temperature Distribution with Deformed Impact Limiters

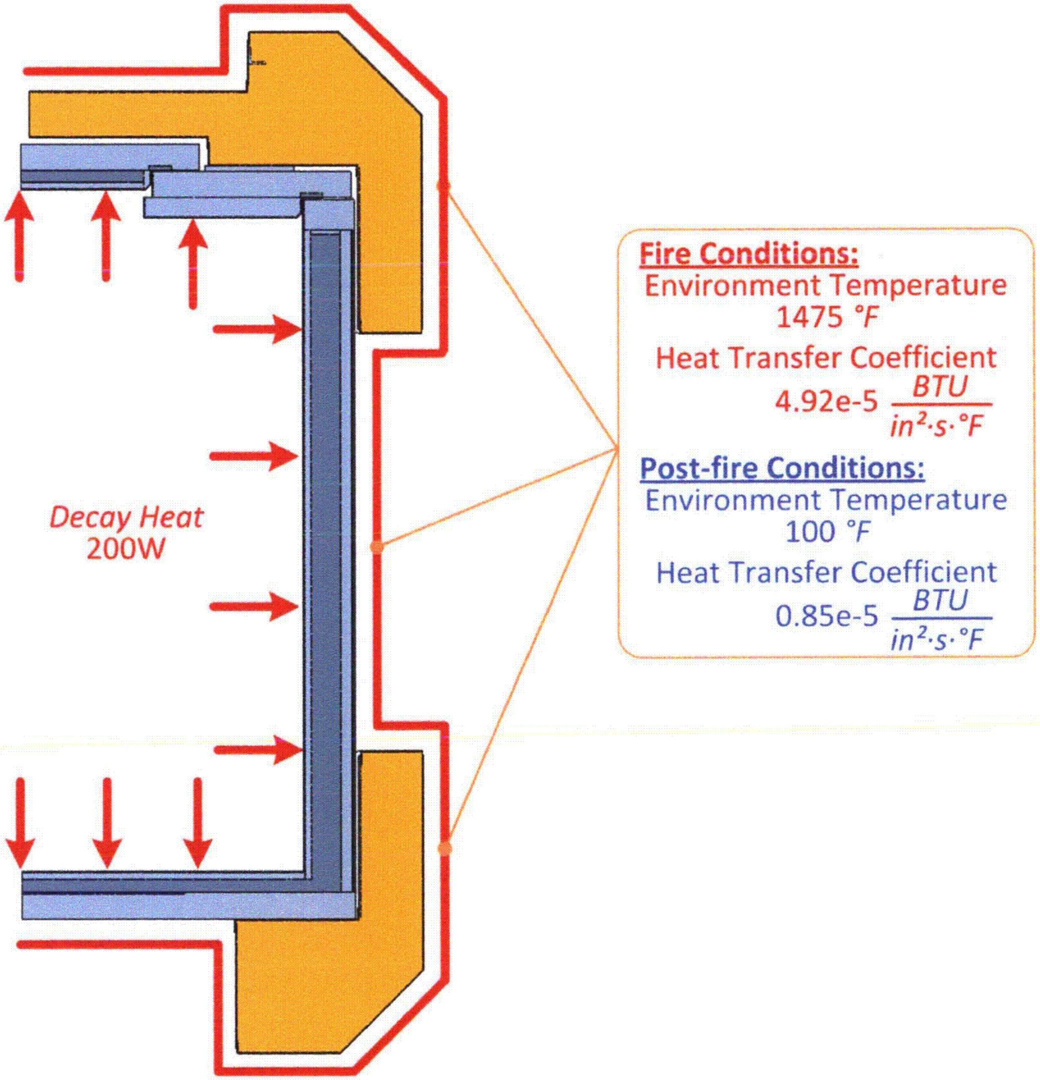


Figure 3-12 – HAC Fire Test Analysis – Boundary Conditions

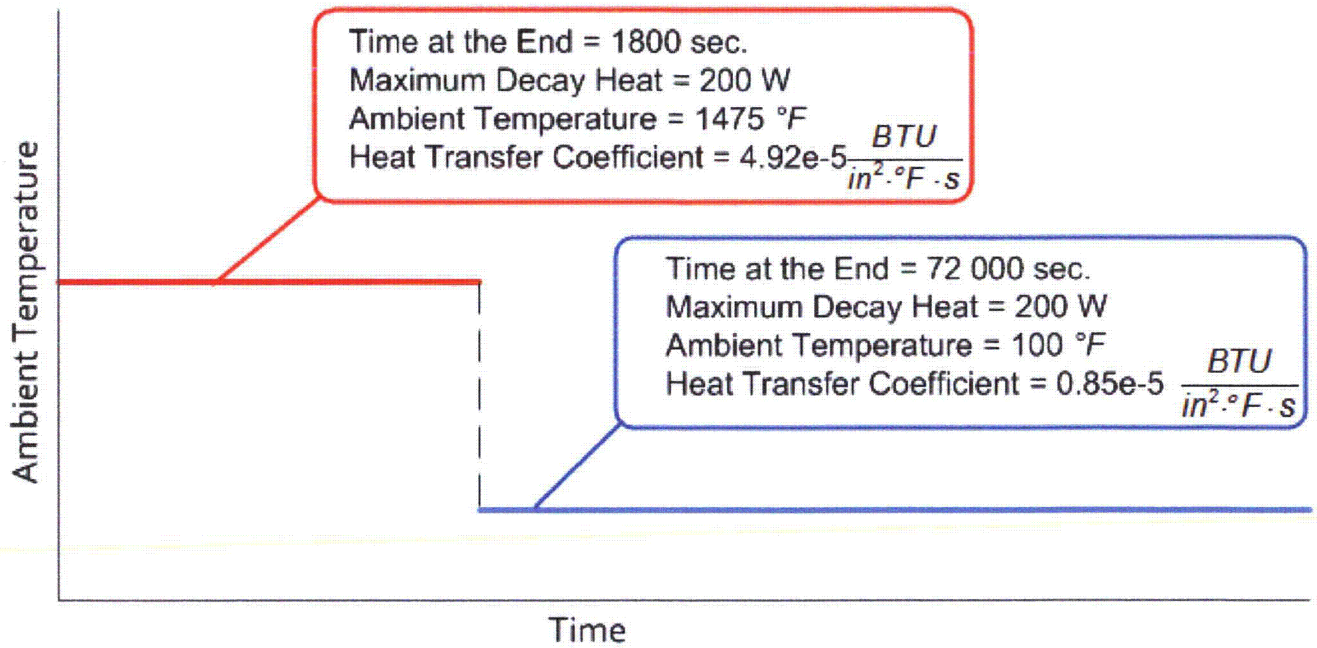


Figure 3-13 – HAC Fire Test Analysis – Load Steps

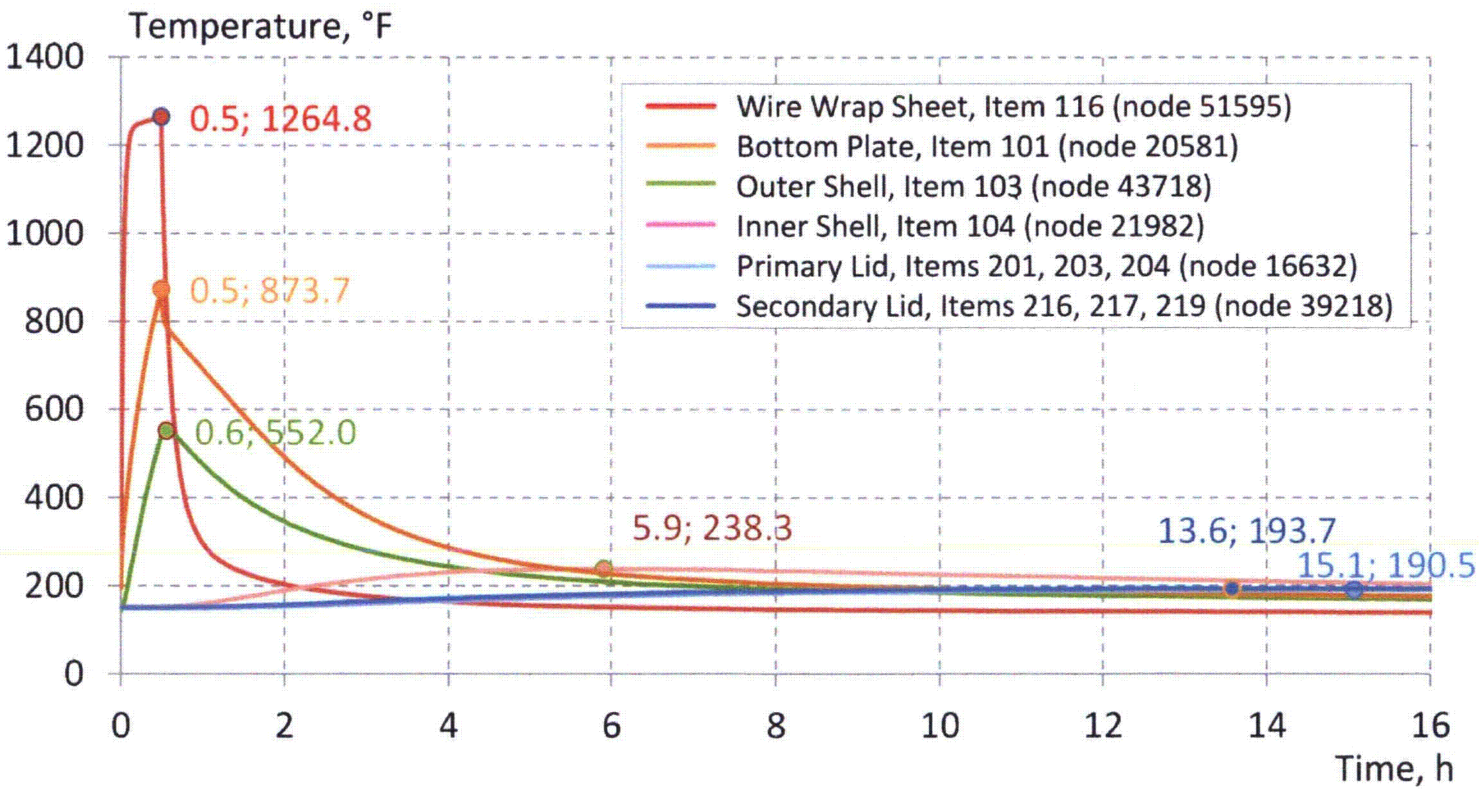


Figure 3-14 – HAC Fire Test Analysis – Temperature Time-History – Metal Components

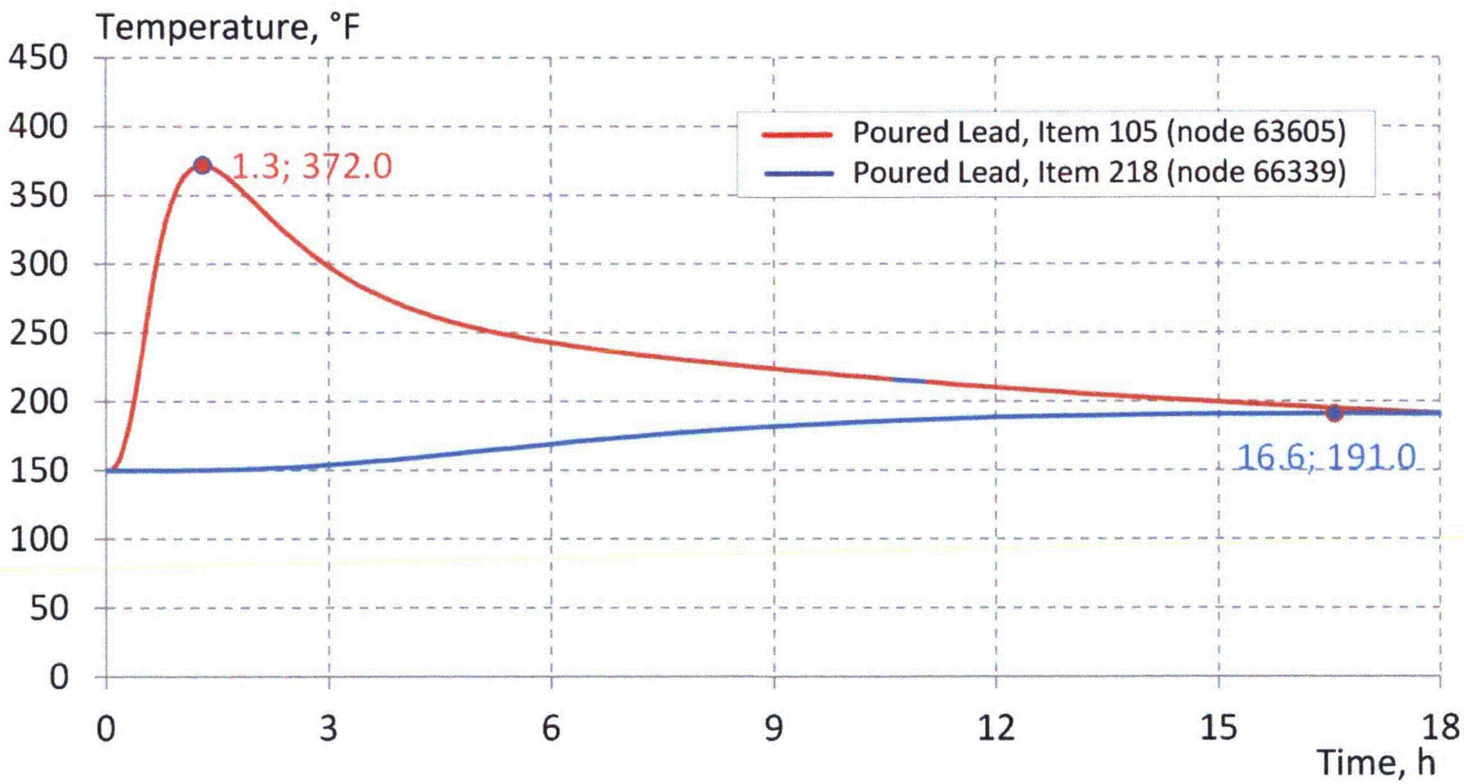


Figure 3-15 – HAC Fire Test Analysis – Temperature Time-History – Lead Components

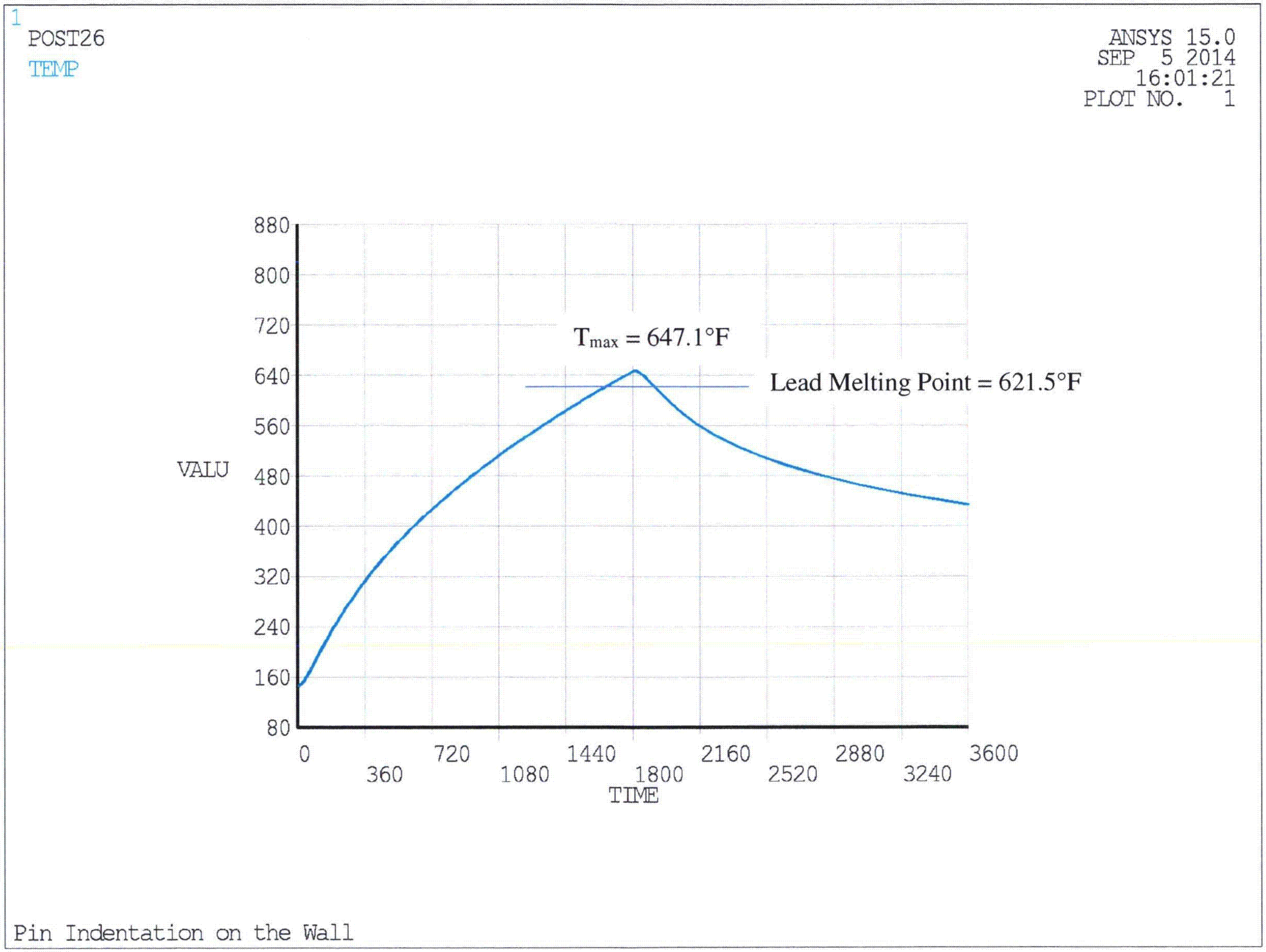


Figure 3-16 – HAC Fire Maximum Lead Temperature Time-History - Puncture Bar Indentation on the Fire-Shield

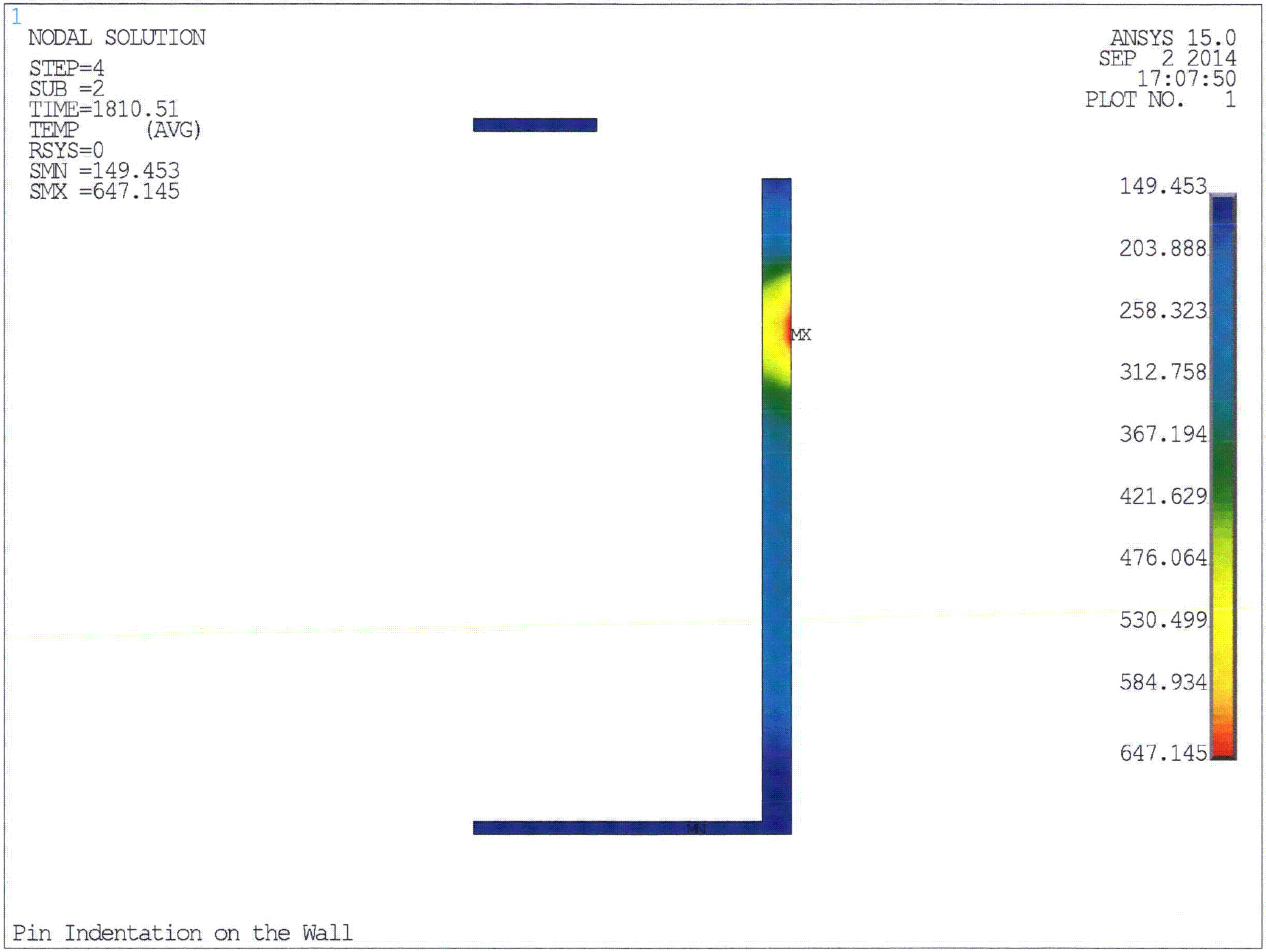


Figure 3-17 – HAC Fire Lead Temperature – Puncture Bar Indentation on the Wall

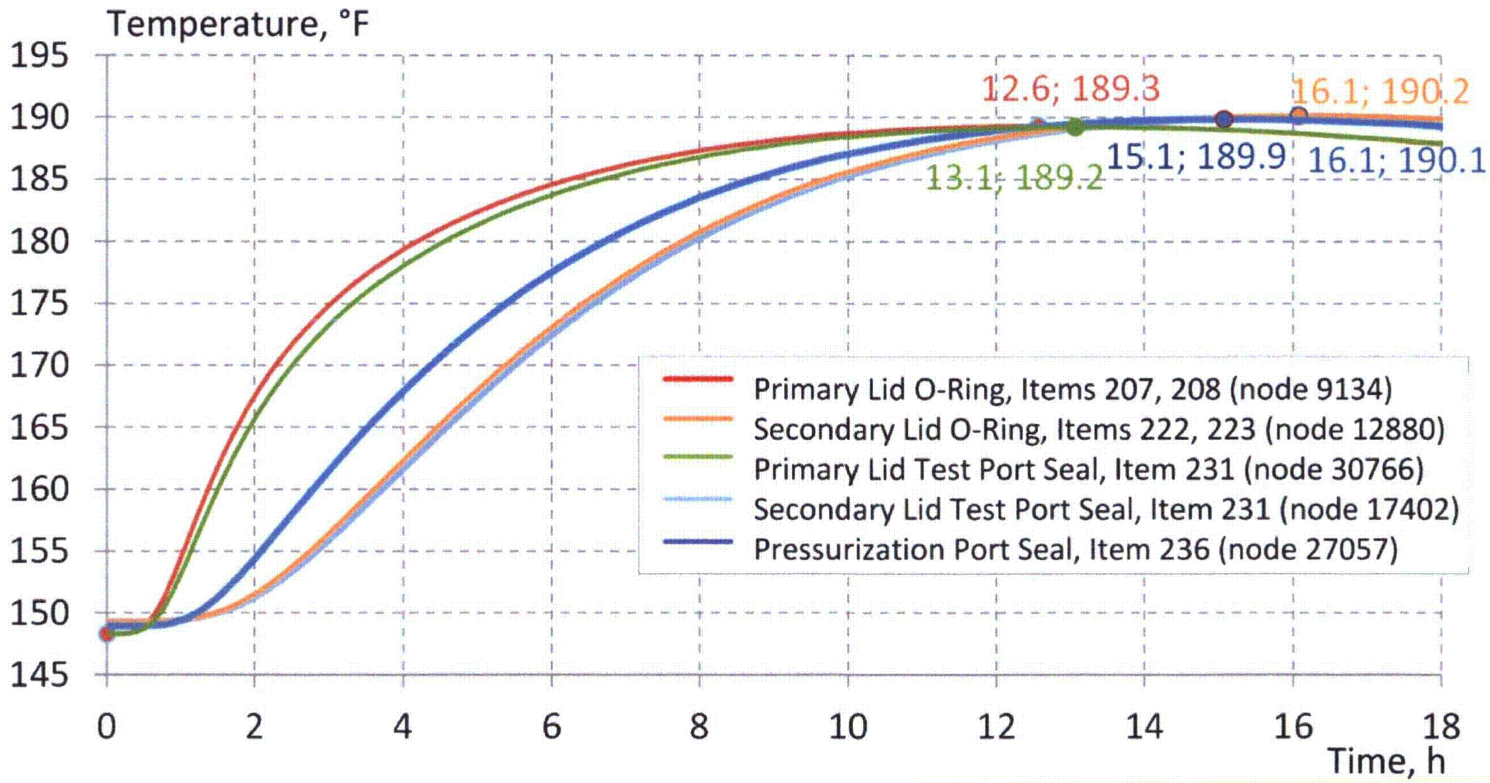


Figure 3-18 – HAC Fire Test Analysis – Temperature Time-History – Non-Metal Components

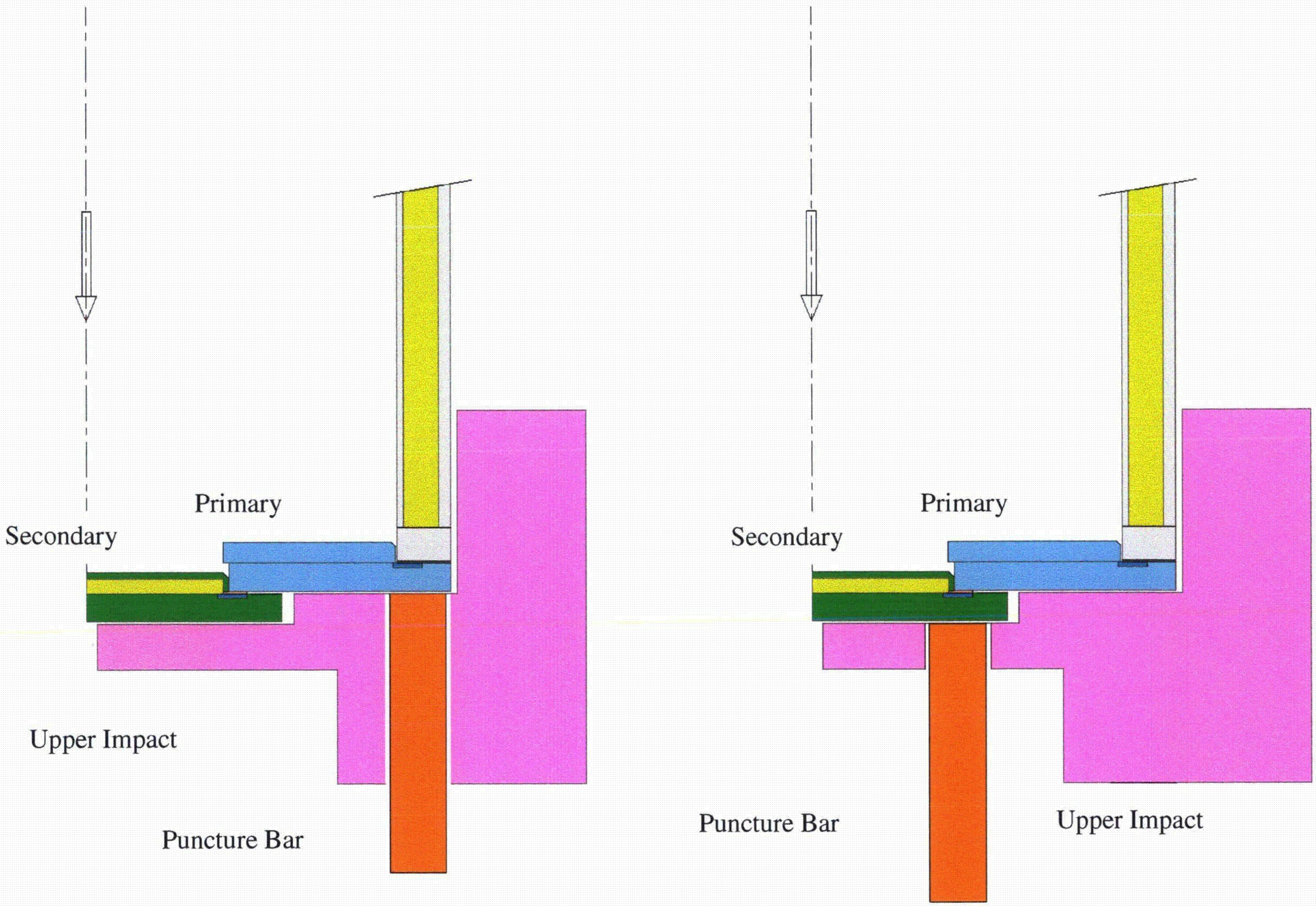


Figure 3-19 – Puncture Bar Impact Limiter Damage Scenarios (Not To Scale)

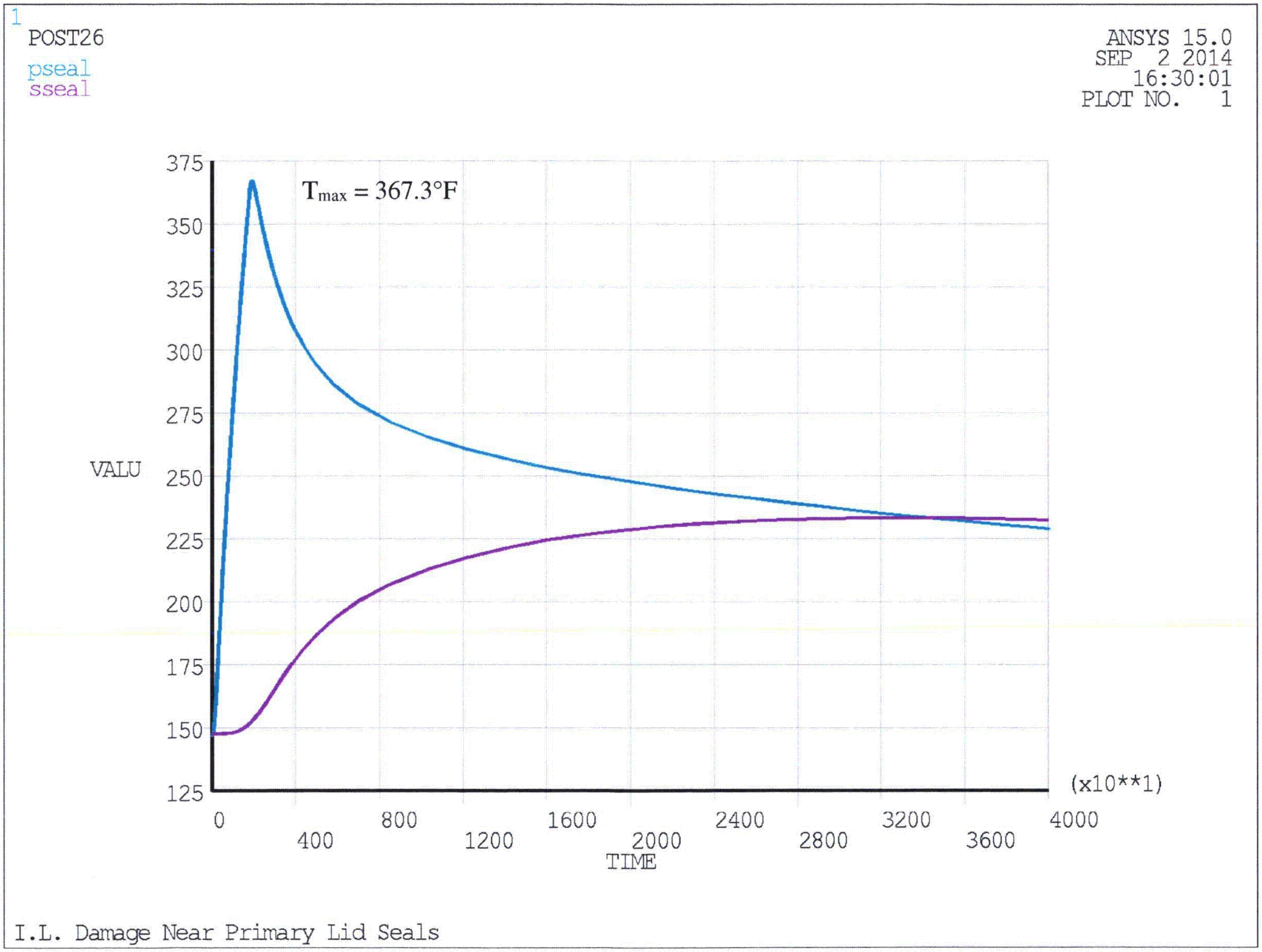


Figure 3-20 – HAC Fire Seal Temperature Time-History – Hole in Impact Limiter near Primary Lid Seals

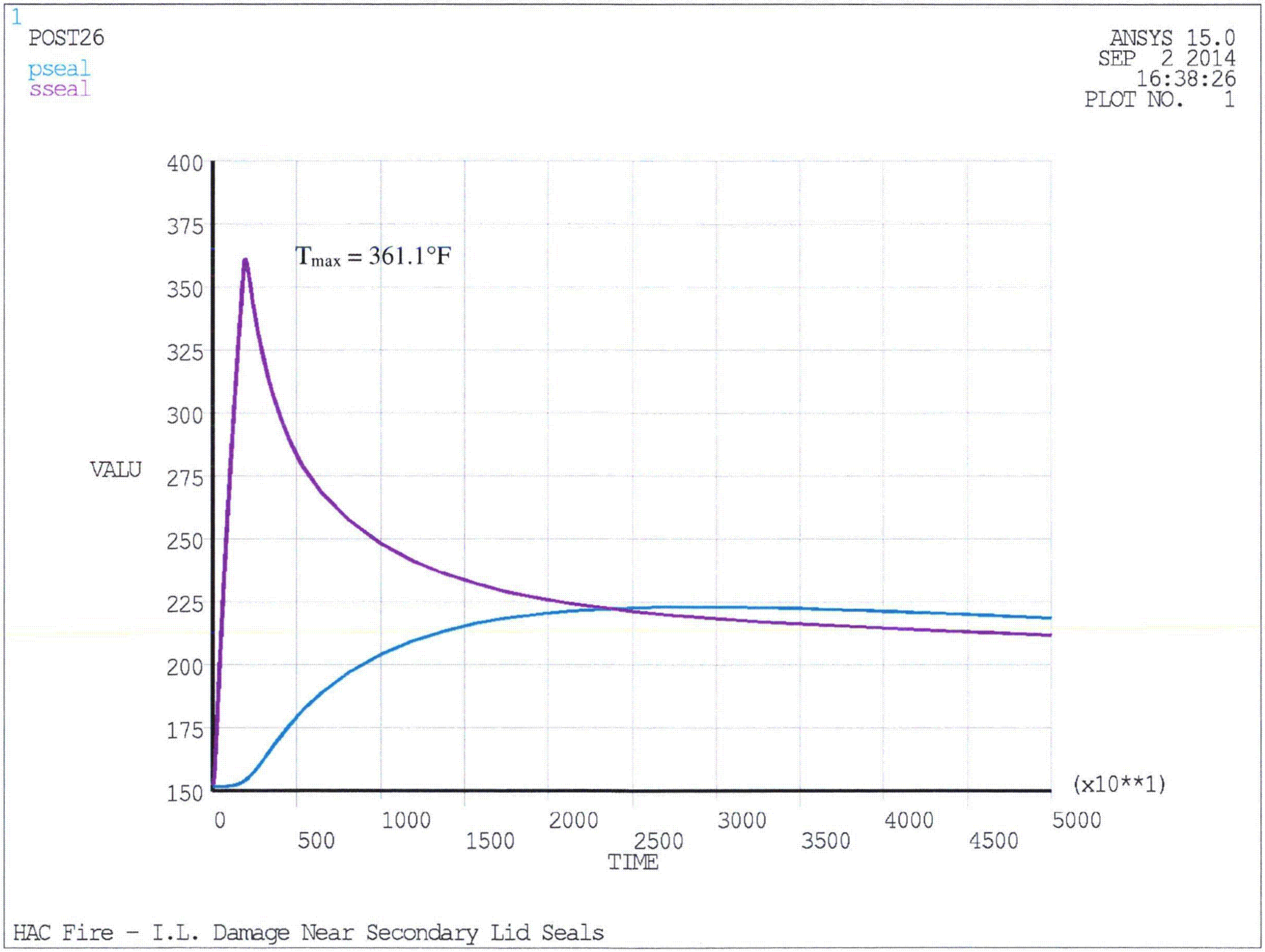


Figure 3-21 - HAC Fire Seal Temperature Time-History – Hole in Impact Limiter near Secondary Lid Seals

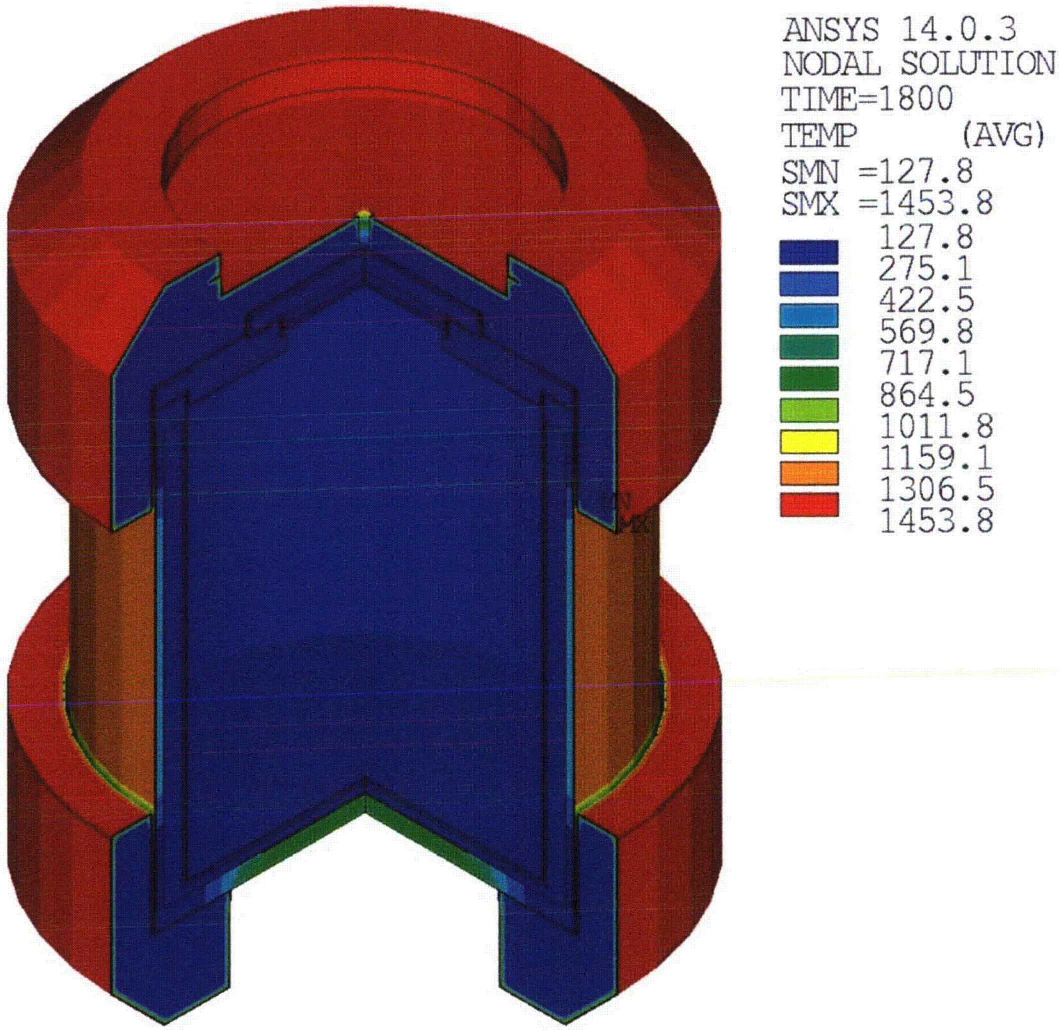


Figure 3-22 – HAC Fire Test Analysis – Package Temperature Distribution at End of Fire (30 Minutes)

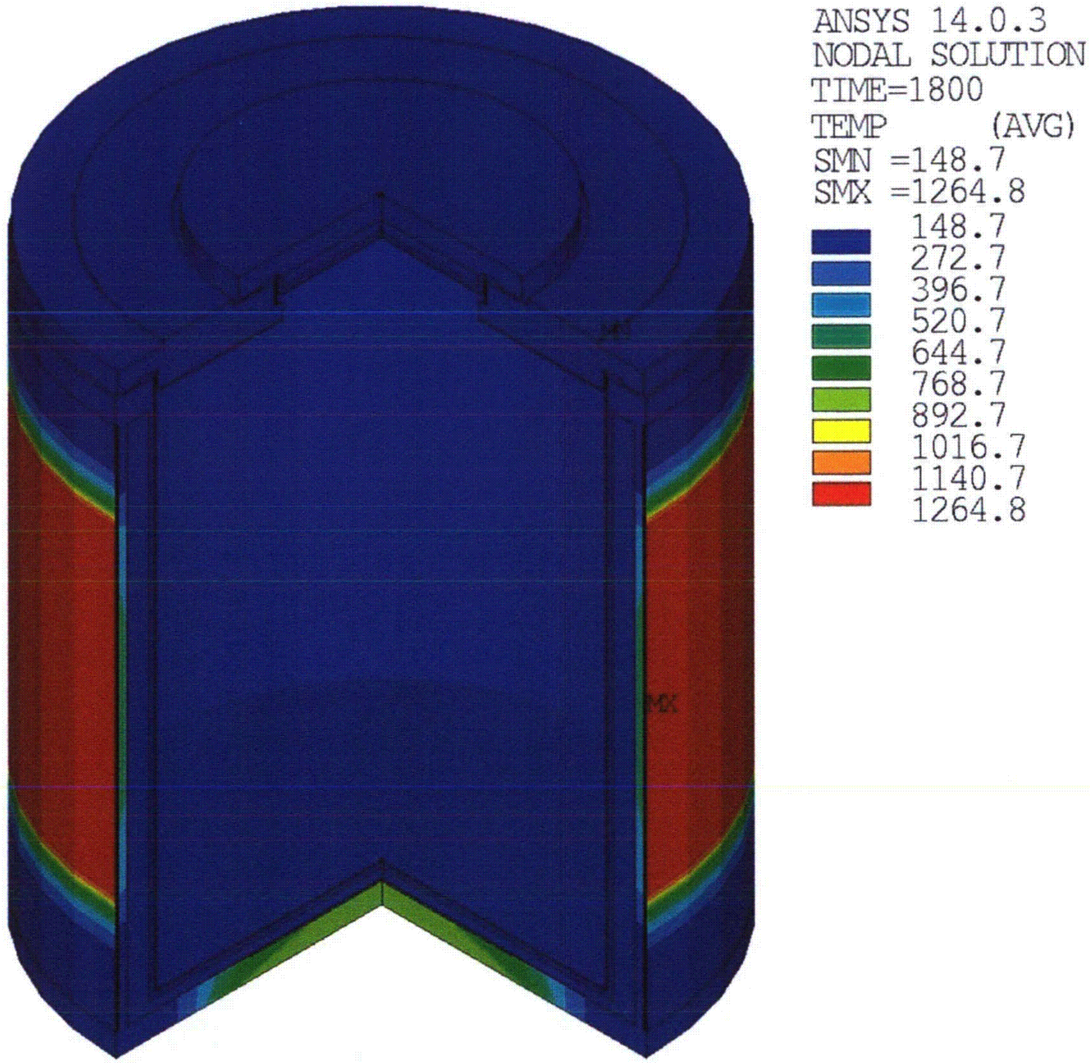


Figure 3-23 – HAC Fire Test Analysis – Cask Temperature Distribution at End of Fire (30 Minutes)

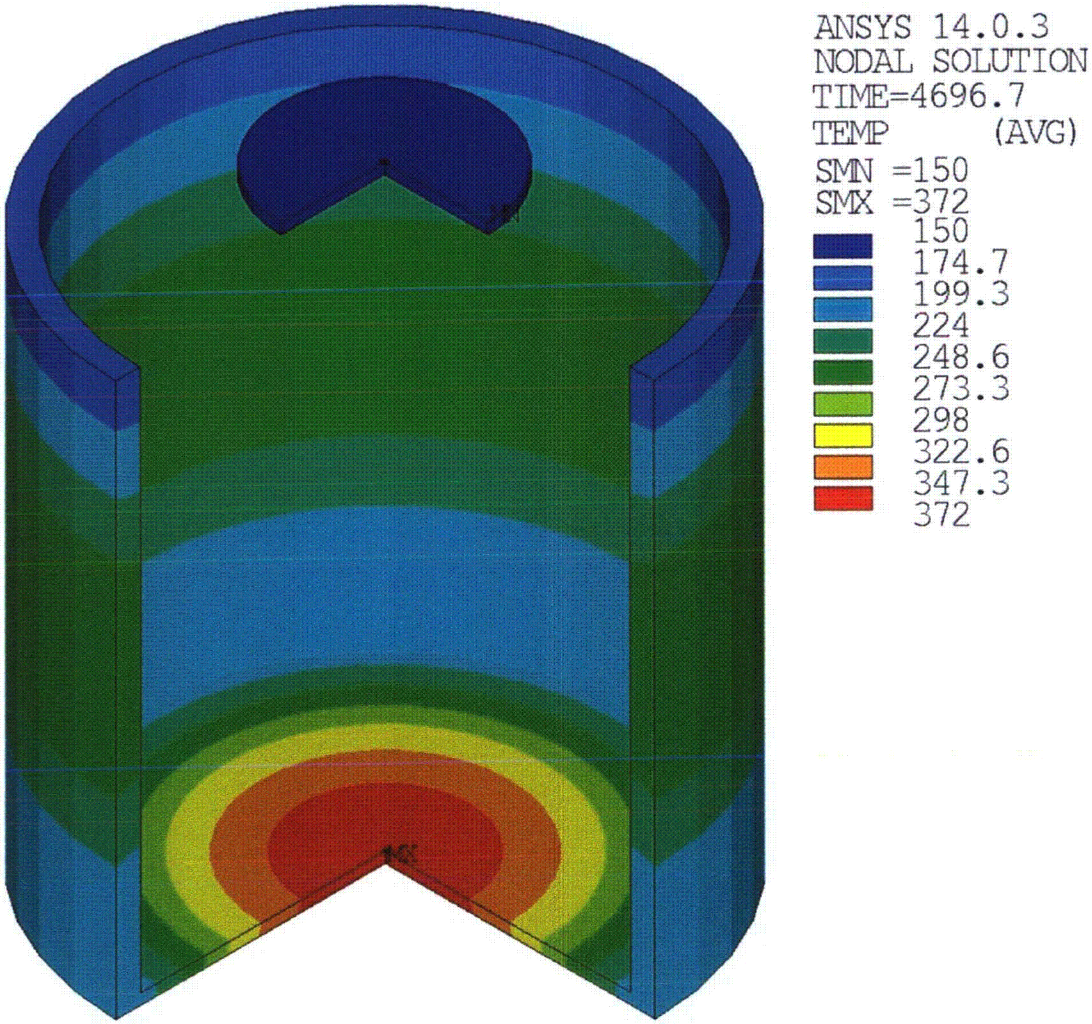


Figure 3-24 - HAC Fire Test Analysis – Maximum Lead Temperature

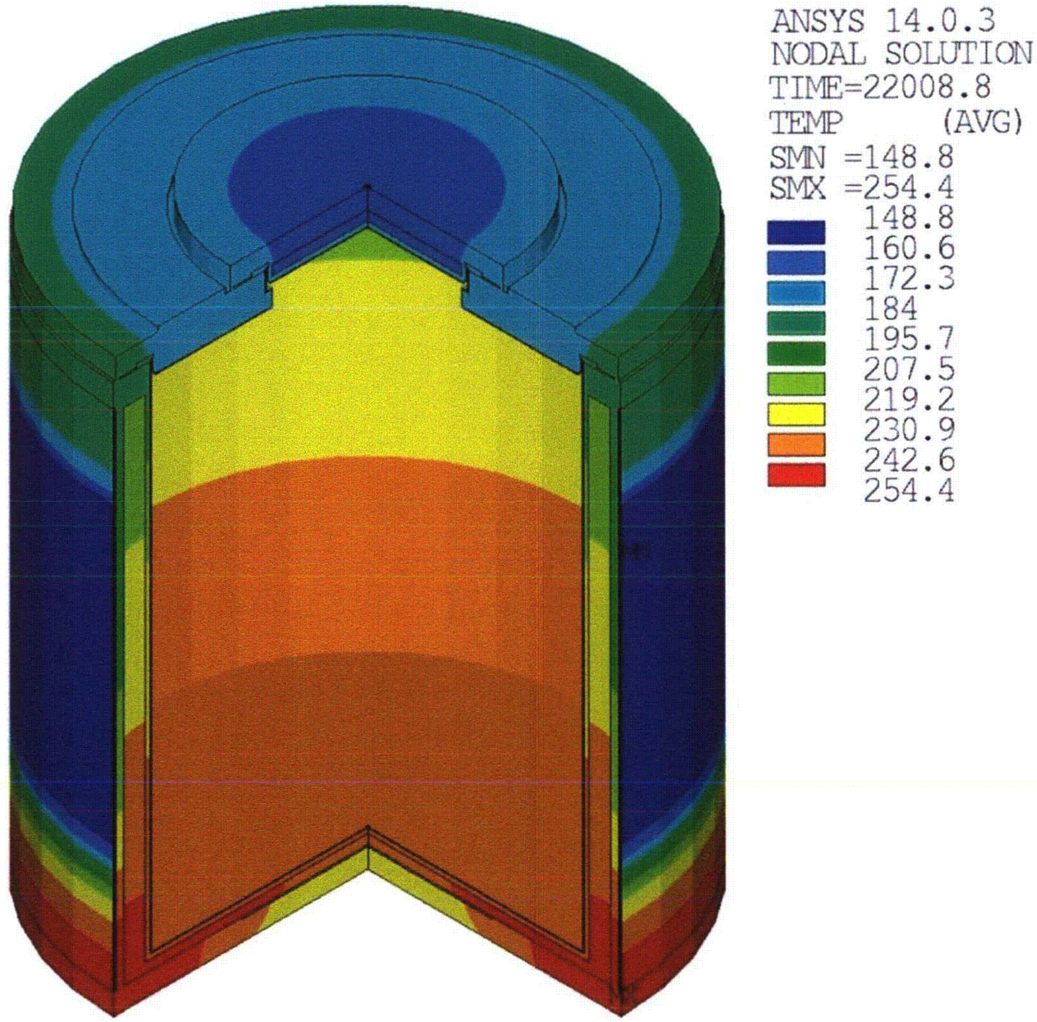


Figure 3-25 - HAC Fire Test Analysis – Maximum Average Temperature of the Cask Cavity

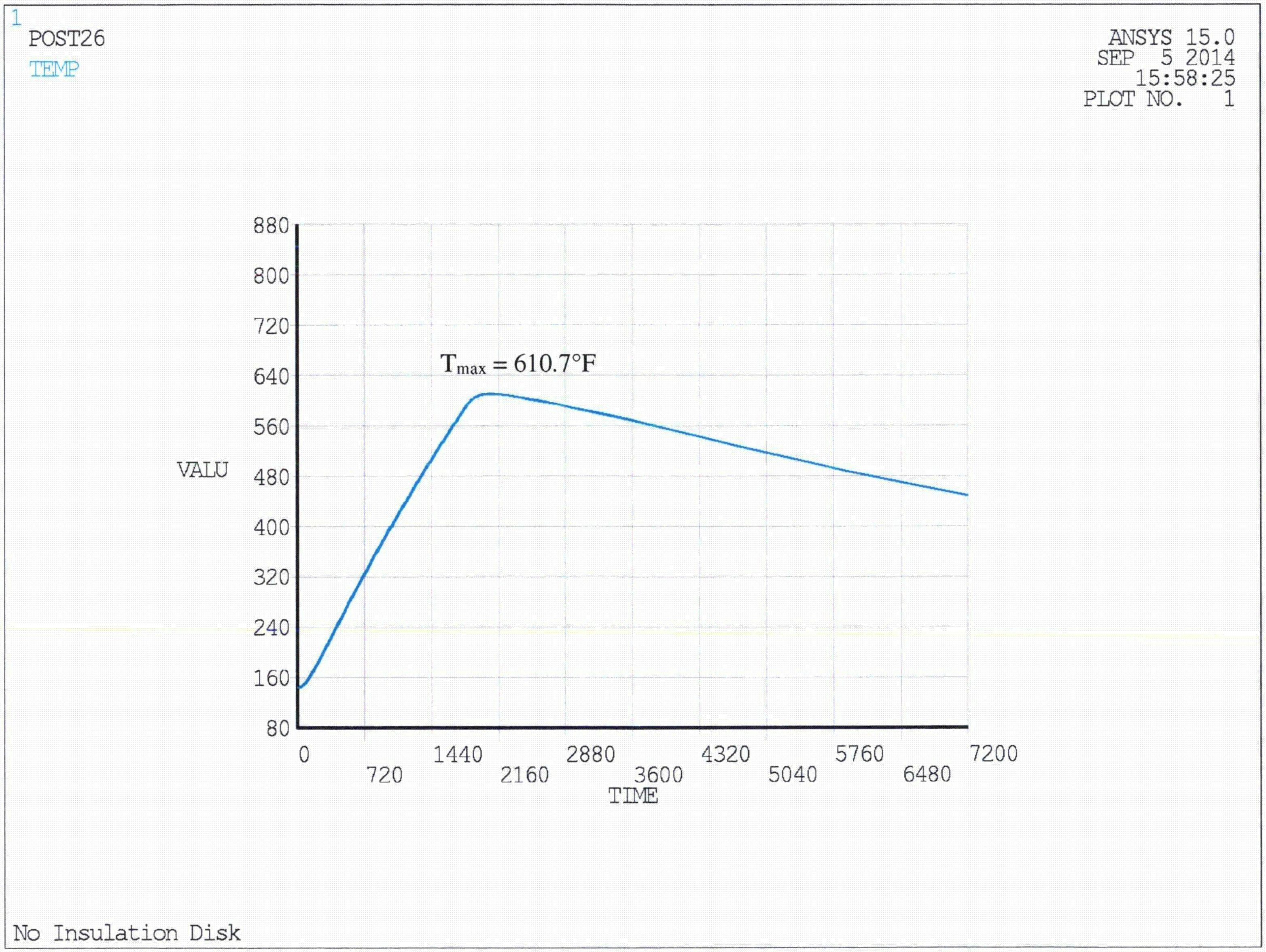


Figure 3-26 – HAC Fire Maximum Lead Temperature Time-History – Without Insulation Disk

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4.0 CONTAINMENT

This chapter describes the containment configuration and test requirements for the WMG 150B Cask. Both normal conditions of transport and hypothetical accident conditions are discussed.

4.1 Containment Boundary

4.1.1 Containment Vessel

The package containment vessel is defined as the inner shell of the shielded transport cask and the primary and secondary lids together with the associated o-ring seals (see Sheet 8 of cask drawing in Section 1). The inner shell of the cask, or containment vessel, consists of a right circular cylinder of 65.8 inches inner diameter and 76.8 inches inside height (nominal dimensions). The inner shell is fabricated of ¾ inch thick steel. The outer cylindrical shell is attached at the base to a circular end plate construction with full penetration welds. The primary lid is attached to the cask body with 24, 1 1/2 inch 6 UNC bolts. A secondary lid covers the 30-3/4 inch opening in the primary lid and is attached to the primary lid using 15, 1 1/2" inch 6 UNC bolts. See Section 4.1.4 for closure details.

4.1.2 Containment Penetrations

There is one penetration of the containment vessel. The pressurization port penetrates the primary lid into the main cask cavity. The port is sealed at the base of the exterior opening with an elastomer Parker Stat-o-Seal and a cap screw. The exterior opening is plugged by a metal plug.

There are no valves or pressure relief devices.

4.1.3 Closure and Seals

The primary lid closure consists of a two layer steel plate construction, stepped to fit over and within the top edge of the cylindrical body. The lid is supported at the perimeter of the cylindrical body by a 3.5-inch thick plate (bolt ring) welded to the top of the inner and outer cylindrical body walls. The lid contains two (2) solid, high temperature elastomer o-rings (Seal & Design Viton GLTS) in machined grooves. Groove dimensions prevent over-compression of the o-rings by the lid closure bolt preload forces and hypothetical accident preload forces. The primary lid is attached to the cask body by 24 bolts. The primary lid is fitted with a secondary lid of similar construction attached with 15 bolts. The secondary lid is also sealed with two (2) solid, high temperature elastomer o-rings (Seal & Design Viton GLTS) in machined grooves. Only the inner o-ring of each lid is part of the containment boundary. A test port is installed for each o-ring pair and is sealed in the same way as the pressurization port. The seal plugs in the ports are lockwired prior to each shipment to prevent unauthorized access.

Table 4-1 gives the torque values for bolts and cap screws.

Table 4-1
Bolt and Cap Screw Torque Requirements

Location	Size	Torque Values +/- 10% (Lubricated) Ft-lb
Test Ports (2)	3/8 - 16 UNC	20
Primary Lid	1 ½ inch, 6 UNC	500
Second Lid	1 ½ inch, 6 UNC	500
Pressurization Port	3/8 - 16 UNC	20

4.2 Containment Under Normal Conditions of Transport

4.2.1 Leak Test Requirements

The WMG 150B cask is designed, fabricated, and leak tested to preclude a release of radioactive material in excess of the limits prescribed in 10CFR71.51(a)(1).

10CFR71.51(a)(1) states the containment requirements for normal conditions of transport as:

> ...no loss or dispersal of radioactive contents, as demonstrated to a sensitivity of 10^{-6} A_2 per hour, no significant increase in external radiation levels, and no substantial reduction in the effectiveness of the packaging; ANSI N14.5-1997 (Reference 4-1) defines "leaktight" as "A degree of package containment that in a practical sense precludes any significant release of radioactive materials. This degree of containment is achieved by demonstration of a leakage rate less than or equal to 1 x 10^{-7} ref-cm^3/s of air at an upstream pressure of 1 atmosphere (atm) absolute (abs) and a downstream pressure of 0.01 atm abs or less."

WMG has determined that the WMG 150B will be used as a "leaktight" Type B package. The leakage tests that demonstrate the WMG 150B meets this requirement are provided in Section 4.4.

4.2.2 Pressurization of the Containment Vessel

Section 3 summarizes normal condition temperatures and pressures within the containment vessel. These pressures and associated temperatures are used in the structural evaluation provided in Section 2 to evaluate the integrity of the WMG 150B package. These conditions do not reduce the effectiveness of the package containment and thus the release of radioactive materials will not occur.

4.3 Containment Under Hypothetical Accident Conditions

4.3.1 Leak Test Requirements

As described above, testing of the WMG 150B will demonstrate that the package is "leaktight". The leak test procedure, described in Section 4.4, which assures compliance with leakage during normal conditions of transport, will also be sufficient to assure compliance during hypothetical accident conditions.

4.3.2 Pressurization of the Containment Vessel

Section 3 summarizes the accident condition temperatures and pressures within the containment vessel. These pressures and associated temperatures are used in the structural evaluation provided in Section 2 to evaluate the integrity of the WMG 150B package. These conditions do not reduce the effectiveness of the package containment and thus the release of radioactive materials will not occur.

4.4 Leakage Rate Tests

Structural and thermal analyses of the WMG 150B show tha the package always maintains its structural integrity and never loses its contents. However, issues in manufacturing, assembly, or use may cause leak paths to develop. Leak testing is used as a means to ensure these leak paths have not developed. The purpose of these calculations is to determine the allowable leakage rate and test sensitivity for the various required leak tests. The test type, frequency, and acceptance criteria are given in Table 1 of American National Standards (ANSI) standard N14.5-1997 (Reference 4-1).

ANSI N14.5-1997 provides containment equations and guidance on performing leak testing, analyzing the leak test results, and determing the acceptability of the results. The equations and guidance result in acceptable lekage rates. The Nuclear Regulatory Commission (NRC) has deemed the ANSI N14.5 methodology acceptable to demonstrate compliance with Title 10 of the United States Code of Federal Regulations, Part 71's (10 CFR 71) leakage requirements.

WMG has determined that the WMG 150B will be used as a "leaktight" Type B package as defined in ANSI N14.5-1997. Thus, the package will be demonstrated to have a leakage rate of less than or equal to 1 x 10^{-7} ref.cm^3/s of air at an upstream pressure of 1 atmosphere (atm) absolute (abs) and a downstream pressure of 0.01 atm abs or less.

In order to perform a leakage test to demonstrate the leak criteria is met, helium will be used a the test gas. The air leakage rate must be converted to a helium leakage rate at the test conditions.

Following the methodology of ANSI N14.5-1997:

$$L_{R\_air} := 1 \cdot 10^{-7}$$

To convert this air leakage rate to a helium leakage rate, the leakage hole diameter, D, must first be determined.

For air leakage:

$P_u := 1$ $\quad P_d := 0.01$ $\quad T_{.K} := 298$ $\quad M_{air} := 29$ $\quad \mu_{air} := 0.0185$

$$P_a := \frac{P_u + P_d}{2} = 5.05 \times 10^{-1}$$

Assume the leakage path length, a, is 1 cm.

$a := 1$

Then

$$F_c = 2.49\cdot 10^6\cdot\frac{D^4}{a\cdot\mu} \quad F_m = 3.81\cdot 10^3\cdot D^3\frac{\left(\frac{T_K}{M_{air}}\right)^{.5}}{a\cdot P_a} \text{ simplify} \rightarrow F_m = 2.418\times 10^4\cdot D^{3\times 10^0}$$

$$F_c =: 1.3459 \times 10^8\cdot D^4 \quad F_m =: 2.418 \times 10^4\cdot D^3$$

$$L_{R\_air} = (F_c + F_m)\cdot(P_u - P_d)\cdot\frac{P_a}{P_u} \text{ solve}, D \rightarrow \begin{pmatrix} -2.621\times 10^{-4} \\ 1.631\times 10^{-4} \\ -4.029\times 10^{-5} - 1.82i\times 10^{-4} \\ -4.029\times 10^{-5} + 1.82i\times 10^{-4} \end{pmatrix}$$

Thus

$D := 1.631\cdot 10^{-4}$ where D equals the leakage hole diameter in centimeters

For a helium test gas

Determine the equivalent air/helium mixture (Lmix) that would leak from D during a leak test. Assume the cask void is first evacuated to 20" Hg vacuum (9.92" Hg abs, 0.33atm) and then pressurized to psig (1.07 atm) resulting in an air/helium mixture.

$P_{air} := 0.33 \quad P_d = 1\times 10^{-2} \quad P_{mix} := 1.070$

$P_{He} := P_{mix} - P_{air}$

$$P_{a\_mix} := \frac{P_{mix} + P_d}{2} = 5.4\times 10^{-1}$$

$M_{He} := 4$

$\mu_{He} := 0.0198$

$$M_{mix} := \frac{M_{He}\cdot P_{He} + M_{air}\cdot P_{air}}{P_{mix}} = 1.171 \times 10^1$$

$$\mu_{mix} := \frac{\mu_{air}\cdot P_{air} + \mu_{He}\cdot P_{He}}{P_{mix}} = 1.94 \times 10^{-2}$$

Determine Lmix as a function of temperature. Assume the viscosities of air and helium do not change significantly over the range of temperatures evaluated:

$T := 273, 276 .. 328$

$$F_c := \frac{2.49 \cdot 10^6 \cdot D^4}{a \cdot \mu_{mix}} = 9.083 \times 10^{-8}$$

$$T_F(T) := (T - 273) \cdot \frac{9}{5} + 32$$

Temperature range for test: 32°F to 130°F

$$F_m(T) := 3.81 \cdot 10^3 \cdot D^3 \left(\frac{T}{M_{mix}} \right)^{.5}$$

$$L_{mix}(T) := \left(F_c + F_m(T)\right) \cdot \left(P_{mix} - P_d\right) \cdot \frac{P_{a\_mix}}{P_{mix}}$$

The Helium component of this leak rate can be determined by multiplying the leak rate of the mixture by the ratio of the Helium partial pressure to the total pressure of the mix, as follows.

$$L_{He}(T) := L_{mix}(T) \cdot \frac{P_{He}}{P_{mix}}$$

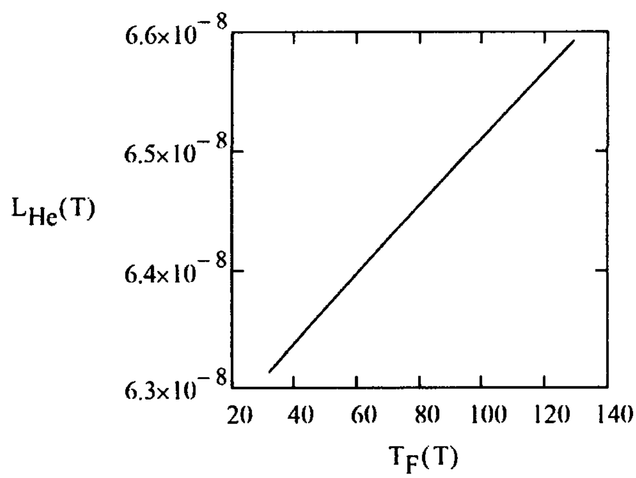

Figure 4-1 – Permissible Helium Leak Rate vs Test Temperature

According to ANSI N 14.1 methodology, the maximum allowable leak rate must be divided by 2 to determine the minimum sensitivity for the test. A graph of the required sensitivity is presented below

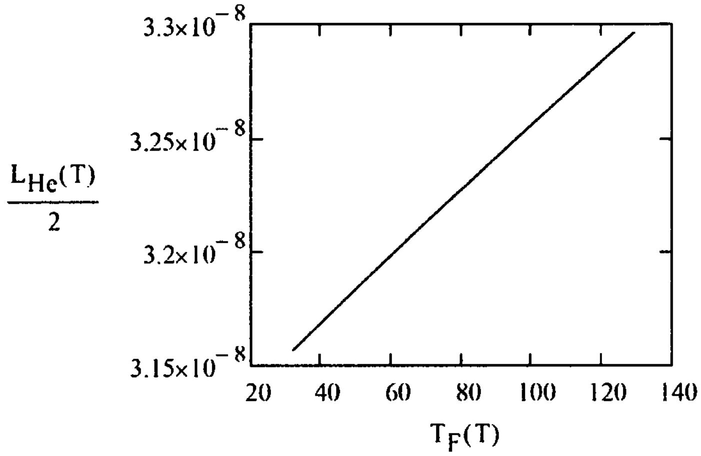

Figure 4-2 – Required Sensitivity of the Test Equipment vs Temperature

DETERMINING TIME FOR PRE-SHIPMENT LEAK TEST USING AIR OR NITROGEN

The pre-shipment leak test is to be performed by the pressure drop test method using air or nitrogen. The test will be performed on the closure lid and vent port. In this section the minimum hold time for each of the tests is determined.

MINIMUM HOLD TIME FOR CLOSURE LID

The pre-shipment leak test is performed by charging the annulus between the O-rings of the closure lid with air or nitrogen at 18 psig and holding the pressure for the prescribed time. The maximumvolume of the test manifold is 20 cm3, which is added to the annulus volume. The annulus between the O-rings is 1/8" deep and 1/8" wide with a center-line diameter (primary lid) of 67 3/4". The volume of the annulus is:

$$ID_{ann} := \left(67.75 - \frac{1}{16}\right)\cdot in = 6.769 \times 10^{1}\cdot in$$

$$OD_{ann} := \left(67.75 + \frac{1}{16}\right)\cdot in = 6.781 \times 10^{1}\cdot in$$

$$V_{ann} := \frac{\pi}{4}\cdot(.125\cdot in)\cdot\left(OD_{ann}^{\ 2} - ID_{ann}^{\ 2}\right)$$

$$V_{ann} = 1.663 \times 10^{0}\cdot V_{ann} = 2.725 \times 10^{1}\cdot cm^{3}$$

The preshipment test volume, V_1 , is the annulus volume plus the manifold volume.

$$V_{mn} := 20\cdot cm^{3}$$

$V_T := V_{mn} + V_{ann} \quad V_T = 4.725 \times 10^1 \cdot cm^3$

Use Equation B.14 from ANSI N14.5 to determine the required hold time given the maximum permitted leak rate, where:

L	=	atm-cm^3 /sec of air at standard conditions
V_T	=	gas volume in the test annulus
T_s	=	reference temperature, 298° K
H	=	test duration, hrs

P_s = standard pressure, 1 atm

P_1 = gas pressure in annulus at start of test, 1.232 atm (18.1 psig)

P_2 = gas pressure in annulus at end of test, 1.225 atm (18.0 psig)

T_1 = gas temperature in annulus at start of test, K

T_2 = gas temperature in annulus at end of test, K

Assume the temperature remains constant and at the T_s throughout the test

$T_s := 298 \cdot K \quad T_1 := T_s \quad T_2 := T_s \quad P_s := 1 \cdot atm$

$P_1 := 1.232 \cdot atm \; P_2 := 1.225 \cdot atm \quad P_{delta} := P_1 - P_2 \quad P_{delta} = 7 \times 10^{-3} \cdot atm$

The maximum permitted sensitivity for the pre-shipment leak test as prescribed in ANSI N14.5 - 1997 is **10-3** ref-cm 3/sec. From Equation B.17 in ANSI N14.5, the maximum permitted leak rate when the sensitivity is prescribed is:

$$L < \frac{S}{2}$$

$$L_{plt} := \frac{1 \cdot 10^{-3}}{2} \cdot \frac{cm^3}{sec}$$

Rearranging Eqn. 4.7-1 to solve H:

$$H_{plt} := \frac{V_T \cdot T_s \cdot P_{delta}}{3600 \cdot \frac{sec}{hr} \cdot L_{plt} \cdot P_s \cdot T_s}$$

$H_{plt} = 1.837 \times 10^{-1} \cdot hr$ $\quad H_{plt} = 1.102 \times 10^{1} \cdot min$

For conservatism, the test will be conducted for 13 minutes.
The smaller diameter secondary lid will be conservatively tested for the same time as the primary.

MINIMUM HOLD TIME FOR PRESSURIZATION PORT

The pre-shipment leak test is performed by charging the port cavity with air or nitrogen at 18 psig and holding the pressure for the prescribed time. The maximum volume of the test manifold is 20 cm3, which is added to the annulus volume.
The pressurization port has a stepped cavity, 1 5/16" dia x 3/4" h and 1 1/8" dia x 3/4" h. The volume of the seal bolt head and stat-o-seal will be conservatively neglected. The volume of the cavity is:

$$V_{cavity} := \frac{\pi}{4} \cdot (1.3125 \cdot in)^2 \cdot 0.75 \cdot in + \frac{\pi}{4} (1.125 \cdot in)^2 \cdot .75 \cdot in$$

$V_{T\_port} := V_{cavity} + V_{mn}$ $\quad V_{T\_port} = 4.885 \times 10^{1} \cdot cm^3$

Rearranging Eqn. 4.7-1 to solve H:

$$H_{port} := \frac{V_{T\_port} \cdot T_s \cdot P_{delta}}{3600 \cdot \frac{sec}{hr} \cdot L_{plt} \cdot P_s \cdot T_s}$$

$H_{port} = 1.9 \times 10^{-1} \cdot hr$

$H_{port} = 1.14 \times 10^{1} \cdot min$

For conservatism, the test will be conducted for 13 minutes.

4.5 References

4-1. American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials, American National Standards Institute, Inc., New York, ANSI N14.5-1997, 1998.

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5.0 SHIELDING EVALUATION

This section addresses the radiation shielding characteristics of the package under both normal conditions of transport (NCT) and hypothetical accident conditions (HAC) (References 5-1 and 5-2). Since the proposed contents are limited to byproduct radioactive material, only gamma radiation shielding was considered in this analysis. Gamma radiation dose rate levels were estimated at the locations of interest using Monte Carlo shielding techniques. The final shielding analysis was performed with MCNP 6 (References 5-3 and 5-4).

Design basis source terms were considered for waste forms consisting of irradiated hardware, ion exchange resin and cartridge filter elements. The filter source term was found to be limiting due to the low density which provides relatively little self-shielding.

The cask has a height of 90 inches and an outer diameter of 77.5 inches and has a 66.0 inch diameter cavity with a 76.25 height. Primary shielding of the package is provided by the steel-lead-steel construction of the cask body and lid. The shielding thicknesses are summarized in Figure 5.1 and are described below. The main shielding in the package side walls are provided by a 0.75 inch inner steel shell, a 3.375 inch poured lead section and a 1.25 inch outer steel shell. Shielding in the bottom is uniform and contains 0.75 inches of steel from the inner plate, 1.5 inches of poured lead and a 3.25 inch thick outer plate on the bottom. The top is comprised of a primary lid and a secondary lid, or fill-port, as shown in Figure 5.1. The primary lid is comprised of 5.25 inches of steel. The secondary lid covers the 31.0 inch diameter fill port in the center of the cask. The secondary lid is comprised of a 0.75 inch inner steel layer and 1.5 inch lead shield and a 3.0 inch outer steel plate.

5.1 Description of Shielding Design

5.1.1 Design Features

Primary shielding of the package is provided by the steel-lead-steel construction of the cask body and lid. The shielding thicknesses are summarized in Figure 5.1 and are described below in detail. The cask cavity has a diameter of 66.0 inches without the stainless steel liner layer.

The cask cavity is lined in 12 gauge A240 316 stainless steel sheet. The cask body walls are made up of an inner shell which is 0.75 inch thick A543 Type B Class 1 steel, a 3.375 inch poured ASTM B29 lead section and a 1.25 inch outer steel shell comprised of A543 Type B Class 1 steel. The exterior radius of the packaging is wrapped with an external wire wrap which is A510 steel which is covered by a 7 gauge (0.1875 inch) A240 316 stainless steel thermal barrier.

Shielding in the bottom is uniform and has a 12 gauge A240 316 stainless steel sheet liner layer, a 0.75 inch thick A543 Type B Class 1 steel plate, 1.5 inches of poured ASTM B29 lead and a 3.25 inch thick bottom plate comprised of A543 Type B Class 1 steel.

The top is comprised of a primary lid and a secondary lid, or fill-port, as shown in Figure 5.1. The primary lid is comprised of 5.25 inches of A543 Type B Class 1 steel, with the interior surfaces lined in 12 gauge A240 316 stainless steel sheet. The primary lid also includes a 0.75 inch thick top shield plate made of A543 Type B Class 1 steel. The secondary lid covers the 31.0 inch diameter fill port in the center of the primary lid. The secondary lid is comprised of a 12 gauge A240 316 stainless steel liner layer, a 0.75 inch A543 Type B Class 1 steel layer, a 1.5 inch ASTM B29 lead shield and a 3.0 inch outer steel plate made from A543 Type B Class 1 steel.

It should be noted that the closure of the secondary lid contains a 2.36 inch thick inner stepped steel shield and the outer steel plate of the secondary lid overlaps the primary lid by 5.48 inches to minimize gamma streaming at the 0.16 inch gap between the primary and secondary lids. This assures that the minimum steel shield thickness for any streaming pathways is at least 5.25 inches thick.

The material densities used for the shielding analysis were 7.87 g/cc for the A543 steel per the ASTM specification and 11.34 g/cc for lead as appropriate. The small quantities of stainless steel present in the inner liner and bearing plates were conservatively modelled as carbon steel at 7.87 g/cc.

It should be noted that while the package was modelled using the nominal shield dimensions the minimum shield thicknesses within the limits of the dimensional tolerances were analyzed and the results were within 10% of the nominal case results.

5.1.2 Summary Table of Maximum Radiation Levels

The maximum dose rates for both normal conditions of transport and hypothetical accident conditions are shown in Table 5-1. Since the package is only intended to be shipped exclusive use, the normal conditions of transport only address the appropriate locations per 10 CFR 71.47.

5.2 Source Specification

The 150B cask is designed to service the commercial nuclear power industry and transport byproduct radioactive material in the form of dewatered and solidified ion exchange resins and sludges, dewatered and solidified filters and irradiated hardware. A wide array of radionuclides are found in commercial low level radioactive waste. The typical radionuclides present are summarized in Table 5-2 which shows the principal means of production, average gamma energy in Mev/dis and the half-life in days.

Historic data was analyzed for the proposed contents and worst case isotopic content for each waste form was calculated based on the historic data as shown in Reference 5-7. The historic data showed that the vast majority of historic Type B cask shipments in this segment were bounded by 100 Curies of Co-60. Therefore, the design basis source term chosen for the cask is 100 Curies of Co-60, or equivalent.

The source configuration was a loaded 150 cubic foot disposal liner with source densities considered for the waste forms analyzed. The source densities were homogenized over the 150 cubic foot source volume. The irradiated hardware source was modeled as 1.205 g/cc of stainless steel, while the ion exchange resin and cartridge filter elements were modeled as water with densities of 0.8 g/cc and 0.16 g/cc respectively. The exposure rates from the filter source were limiting due to the low density of the postulated filter material and the relatively low self-shielding afforded by this source configuration. Therefore, the design basis source term of 100 Curies of Co-60 was modelled using a representative filter source density of 0.16 g/cc.

Since the proposed contents for the package are limited to byproduct radioactive materials, the shielding analysis was limited to gamma shielding estimates. Details for the gamma source are presented in Reference 5-7 and provided below.

5.2.1 Gamma Source

The design basis gamma source term for the 150B Cask is 100 Curies of Co-60. Co-60 has the limiting source strength in terms of photon energy for the expected gamma emitting radioisotopes found in low level radioactive waste at light water reactors. Co-60 is also the predominant gamma emitting radionuclide found in low level waste typically shipped for disposal in Type B packages such as the 150B. The gamma photon yields and energy distribution for Co-60 were taken from Kocher's compilation to define the gamma source term (Reference 5-5). Only seven nuclides were identified that might not be bounded by Co-60. Of those seven nuclides, only Sb-124 is commonly found in commercial nuclear power plant waste. See Reference 5-7 for a detailed description.

5.2.2 Neutron Source

Since the cask will be licensed for byproduct material and not spent fuel or neutron sources, a neutron source term was not considered for this application. While the contents may include trace amounts of transuranic nuclides, the contents are limited to fissile excepted per 10 CFR 71.15 (Reference 5-1).

5.3 Shielding Model

5.3.1 Configuration of Source and Shielding

The final shielding models were performed with MCNP6. The cask was modeled in detail based on the dimensions and physical materials discussed above. The source region was modeled as a 150 cubic foot distributed source contained within an internal container or disposal liner. The disposal liner was modeled as a typical quarter inch steel liner with no credit taken for any shielding provided by the liner, i.e. the liner walls were modeled as voids under hypothetical accident conditions. The shielding analysis report (Reference 5-7) provides details of the source term, the models used, assumptions made and the input and output.

The cask's inner stainless steel liner layer was conservatively neglected in the shielding model with the exception of the impact the stainless steel sheet has on the gap thicknesses between the primary cask lid and the cask body and the secondary cask lid and the primary cask lid. At these interface locations the stainless steel sheet was included in the adjacent carbon steel regions in order to more accurately model the 0.16 inch gap present.

In MCNP the model geometry is based on simple geometric surfaces and combinations of these surfaces are used to define three dimensional cells. The cells within the MCNP model are summarized in Table 5-3. An illustration of the model geometry generated using the MCNP visual editor (Reference 5-6) is provided in Figure 5-2. This data reflects the configuration for normal conditions of transport. Under hypothetical accident conditions there was a reduced shielding region where the puncture impacted the side of the cask and a gap of up to 0.375 inches in the lead shielding caused by "slumping" of the lead. The effects of the lead slumping were explicitly modelled for the accident condition cases and dose rates adjacent to the slump gap were found to be limiting. The lead slump gap as modelled is shown in Figure 5-3.

The locations of interest for the shielding analysis to estimate the exposure rates for both normal conditions of transport and hypothetical accident conditions are shown in Table 5-4. It should be noted that numerous detector locations were evaluated to identify the maximum exposure locations on and around the cask before selecting the locations in Table 5-4 as limiting. It should be noted that the shielding effects of the impact limiters were ignored for all cases and detector locations for the hypothetical accident cases were taken at 1 meter from the cask body assuming the impact limiters were lost under postulated accident conditions. The detector locations for the normal conditions of transport were taken at 1 inch from the cask body, for the contact cases to aide in convergence, and at 2 meters from the side plane of the conveyance.

Note that the main geometry inputs were augmented for sensitivity analyses performed to estimate dose rates around the pressurization port and the bottom insulation disk.

5.3.2 Material Properties

Material properties for the source and shielding materials are summarized in Table 5-5 below. The source region was modeled as partial density water which is typical and the impact limiter materials and the alumina insulation disk in the cask bottom were conservatively modelled as voids so only standard materials were included in the analysis. The standard densities were used for carbon steel at 7.87 g/cc and lead at 11.34 g/cc. The elemental composition used in the models was based on the MCNP defaults for carbon steel as shown in Table 5-5. The ASTM standard density for A543 steel is 7.87 g/cc and its composition is shown in Table 5-5 as well. The A543 has more carbon and contains Nickel, Chromium and Molybdenum. It was assumed that the A543 could be modelled using the standard carbon steel composition and this assumption was tested with a sensitivity analysis that showed the shielding results for the 150B cask when modelled with the detailed A543 composition are bounded by the results for standard carbon steel and are within 0.2%.

5.4 Shielding Evaluation

5.4.1 Methods

The shielding evaluation was performed with the MCNP 6 program which uses the Monte Carlo shielding technique to perform the shielding calculations. The physical models were constructed as described in Section 5.3 above.

The MCNP 6 program has a weight windows generator that can be used to automatically calculate importance weighting factors for mesh superimposed on the model. The mesh used for the weight windows is shown in Figure 5-4. As shown the mesh breaks down thick shielding regions into segments that are relatively small and typically less than 1 mean free path thick. The code assigns an importance weighting factor to each segment based on the detector location. Separate models were run for each detector location in order to customize the importance weighting factors for each detector location. Using the weight windows generator is an iterative process and there were typically 6 to 10 iterations performed with the weight windows function to generate the proper weighting factors to get a converged solution.

Point detectors were used at the locations shown in Table 5-4. The contact cases for normal conditions of transport proved to be the most challenging from a convergence standpoint. As discussed above weight windows were used and variance reductions techniques including both splitting and Russian roulette are used by MCNP to achieve proper convergence. For all four cases under normal conditions of transport, surface detectors were used at the point detector locations to validate the results for the point detectors as discussed in Reference 5-7.

5.4.2 Input and Output Data

The MCNP6 input data used for the analysis is included in Reference 5-7 along with hardcopies of the output files. As shown in the Reference 5-7, it can be verified that the cell geometry inputs from Tables 5-3 are incorporated in the models.

All case outputs are provided in Reference 5-7 with the tallies used highlighted for clarity. The relative errors for the calculated results varied from a low of 0.002 to a high of 0.028, but in all cases were well below the acceptance criteria of 0.05 commonly used for point detectors in Monte Carlo shielding calculations.

5.4.3 Flux-to-Dose-Rate Conversion

Flux to dose conversion with MCNP6 uses built in flux to dose conversion factors based on the 1991 ANSI/ANS AP standard. The MCNP DF card was set to provide dose rate output in units of Rem/hr per source particle using the ic=31 from the Standard Flux to Dose Functions tabulated in Table 3-88 of Reference 4.

5.4.4 External Radiation Levels

The analysis results tabulated in Table 5-1 show the packaging effectively shields the design basis source term with margin to spare relative to the limits in 10 CFR Part 71. The limiting dose rate is the contact reading on the bottom which is 88% of the limit at 175.8 mrem/hr. The bottom of the cask will never be accessible under normal conditions of transport. The case results for the top of the cask is 114.8 mrem/hr which is less than 60% of the limit and the results at 2 meters are less than half the limit at 3.7 mrem/hr. This shows the shielding design provides an additional level of radiation safety to the workers handling the cask and to the general public when the cask rolls down the road.

Under hypothetical accident conditions the limiting dose rate is found at 1 meter from the package top at 114.5 mrem/hr which is less than 12% of the limit. The effects of lead slumping were analyzed assuming a 3/8" lead slump under hypothetical accident conditions. The radiation streaming due to the reduced shielding caused the 1 meter dose rates to increase by almost a factor of 2, but at only 36 mrem/hr it is well within the 1000 mrem/hr limit. The maximum dose rate at 1 meter from the bottom of the cask under hypothetical accident conditions is 90.6 mrem/hr which is less than 10% of the limit.

The effects of concentrating the source material at the cask top, bottom or side adjacent to the slump were considered. However, when considering the source material types (i.e. spent ion exchange resins and sludges, solidified waste, cartridge filters, irradiated hardware) it is very difficult to concentrate the waste material to increase the source concentrations locally by more than a factor of two. As long as the free flowable materials, such as resin, meet the 85% percent fill criteria and more discrete items, such as filters or irradiated components, are packaged so they are physically full or shored to prevent shifting of contents, the source cannot be concentrated appreciably. Since the dose rates under hypothetical accident conditions were less than 10% of the limits, if the source were to concentrate by a factor of two it would still be well within the limits. It should be noted that for many waste forms, physical concentration of the source material results in an increase in the source density and the increased self-shielding tends to cancel out much of the increased dose rate.

5.5 Appendix

5.5.1 References

5-1 Code of Federal Regulations, Title 10, Part 71, *Packaging and Transportation of Radioactive Material.*

5-2 U.S. NRC Regulatory Guide 7.9, Revision 2, Standard Format and Content of Part 71 Application for Approval of Packages for Radioactive Material, 2005.

5-3 RSICC Computer Code Collection, *Monte Carlo N-Particle Transport Code System Including MCNP6.1, MCNP5-1.60, MCNPX-2.7.0 and Data Libraries.*

5-4 RSICC Computer Code Collection, *MCNP6 User's Manual,* Version 1.0, LA-CP-13-00634, Rev 0, May 2013

5-5 D. C. Kocher, *Nuclear Decay Data for Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities*, ORNL/NUREG/TM102, August 1977.

5-6 RA Schwarz, *MCNP/MCNPX Visual Editor Computer Code*, Feb 2011

5-7 WMG-150B-AR-132S-P71, Rev.0, *WMG 150B MCNP Shielding Analysis.*

Table 5-1
Maximum Dose Rates

Normal Conditions of Transport	Package Surface mSv/h (mrem/h)			2 Meters mSv/h (mrem/h)
Radiation	**Top**	**Side**	**Bottom**	**Side**
Gamma	1.15 (114.8)	0.24 (24.4)	1.76 (175.8)	0.04 (3.7)
Neutron	n/a	n/a	n/a	n/a
Total	1.15 (114.8)	0.24 (24.4)	1.76 (175.8)	0.04 (3.7)
10 CFR 71.47(b) Limit mSv/h	2 (200)	2 (200)	2 (200)	0.1 (10)

Hypothetical Accident Conditions	1 Meter From Package Surface mSv/h (mrem/h)		
Radiation	**Top**	**Side**	**Bottom**
Gamma	1.15 (114.5)	0.36 (35.6)	0.91(90.6)
Neutron	n/a	n/a	n/a
Total	1.15 (114.5)	0.36 (35.6)	0.91 (90.6)
10 CFR 71.51(a)(2) Limit mSv/h	10 (1000)	10 (1000)	10 (1000)

Figure 5-1
Cask Shielding Cut Away

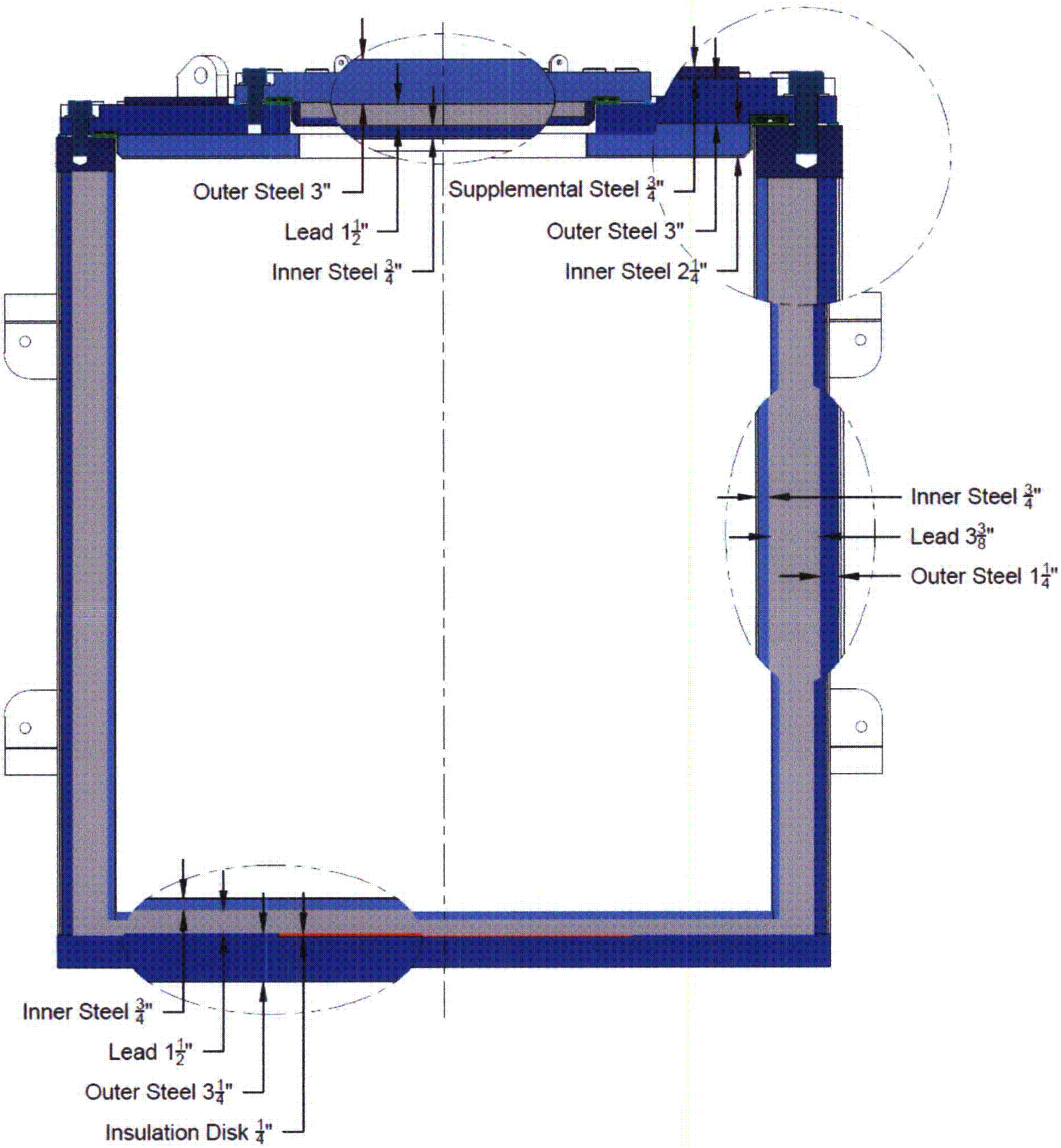


Table 5-2
Typical Radionuclides From Commercial LLW

Nuclide Name	Nuclide Type	Half Life (Days)	Gamma Energy (Mev/dis)
Ag-110m	Activation Product	2.50E+02	2.73E+00
C-14	Activation Product	2.09E+06	-
Co-57	Activation Product	2.71E+02	1.25E-01
Co-58	Activation Product	7.08E+01	9.76E-01
Co-60	Activation Product	1.92E+03	2.51E+00
Cr-51	Activation Product	2.77E+01	3.26E-02
Fe-55	Activation Product	9.86E+02	1.66E-03
Fe-59	Activation Product	4.46E+01	1.19E+00
Mn-54	Activation Product	3.13E+02	8.36E-01
Ni-59	Activation Product	2.74E+07	2.37E-03
Ni-63	Activation Product	3.65E+04	-
Sb-124	Activation Product	6.02E+01	1.87E+00
Sn-113	Activation Product	1.15E+02	2.31E-02
Zn-65	Activation Product	2.44E+02	5.84E-01
Ce-141	Fission Product	3.25E+01	7.66E-02
Ce-144	Fission Product	2.84E+02	1.93E-02
Cs-134	Fission Product	7.53E+02	1.56E+00
Cs-137[1]	Fission Product	1.10E+04	5.98E-01
H-3	Fission Product	4.48E+03	-
I-129	Fission Product	5.73E+09	2.46E-02
Nb-95	Fission Product	3.51E+01	7.64E-01
Sb-125	Fission Product	1.01E+03	4.33E-01
Sr-89	Fission Product	5.05E+01	1.36E-04
Sr-90	Fission Product	1.04E+04	-
Tc-99	Fission Product	7.77E+07	5.18E-07
Zr-95	Fission Product	6.40E+01	7.35E-01
Am-241	Transuranic	1.58E+05	2.81E-02
Cm-242	Transuranic	1.63E+02	1.67E-03
Cm-243	Transuranic	1.04E+04	1.33E-01
Cm-244	Transuranic	6.61E+03	1.49E-03
Pu-238	Transuranic	3.20E+04	1.60E-03
Pu-239	Transuranic	8.81E+06	6.54E-04
Pu-240	Transuranic	2.39E+06	1.53E-03
Pu-241	Transuranic	5.26E+03	-

Table 5-3
MCNP Cells

Cell No	Material	Density	Surface Combination	Importance	Description
1	1	-0.16	-1 -3 2	imp:p=1	Source Region
2	224	-7.87	-4 -6 5 (-2 :1 :3)	imp:p=1	Waste Disposal Liner
3	0		(-5 :4 :6)(29 :-27 :26)	imp:p=1	Gap between the liner and cask wall
4	224	-7.87	-9 10 -25 (8 :7 :-5)	imp:p=1	Cask body inner steel
5	252	-11.34	-12 13 -25 (11 :9 :-10)	imp:p=1	Cask body lead shield
6	224	-7.87	(-13 :12 :14)(21 :-22 :13)	imp:p=1	Cask body outer steel
7	0		-18 40 -20 (-40 :43 :44)	imp:p=1	Void used for surface detectors
8	0		-21 22 -13	imp:p=1	Void used for bottom insulation disk
9	0		-25 -23 13 (-16 :15 :17)	imp:p=1	Void used for radial insulation gap
10	224	-7.87	-24 -25 16 (23 :-16 :17)	imp:p=1	Outer steel sheet
11	224	-7.87	-24 7 25 -26	imp:p=1	Cask body sidewall top steel
12	224	-7.87	-29 27 -33 (28 :-27 :33)	imp:p=1	Primary lid bottom steel
13	224	-3.73	-24 26 -33 (-26 :33 :29)	imp:p=1	Primary lid bearing ring
14	224	-7.87	-32 -31 33 (30 :-33 :32)	imp:p=1	Primary lid top steel
15	252	-11.34	-34 35 -32	imp:p=1	Secondary lid lead shield
16	224	-7.87	37 -32 -36 (32 :-35 :34)	imp:p=1	Secondary lid bottom steel
17	224	-7.87	32 -38 -39	imp:p=1	Secondary lid top steel
18	0		-39 33 -24 (39 :38 :-32)(32 :-33 :15)	imp:p=1	Exterior void
19	0		-30 -32 33 (-37 :32 :36)	imp:p=1	Interior void
20	0		-28 27 -33	imp:p=1	Interior void
21	224	-7.87	-23 -13 16 (13 :-16 :15)	imp:p=1	Bottom plate steel outer section
22	0		-19 :18 :20	imp:p=0	Outer universe
23	0		-40 19 -18	imp:p=1	Exterior void
24	0		-43 40 -44 (39 :24 :-16)	imp:p=1	Exterior void
25	0		47 -12 -25 9	imp:p=1	Lead slump gap under HAC

Figure 5-2
MCNP Model Illustration

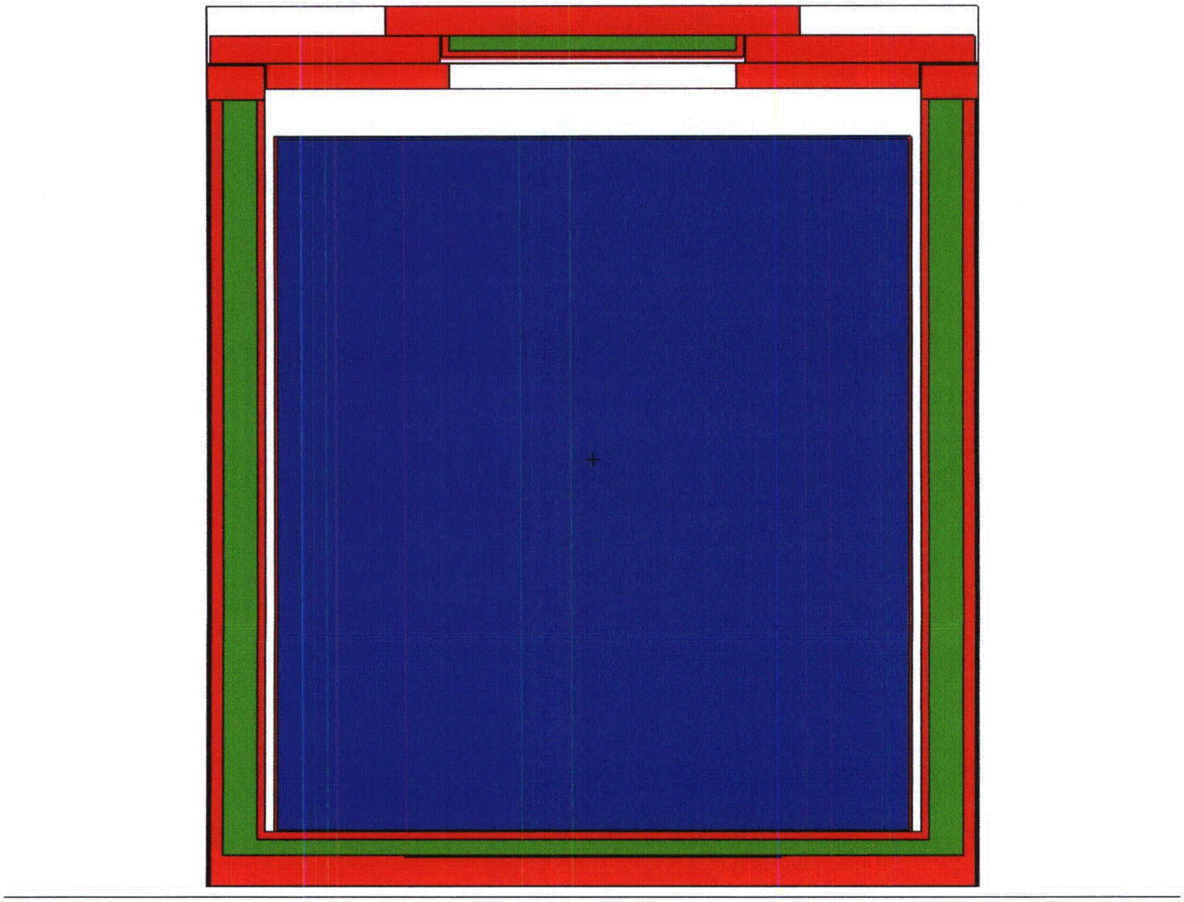


Figure 5-3
Lead Slump Gap As Modelled

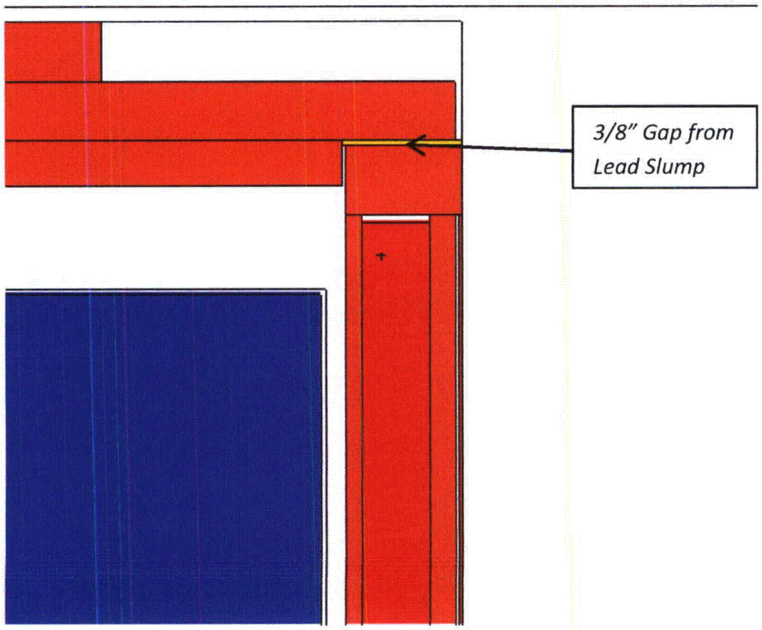


Table 5-4
Detector Locations Analyzed

	Top	Side	Bottom
Normal conditions contact	(0.0, 0.0,151.9)[1]	(101.0, 0.0, 0.0)[2]	(0.0, 0.0, -112.9)[2]
Accident Conditions 1 meter[3]	(0.0, 0.0, 217.6)	(0.0, 198.4, 92.0)[4]	(0.0, 0.0, -210.3)
2 meters side plane[5]	---	(0.0, 321.9, 0.0)	---

Notes:

1. *Contact on the top is at the screen inside the donut hole of the upper impact limiter*
2. *Contact side and bottom are at 2.54 cm from cask body*
3. *1 meter results are conservatively taken at 1 meter from cask body*
4. *The Z elevation corresponds to the location of the slump gap which had the maximum dose rate.*
5. *2 meter results are taken at 2 meters from the side plane of the conveyance.*

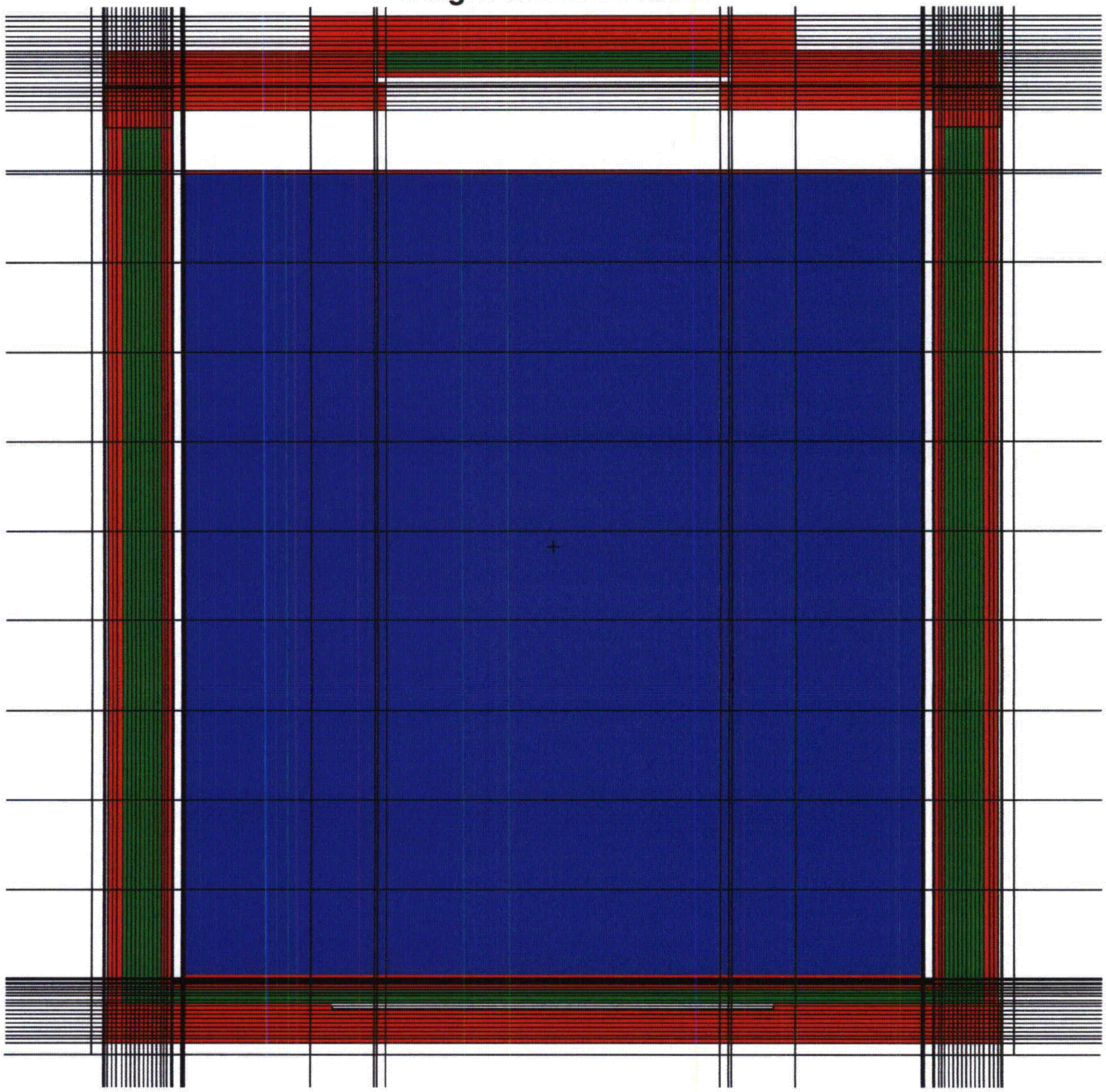
Table 5-5

Shielding Materials

Material	Density	Element	Element Symbols	Model Default CS Wt Percent	ASTM A543 Wt Percent
Carbon steel	7.87	26000	Fe	99.59	93.75
		6000	C	0.06	0.23
		25000	Mn	0.35	0.40
		28000	Ni	- -	3.30
		24000	Cr	- -	1.80
		42000	Mo	- -	0.52
LEAD	11.34	82000	Pb	100.00	
H2O		1000	H	11.111	
		8000	O	88.888	

Figure 5-4

Weight Windows Mesh



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6.0 CRITICALITY EVALUATION

Not Applicable.

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7.0 OPERATING PROCEDURES

This chapter describes the general operational steps for loading the WMG 150B and preparing it for transport. In addition, steps for the unloading of the WMG 150B cask are provided. A separate operations manual describes the operational steps in greater detail.

The maximum permissible activity is the lesser of the following criteria:

1. Less than 3000 A2, and
2. Less than 100 Curies of Co-60 or equivalent, and
3. Less than a radionuclide activity that results in 200 watts of decay heat

For most shipments the 100 Curie Co-60 or equivalent value is limiting and this determination shall be made first. Attachment 7-1 presents the methodology for determining Co-60 equivalence. As discussed in Section 5, Sb-124 is a gamma emitting nuclide that may be encountered in commercial nuclear power plant waste and it requires special consideration. Attachment 7-2 presents the Steps to evaluate the payload for hydrogen concentration in accordance with NUREG 6673. Radioactive contents are to be transported as exclusive use, per 10 CFR 71.4 and 10 CFR 71.5.

The maximum permissible payload of the cask is 15,500 pounds, including contents, secondary containers, and shoring.

The WMG 150B is transported as leak tight.

7.1 Procedure for Loading the Package

The cask may be loaded on or off the trailer and this determination is made before any loading operations take place.

7.1.1 Preparation for Loading

Preparation for loading varies with the cask payload and access to loading facilities and may or may not require removal of the cask from the trailer.

7.1.1.1 Removal of Cask from Trailer (optional)

7.1.1.1.1 Loosen and disconnect bolts that attach the upper impact limiter to the cask body.

7.1.1.1.2 Using suitable lifting equipment, remove upper impact limiter. Care should be taken to prevent damage to impact limiter during handling and storage.

7.1.1.1.3 Disconnect cask to trailer tie-down equipment.

7.1.1.1.4 Loosen and disconnect bolts that attach the lower impact limiter to the cask body.

7.1.1.1.5 Using suitable lifting equipment, remove cask from trailer and place cask in level loading position.

7.1.1.2 Remove Primary (Secondary) Lid

Dependent on the Package content, the Cask may be loaded through the secondary lid in which case the primary lid is not removed, or through the primary lid in which case the secondary lid is not removed. The steps related to secondary lid removal are designated with an asterisk* and replace the equivalently numbered primary lid step.

7.1.1.2.1 Loosen the pressurization port, on the primary lid, to relieve any vacuum that may have been created during transit.

7.1.1.2.2 Loosen and remove the twenty four (24) bolts, which secure the primary lid to cask body.

NOTE: The cables used for lifting either lid must have a true angle, with respect to the horizontal, of not less than 60°. Standard shackles with working load limit (WLL) of 1.5 tons shall be used with the secondary lid lugs, and 17 tons shall be used with the primary lid lugs.

7.1.1.2.3 Inspect the bolts for defects. Obtain replacement bolts as specified on the drawing listed in Appendix 1.3 for any bolts that show cracking or other visual signs of distress.

7.1.1.2.4 Inspect rigging and lid lifting lugs prior to use. Remove primary lid from cask body using suitable lifting equipment. Care should be taken during lid handling operations to prevent damage to cask or lid seal surfaces.

*7.1.1.2.2 Loosen and remove the fifteen (15) bolts, which secure the secondary lid to the primary lid.

NOTE: The cables used for lifting either lid must have a true angle, with respect to the horizontal, of not less than 60°.

*7.1.1.2.3 Inspect the bolts for defects. Obtain replacement bolts as specified on the drawing listed in Appendix 1.3 for any bolts that show cracking or other visual signs of distress.

*7.1.1.2.4 Inspect rigging and lid lift lugs prior to use. Remove secondary lid from primary lid using suitable lifting equipment. Care should be taken during lid handling operations to prevent damage to cask or lid seal surfaces.

7.1.1.2.5 Inspect the lid and body bolt holes for defects. Contact WMG Inc. for any bolt holes that show signs of cracking or visual signs of distress.

7.1.1.2.6 Inspect cask interior for damage, loose materials or moisture. Clean and inspect seal surfaces. Replace seals when defects or damage is noted which may preclude proper sealing.

NOTE: Radioactively contaminated liquids may be pumped out or removed by use of an absorbent material. Removal of any material from inside the cask shall be performed under the supervision of qualified health physics personnel with the necessary H.P. monitoring and radiological health safety precautions and safeguards.

NOTE: When seals are replaced, leak testing is required as specified in Section 8.

NOTE: Verify intended contents meet the requirements of the Certificate of Compliance.

NOTE: Ensure the contents, secondary container, and packaging are chemically compatible, i.e., will not react to produce flammable gases.

7.1.2 Loading of Contents

The method of loading depends on the nature of the payload and whether the primary lid or secondary lid is removed in 7.1.1 above. Operations related to secondary lid removal and replacement are shown with an asterisk* and replace the equivalently numbered primary lid step.

7.1.2.1 Place disposable liner, drums or other containers into cask and install shoring or bracing, if necessary, to restrict movement of contents during normal transport. Greater than 1/2" radial and axial gaps shall be shored.

*7.1.2.1 If loading a liner already within the cask, prepare and process the liner in accordance with Site Specific procedures, and cap using standard capping devices.

7.1.2.2 Clean and inspect lid seal surfaces.

7.1.2.3 Replace the primary lid on the cask body. Lubricate bolts. Secure the lid by hand tightening the twenty four (24) primary lid bolts.

7.1.2.4 Torque, using a star pattern, the twenty four (24) primary lid bolts to 250 ft-lbs. ± 25 ft-lbs.

7.1.2.5 Re-Torque, using a star pattern, the twenty four (24) primary lid bolts to 500 ft-lbs. ± 50 ft-lbs.

*7.1.2.3 Replace the secondary lid on the primary lid. Lubricate bolts. Secure the lid by hand tightening the fifteen (15) secondary lid bolts.

*7.1.2.4 Torque, using a star pattern, the fifteen (15) secondary lid bolts to 250 ft-lbs. ± 25 ft-lbs.

*7.1.2.5 Re-torque, using a star pattern, the fifteen (15) secondary lid bolts to 500 ft-lbs. ± 50 ft- lbs.

7.1.2.6 Replace the vent port cap screw and seal (if removed) and torque to 20 ft- lbs. ± 2 ft-lbs.

NOTE: Leak test the primary lid and secondary lid O-rings and the vent port in accordance with Section 8, prior to shipment of the package loaded with greater than "Type A" quantities of radioactive material.

7.1.2.7 Torque pressurization port, on primary lid, to 20 ft-lbs. ± 2 ft-lbs.

7.1.2.8 Install security seals on the primary lid, secondary lid, and the test port as shown in the SAR drawing.

7.1.3 Preparation for Transport

7.1.3.1 Return Cask to Trailer

If cask has been removed from trailer for loading, proceed as follows to return cask to trailer:

7.1.3.1.1 Inspect rigging prior to use. Using suitable lifting equipment, lift and position cask into lower impact limiter on trailer in the same orientation as removed.

7.1.3.1.2 Reconnect cask to trailer using tie-down equipment.

7.1.3.1.3 Inspect rigging prior to use. Using suitable lifting equipment, lift, inspect for damage, and install impact limiter assemblies on cask in the same orientation as removed.

7.1.3.1.4 Attach and hand tighten impact limiter attachment bolts to secure upper and lower impact limiters to cask body. Torque bolts to 70 ft-lbs ± 7 ft-lbs.

7.1.3.2 Prepare for Shipment

7.1.3.2.1 Inspect package for proper placards and labeling.

7.1.3.2.2 Complete required shipping documentation.

7.1.3.2.3 Confirm that the licensee who expects to receive a package containing quantities of radioactive material in excess of a Type A quantity specified in 10 CFR 20.1906(a) meets and follows the requirements of 10 CFR 20.1906, as applicable.

7.1.3.2.4 Confirm that trailer placarding and cask labeling meet DOT specifications (49 CFR 172).

7.1.3.2.5 Confirm that the provisions of 10 CFR 71.87 are met including that the external radiation dose rates are less than or equal to 200 millirem per hour (mrem/hr) at the surface and less than or equal to 10 mrem/hr at 2 meters in accordance with 10 CFR 71.47. Perform sufficient surveys to ensure that a non-uniform distribution of radioactivity does not cause the surface or 2 meter limit to be exceeded.

7.1.3.2.6 Confirm that all security seals are properly installed.

7.2 Procedure for Unloading Package

In addition to the following sequence of events for unloading a package, packages containing quantities of radioactive material in excess of Type A quantities specified in 10 CFR 20.1906(b) shall be received, monitored, and handled by the licensee receiving the package in accordance with the requirements of 10 CFR 20.1906 as applicable.

7.2.1 Move the unopened package to an appropriate level unloading area.

7.2.2 Perform an external examination of the unopened package. Record any significant observations.

7.2.3 Loosen and remove bolts that attach the upper impact limiter to the cask body.

7.2.4 Remove upper impact limiter using caution not to damage the cask or impact limiter assembly.

7.2.5 Remove security seals.

7.2.6 If cask must be removed from trailer, refer to Step 7.1.1.1.

7.2.7 Vent cask cavity by removing the plug from the pressurization port.

7.2.8 Loosen and remove the twenty-four (24) primary lid bolts.

7.2.9 Using suitable lifting equipment, lift lid from cask using care during handling operations to prevent damage to cask and lid seal surfaces.

NOTE: The cables used for lifting either lid must have a true angle, with respect to the horizontal, of not less than 60°.

7.2.10 Remove contents.

NOTE: RADIOACTIVELY CONTAMINATED LIQUIDS MAY BE PUMPED OUT, REMOVED BY USE OF AN ABSORBENT MATERIAL, REMOVAL OF ANY MATERIAL FROM INSIDE THE CASK SHALL BE PERFORMED UNDER THE SUPERVISION OF QUALIFIED HEALTH PHYSICS (HP) PERSONNEL WITH THE NECESSARY HP MONITORING AND RADIOLOGICAL HEALTH SAFETY PRECAUTIONS AND SAFEGUARDS.

7.2.11 Re-assemble package in accordance with sections 7.1.2.2 through 7.1.2.8 above and prepare for transport in accordance with section 7.1.3. above.

7.3 Preparation of Empty Packages for Transport

The Model WMG 150B cask requires no special transport preparation when empty. Loading and unloading procedures outlined in this chapter shall be followed as applicable for empty packages. The requirements of 49 CFR 173.428 shall be complied with.

NOTE: EACH PACKAGE USER WILL BE SUPPLIED WITH A COMPLETE DETAILED OPERATING PROCEDURE FOR USE WITH THE PACKAGE.

7.4 Appendix

7.4.1 References

7-1 10 CFR 20, Standards for Protection Against Radiation

7-2 CFR 71, Packaging and Transportation of Radioactive Material

7-3 49 CFR 172, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans

7-4 49 CFR 173, Shippers – General Requirements For Shipments and Packagings

7-5 D. C. Kocher, *Nuclear Decay Data for Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities*, ORNL/NUREG/TM102, August 1977.

Attachment 7-1

Co-60 Equivalent Curie Calculation

Nuclide	A Activity Millicuries (mCi)	B ** Decay Energy (Mev\Dis)	C (Dis/s/mci)	A x B x C (Mev/S)
Ag-110m		2.73E+00	3.70E+07	
C-14		<0.01	3.70E+07	
Ce-141		7.65E-02	3.70E+07	
Ce-144		2.02E-02	3.70E+07	
Co-57		1.25E-01	3.70E+07	
Co-58		9.76E-01	3.70E+07	
Co-60		2.50E+00	3.70E+07	
Cr-51		3.26E-02	3.70E+07	
Cs-134		1.56E+00	3.70E+07	
Cs-137 *		5.66E-01	3.70E+07	
Fe-55		<0.01	3.70E+07	
Fe-59		1.19E+00	3.70E+07	
H-3		<0.01	3.70E+07	
I-129		2.47E-02	3.70E+07	
Mn-54		8.36E-01	3.70E+07	
Nb-94		1.57E+00	3.70E+07	
Nb-95		7.64E-01	3.70E+07	
Ni-59		<0.01	3.70E+07	
Ni-63		<0.01	3.70E+07	
Sb-124 *	(________) x 1.498 = ________	1.87E+00	3.70E+07	
Sb-125		4.33E-01	3.70E+07	
Sn-113		2.31E-02	3.70E+07	
Sr-89		<0.01	3.70E+07	
Sr-90		<0.01	3.70E+07	
Tc-99		<0.01	3.70E+07	
Zn-65		5.84E-01	3.70E+07	
Zr-95		7.35E-01	3.70E+07	
Am-241		2.81E-02	3.70E+07	
Cm-242		<0.01	3.70E+07	
Cm-243		1.33E-01	3.70E+07	
Cm-244		<0.01	3.70E+07	
Pu-238		<0.01	3.70E+07	
Pu-239		<0.01	3.70E+07	
Pu-240		<0.01	3.70E+07	
Pu-241		<0.01	3.70E+07	

Total Mev/s = ____________

Divide total Mev/s by 9.25E+10 to get Co-60 Equivalent Curies

Co-60 Equivalent Curies = ____________

Is Co-60 Equivalent Curies < 100 ? Yes___ No__

*Note: * Cs-137 gamma energy based on Ba-137m decay and a Cs-137 yield of 0.946*

Sb-124 Activity must be multiplied by its Correction Factor of 1.498

Compliance can be demonstrated by using the Co-60 Equivalent Curies calculated by the RADMAN computer program

** For radionuclides not listed, the gamma energy in Mev/Dis must be determined from Reference 7-5.

Attachment 7-2

Determination of Hydrogen Concentration

1. Determine the radionuclide concentration in the contents.
    - 1.1.1. For any package containing materials with radioactivity concentration not exceeding that for LSA, ensure the shipment occurs within 10 days of preparation, or within 10 days of venting the secondary container.
    - 1.1.2. For packages which satisfy the 10 day LSA condition, go to step 11, otherwise continue with step 2.
2. Determine the secondary package(s) void volume and the cask cavity void volume.
3. Identify the secondary container(s) vent path, if applicable
4. Determine the quantity of hydrogenous contents
5. Determine the G value of the hydrogenous contents per NUREG/CR-6673, Section 3.
6. Determine the energy deposition rate in the hydrogenous contents
7. Determine the hydrogen generation rate per NUREG/CR-6673, Section 4.2
8. Determine the effective hydrogen transport rate due to diffusion for the vent path; see NUREG/CR-6673, Section 4.1
9. Determine the shipping time to reach a hydrogen concentration of 5% in the package; see NUREG/CR-6673, Section 4.2.2.1 and Appendix F; Example #4.
10. If the time to reach 5% concentration is more than double the expected shipping time, the shipment meets the hydrogen concentration requirement.
11. Authorize the shipment.

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8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This section of the application describes the acceptance tests and maintenance program that will be used for the WMG 150B in compliance with Subpart G of 10 CFR Part 71.

8.1 Acceptance Tests

Prior to the first use of a WMG 150B package the following tests and evaluations will be performed:

8.1.1 Visual Inspections and Measurements

Throughout the fabrication process, confirmation by visual examination and measurement are required to be performed to verify that the WMG 150B packaging dimensionally conforms to the drawing WMG-150B-DW-004-P71 provided in Section 1.

The packaging is also required to be visually examined for any adverse conditions in materials or fabrication that would not allow the packaging to be assembled and operated per Section 7.0 or tested in accordance with the requirements of this section.

Throughout the fabrication process, the fabricator shall request approval from WMG prior to implementation of any options allowed in the drawing.

8.1.2 Weld Examinations

8.1.2.1 All the containment welds, identified on drawing WMG-150B-DW-004-P71 and in Figure 2-2 of this SAR, will be examined in accordance with ASME Code, Section III, Division I, Subsection NB. These welds will be examined as listed below.

Components	BOM Items	Examination Type
Inner Shell Segments	104	RT and MT
Inner Baseplate - Inner Shell	102 - 104	MT
Inner Shell – Bolting Ring	104 - 106	MT
Bolting Ring – Bearing Plate	106 - 110	PT
Seal Plate – Primary Lid Plate	206 - 201	PT
Primary Lid Plate – Bearing Plate	201 - 213	PT
Seal Plate – Secondary Lid Plate	221 - 216	PT
Pressurization Port Plug – Primary Lid Plate	232 -201	MT

8.1.2.2 All welding of Non-Containment Boundary items will be examined in accordance with ASME Code, Section III, Division I, Subsection NF. All structural welds shown in

drawing WMG-150B-DW-004-P71, not identified in 8.1.2.1 will be considered non-containment welds. These welds will be examined by MT or PT as appropriate.

8.1.2.3 Welding on lifting and tiedown lugs shown in drawing WMG-150B-DW-004-P71 will be examined in accordance with ASME Code, Section III, Division I, Subsection NF and shall be inspected by magnetic particle examination (MT) with acceptance requirements of ASME Code, Section III, Division I, Subsection ND-5000 or NF-5000. Inspection shall be before and after 150% load test. These welds will be examined by MT.

8.1.2.4 All welds used for installing the stainless steel liners in the cavity of the cask, and on the lid inside surfaces, shall be considered non-structural and will be examined per ASME Section III, Division I, Subsection ND-5000 or NF-5000. They will be examined by VT.

8.1.3 Structural and Pressure Tests

Before the first use of the package, a pressure test of the cask will be performed as required by 10CFR71.85 "to verify the capability of that system to maintain its structural integrity at that pressure".

As determined in Section 3.3.2.2, the maximum normal operating pressure for the cask cavity is 26.36 psia; therefore the minimum test pressure will be $1.5 \times 26.36 = 39.54 \approx 40$ psia. The hydrostatic test pressure will be held for a minimum of 10 minutes. Successfully maintaining the pressure shall be considered as the acceptance criteria for this test.

After depressurization and draining, the cask cavity and seal areas will be visually inspected for cracks and deformation. Any cracks or deformation will be remedied and the test and inspection will be repeated.

8.1.4 Leakage Tests

8.1.4.1 General requirements

- Test configuration – In order to allow access to all containment welds shown in Figure 2-2, testing of the entire containment boundary will be performed prior to lead pour. No non-containment welds that may mask the containment weld from leak examination will be made prior to this test.
- Testing method - Per ANSI N-14.5 in accordance with ASTM E-499 using a helium leak detector.
- Test Sensitivity - the test method must be capable of meeting the appropriate sensitivity requirements specified in Figure 4-2 in Section 4.0. Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST.
- The leak standard's setting shall correspond to the approved leak test rate (see Section 4.0).
- Any condition, which results in leakage in excess of the maximum allowable leak rate specified in Figure 4-1, shall be corrected and retested.

8.1.4.2 Test Procedure

- (Optional) Insert a sealed metal cavity-filler canister into the cask cavity. Verify the canister does not obstruct the pressurization port penetration. The metal must be chemically compatible with the cask liner and the test gas.
- Assemble the cask lids per Section 7.1.2.
- Evacuate the cask cavity to 20" Hg vacuum, minimum (sealed metal cavity filler canister may be used within the cask cavity)
- Pressurize the cask cavity to a minimum pressure of 1 psig with pure helium.
- Check for leakage of the inner shell and base plate components
- Measure the leakage of the inner (containment) O-ring via the test port in each lid.
- Check for leakage at the pressurization port.

8.1.5 Component and Material Tests

WMG will apply its USNRC approved 10CFR71 Appendix B Quality Assurance Program, which implements a graded approach to quality based on a component's or material's importance to safety to assure all materials used to fabricate and maintain the WMG 150B are procured with appropriate documentation which meet the appropriate tests and acceptance criteria for packaging materials.

This includes:

- Steel material used for shells, lids, bolts, etc. will comply with ASTM Standard.
- Poured-in lead shall comply with ASTM B-29, Chemical Lead Standard.
- O-Ring seal material shall conform to ASTM D-2000 standard. The material, if procured from a non-approved vendor, shall be dedicated per WMG commercial grade dedication (CGD) procedure (WMG-EN-105). As a minimum the characteristics specified in WMG specification WMG-150B-ES-003 (Reference 8-2) shall be considered in the CGD process.

  The seal material, if procured from a non-approved vendor, shall meet the critical characteristics through testing by a Q-Level 1 qualified testing laboratory.

  The seal manufacturer, specific material and/or material combinations of materials, minimum dimensions, and maximum dimensions are seal parameters that are subject to NRC approval.
- The impact limiter foam will meet the requirements of WMG specification WMG-150B-ES-002 (Reference 8-1).

8.1.6 Shielding Tests

Shielding integrity of the package will be verified by gamma scan to assure the package lead layer meets or exceeds the minimum thickness specified on the cask drawing. All gamma scanning will be performed on a 4-inch square or less grid system. The acceptance criteria (maximum dose rate value) will be determined by: Option 1) measurement of the maximum dose rate value using a test block, which has shield layers that replicate the cask geometry per the drawing, using the gamma scan source and reproducing the source/shield/detector geometry that

will be used during the scan of the cask, or Option 2) calculation of the maximum dose rate value using detailed modeling software (MCNP or equivalent) incorporating the specific cask dimensions from the drawing and the source/shield/detector geometry applicable to the gamma scan. Any location on the cask which shows a gamma scan dose rate value greater than the maximum dose rate value will be identified as unacceptable. All unacceptable areas will be remedied and re-scanned. Remedy for an unacceptable gamma scan include actions such as controlled re-heating of the cask body to melt the lead to remove any voids or streaming paths. This process may be used as long as average metal temperatures are kept below 800°F. If the remedy could affect more than just the unacceptable area, e.g., re-heating of the cask body, all affected portions will be re-scanned.

8.1.7 Thermal Tests

No thermal acceptance testing will be performed on the WMG 150B packaging. Refer to the Thermal Evaluation, Section 3.0 of this report.

8.1.8 Miscellaneous Tests

No additional tests will be performed.

8.2 Maintenance Program

The WMG 150B package will be subjected to routine and periodic inspection and tests as outlined in this section and the approved procedure based on these requirements. Defective items are replaced or remedied, including testing, as appropriate.

Examples of inspections performed prior to each use of the cask include:

- Cask Seal Areas: O-rings are inspected for any cracks, tears, cuts, or discontinuities that may prevent the O-ring from sealing properly. O-ring seal seating surfaces are inspected to ensure that they are free of scratches, gouges, nicks, cracks, etc. that may prevent the O-ring from sealing properly. Defective items are replaced or remedied, as appropriate.
- Cask bolts, bolt holes, and washers are inspected for damaged threads, severe rusting or corrosion pitting. Defective items are replaced or remedied, as appropriate.
- Lift Lugs and visible lift lug welds are inspected to verify that no deformation of the lift lug is evident and that no obvious defects are visible. Defective items are replaced or remedied, as appropriate.

Examples of inspections performed on a periodic/annual basis:

Component	**Inspection Method** (Visual, Measurement)	**Condition** (Any corrosion, pitting, cracking, gouges, scratches, nicks, thread damage)	**Condition** (Section loss, out of tolerance as measured against BOM)	**Action**
Lift Lugs	V & M	X	X	Engineering Evaluation, Rework,
Bolt	V & M (No Go Lo/Hi gauge test IAW Section 6 of ASME B1.2)	X	X	Replace
Bolt Hole	V & M	X	X	Engineering Evaluation, Rework
Washer	V & M	X	X	Replace
"O" Ring	V & M	X	X	Replace
"O" Ring Sealing Surface	V & M	X	X	Engineering Evaluation, Rework

8.2.1 Structural and Pressure Tests

No routine or periodic structural or pressure testing will be performed on the WMG 150B packaging.

8.2.2 Leakage Tests

8.2.2.1 Periodic and Maintenance Leak Test

The WMG 150B packaging shall have been leak tested as described below within the preceding 12-month period before actual use for shipment and after maintenance, repair (such as weld repair), or replacement of components of the containment system.

The WMG 150B packaging seals shall have been replaced within the 12-month period before actual use for shipment.

General requirements

- Testing method - Per ANSI N-14.5 in accordance with ASTM E-499 using a helium leak detector.
- Test Sensitivity - the test method must be capable of meeting the sensitivity requirements 0.5×10^{-7} atm-cm^3/sec (leaktight status).

- Calibration of the leak detector shall be performed using a leak rate standard traceable to NIST.
- The leak standard's setting shall correspond to a maximum leak rate of 1.0×10^{-7} atm-cm^3/sec of air (leaktight status).
- Any condition, which results in leakage in excess of the appropriate maximum allowable leak rate of 1.0×10^{-7} atm-cm^3 /sec (leaktight status), shall be corrected and re-tested.

Testing of the Lids and Pressurization Port

- (Optional) Insert the sealed metal cavity filler canister into the cask cavity. Verify the canister does not obstruct the pressurization port penetration. The metal must be chemically compatible with the cask liner and the test gas.
- Assemble the cask lids per Section 7.1.
- Evacuate the cask cavity to 20" Hg vacuum (minimum)
- Pressurize the cask cavity to 1 psig (minimum) with pure helium
- Measure the leakage of the inner (containment) O-ring via the test port in each lid.
- Measure the leakage of the pressurization port.

8.2.2.2 Pre-Shipment Leak Test

The pre-shipment leak test is required before every WMG 150B cask shipment to verify that the containment system has been assembled properly. Sensitivity at the test conditions is equivalent to the prescribed procedure sensitivity of 1×10^{-3} ref-cm^3/sec based on dry air at standard conditions as defined in ANSI N 14.5-1997.

General Requirements

- The test will be performed by pressurizing the annulus between the O-ring seals of each lid, or inlet to the pressurization port with dry air or nitrogen to 18 psig.
- The pre-shipment leak test is performed using a test manifold that may be constructed from tubing, fittings, isolation valves and a pressure gauge. The test apparatus used for this test must have an internal volume, with isolation valves closed and the apparatus connected to the test port location, of less than or equal to 10 cm^3 to achieve the required test sensitivity for the specified hold time.
- If air is used for the test, the air supply should be clean and dry. If it is not, or if the quality of the air supply is uncertain, the test should be performed with nitrogen to ensure reliable results.
- The test shall be performed using a pressure gauge, accurate within 1%, or less, of full scale.
- The test pressure shall be applied for at least 13 minutes for the lid or pressurization port. A drop in pressure of greater than 0.1 psig shall be cause for test failure.

Primary and Secondary Lid O-Rings Helium Leak Testing

Verification of the primary and secondary lid containment boundaries is performed prior to its initial use, periodically every 12 months, and after maintenance. This test is conducted using a

helium leak detector in accordance with ANSI N14.5-1997 Table 1 test 7.4 and 7.5 to demonstrate compliance with the ANSI N14.5 leaktight criteria. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 or equivalent. The leak test for the Primary lid O-rings is performed with the Primary lid installed and torqued to the cask body and the Secondary lid removed. The leak test for the Secondary lid O-rings is performed with the Primary lid off the cask body and the Secondary lid installed and torqued to the Primary lid.

Test Personnel Qualifications

Test personnel shall be ASNT NDT Level III certified in leakage testing.

Frequency

This test is performed prior to initial use, periodically every 12 months, and after maintenance involving O-rings or bolts.

Components to be tested

The components tested are the inner O-rings in the primary lid or the secondary lid.

Testing Procedure

1. Assemble the cask lids per Chapter 7, Section 7.1.2 Loading of Contents. The bolts must be torqued to the specifications listed in this Section.

2. Remove the test port cover.

3. Remove the leak test port plug on either the primary or secondary lid, whichever containment boundary is to be tested.

4. Install manifold with vacuum isolation valve, test gas isolation valve and compound test gauge to the top of the Pressurization port.

5. Ensure the test gas supply isolation valve is closed.

6. Open the vacuum isolation valve and evacuate the area between cask lid O-rings to 20" hg (minimum).

7. Close the vacuum isolation valve.

8. Set the test gas regulator on the manifold to 0 psig and connect the test gas supply to the manifold's adapter.

9. Open the manifold isolation and test gas supply isolation valves. Ensure the test gas supply isolation valve is closed.

10. Set the test gas regulator on the manifold to 0 psig and connect the test gas supply to the manifold's adapter.

11. Open the manifold isolation and test gas supply isolation valves.

12. Adjust the regulator as necessary until 1.0 +/– 0.5 psig is obtained on the pressure gauge.

13. Close the manifold isolation valve, then close the test gas supply isolation valve.

14. Allow the test gas temperature to equalize with that of the cask body / lids for 30 minutes.

15. Remove the test gas supply from the manifold isolation valve.

16. After 1.0 +/- 0.5 PSIG is obtained on the gauge, Check for leakage of the inner (containment) O-ring by moving a detector probe along the interior surface of the inner seal according to the specifications of ASTM E-499.

Acceptance Criteria

Refer to Chapter 8, Section 8.2.2.1 for test acceptance criteria.

Actions to be taken if test fails

Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

Pressurization / Test Port Cover Helium Leak Testing

Verification of the pressurization / test port cover is prior to its initial use, periodically every 12 months, and after maintenance. This test is conducted using a helium leak detector in accordance with ANSI N14.5-1997 Table 1 test 7.4 and 7.5 to demonstrate compliance with the ANSI N14.5 leaktight criteria. Calibration of the helium detector is performed using an appropriate standard, in accordance with Section 10 of ASTM E-499 or equivalent. The leak test of the Pressurization / Test port can be performed with the Primary lid installed or removed from the cask body. If Primary lid is installed on the cask body, the Secondary lid shall be removed to allow access to the pressurization / test port on the underside of the Primary lid.

Test Personnel Qualifications

Test personnel shall be ASNT NDT Level III certified in leakage testing.

Frequency

This test is performed prior to initial use, periodically every 12 months, and after maintenance involving the O-rings or covers.

Components to be tested

The component tested is the pressurization / test port cover.

Testing Procedure

1. Assemble the cover plate per Chapter 7, Section 7.1.2. The Stat-O-Seal cap screw must be torqued to the specifications listed this Section.

2. Install manifold with vacuum isolation valve, test gas isolation valve and compound test gauge to the top of the Pressurization port.

3. Ensure the test gas supply isolation valve is closed.

4. Open the vacuum isolation valve and evacuate the area above the Stat-O-Seal / cap screw to 20" hg (minimum).

5. Close the vacuum isolation valve.

6. Set the test gas regulator on the manifold to 0 psig and connect the test gas supply to the manifold's adapter.

7. Open the manifold isolation and test gas supply isolation valves.

8. Adjust the regulator as necessary until 1.0 +/ – 0.5 psig is obtained on the pressure gauge.

9. Close the manifold isolation valve, then close the test gas supply isolation valve.

10. Allow the test gas temperature to equalize with that of the cask body / lids for 30 minutes.

11. Remove the test gas supply from the manifold isolation valve.

12. After 1.0 +/- 0.5 PSIG is obtained on the gauge, Check for leakage of the Vent Port Cap Screw and Seal by moving the detector probe along the interior surface of the PRIMARY Lid in the area of the vent port according to the specifications of ASTM E-499.

Acceptance Criteria

Refer to Chapter 8, Section 8.2.2.1 for test acceptance criteria.

Actions to be taken if test fails

Any condition which results in leakage in excess of the maximum allowable leak rate is corrected and re-tested.

8.2.3 Component and Material Tests

Cask seals (O-rings) are inspected each time the cask lids or pressurization port cap screw are removed. Inspection and replacement of the seal is discussed in Section 8.2.2.

New seals are lightly coated with a lightweight lubricant such as Parker Super O-Lube or equivalent prior to installation. The lubricant will minimize deterioration or cracking of the elastomer during usage and tearing if removal from the dovetail groove is necessary for inspection. Coating the exposed surfaces of installed lid seals with the lightweight lubricant immediately prior to closing the lid can help to minimize deterioration or cracking of the seal during use. Excess lubricant should be wiped off before closing the lid.

Painted surfaces, identification markings, and match marks used for closure orientation shall be visually inspected to ensure that painted surfaces are in good condition, identification markings are legible, and that match marks used for closure orientation remain legible and are easy to identify.

Visible cask external and cavity welds shall be inspected within twelve months prior to use to verify that the welds specified by the applicable cask drawing are present and that no obvious weld defects are visible. If paint is covering these welds, the inspection may be completed without removing the paint.

8.2.4 Thermal Tests

No periodic or routine thermal testing will be performed on the WMG 150B packaging.

8.2.5 Miscellaneous Tests

No additional tests will be performed periodically on the package or its components.

8.3 Appendix

8.3.1 List of References

8-1 WMG Specification WMG-150B-ES-002, Rev.1.

8-2 WMG Specification WMG-150B-ES-003, Rev.0.

Chapter 1 General Information

1-1 Provide a detailed description of the characteristics of each type and form of permitted contents of the package, including the identification of the main isotopes and radioactive constituents.

The application, as submitted, does not address important aspects such as the type of radionuclides in the contents. Also, it is not clear that the proposed contents preclude materials containing significant sources of neutron radiation. Thus, the application should describe clearly the radionuclides proposed to be shipped in the package and provide an evaluation for these radionuclides. The staff also notes that contents that have the capacity to induce stress corrosion cracking of the containment boundary or degrade the seals must be prohibited.

This information is required to determine compliance with 10 CFR 71.31(a), 71.33(b), 71.35(a), 71.47 and 71.51.

Response:

Descriptions of the proposed contents including identification of the main radionuclides and historic data regarding isotopic content for each waste form are now provided in Reference 5-7 of the SAR along with the rationale for the design basis source term used. Furthermore, the revision to section 5 includes a list of the typical radionuclides found in commercial low level waste to be shipped in the package.
Contents are limited to 3000 A2 per Section 1.2.2.1 with the activity of gamma emitting nuclides limited to 100 Co-60 equivalent curies as demonstrated in Section 5 and calculated per Attachment 7-1. Sealed sources are not included in the proposed contents and neutron sources will not be shipped in the package. The proposed package contents do not include fissile material and neutron exposure is minimized by limited the contents to Fissile Excepted per 10 CFR 71.15 as stated in Sections 1.1, 1.2 and 5.2 of the SAR
The 150B cask is designed to transport byproduct radioactive material in the form of dewatered and solidified ion exchange resins and sludges, dewatered and solidified filters and irradiated hardware. The aforementioned contents will be packaged in a Steel or High Density Poly-ethylene Secondary Container prior to placement in the cask. The contents do not have the capacity to induce stress corrosion cracking to the Secondary Container nor to the cask interior or seals in the event of Secondary Container breach.

Licensing Drawings

1-2 Categorize all components listed in the Bill of Materials on the licensing drawings following the guidance of NUREG/CR6407. Clarify their safety classification and acceptance criteria (if applicable) used to characterize the components.

All components should have their safety category indicated on the Bill of Materials according to NUREG/CR 6407, i.e., Category A, B, or C, for components important to safety.

This information is required to determine compliance with 10 CFR 71.33(a)(5).

Response:

All the items listed in the BOM of drawing WMG-150B-DW-004-P71 have been categorized as safety level A, B, or C according to NUREG/CR 6407 in column QL of the BOM. Flag-Note 20 is indicated next to this column that has been modified to read:

Bill of Material items have been categorized per NUREG/CR 6407 based on their safety level as A, B or C. These items shall be procured, fabricated, and documented per their safety level in accordance with the NRC-approved WMG QA Program (NRC Approval Number 0954).

Please note that *Safety Level* and *Quality Level* are synonymously used in order to be consistent with the WMG QA program terminology.

1-3 Item 323 is not shown on the Bill of Materials. Provide details and dimensions of this item on the licensing drawings and clarify its integration into the impact limiter.

Section 2.5.1.4.1 of the application mentions item 323 which appears to be a lifting lug for the impact limiter; however, no impact limiter lifting lugs are shown on the drawings and the adjoining angle made of A36 steel.

This information is required to determine compliance with 10 CFR 71.33 and 10 CFR 71.45.

Response:

Impact limiter lifting lug details and dimensions have been added in drawing WMG-150B-DW-004-P71. Items 322, 323, and 324 have been included in the BOM to provide the complete details of the impact limiter lifting attachments.

Observations

1-4 Indicate, on the drawings, what welding process, weld filler material, and welding notes will be used at each of the welds specified on the plans along with their associated welding calculations.

Base material welding calculations have been provided in the application, but the welds themselves were not. Weld filler material and welding process have not been provided. Reference to the ASME codes alone is insufficient.

This information is required to determine compliance with 10 CFR 71.45, 10 CFR 71.71, and 10 CFR 71.73.

Response:

Will be provided later.

1-5 Identify the bolting ring on the licensing drawings.

Section 2.1.1.1 of the application mentions a bolting ring but this item and associated nomenclature are not clearly marked on the plans.

This information is required to determine compliance with 10 CFR 71.33.

Response:

Bolting Ring has been consistently used throughout the drawing WMG150B-DW-004-P71 and the SAR for Item No. 106.

1-6 Specify on the drawings and associated calculations the minimum shackle pin diameter to be used to lift any lifting lug on the plans.

All calculations assume a shackle or lifting device that is as large as the opening in the lifting lug.

This information is required to determine compliance with 10 CFR 71.45.

Response:

Note 29 has been added to the SAR drawing that specifies the shackle sizes. Step 7.1.1.2.2 of the operating procedure in Section 7 of the SAR also specifies these sizes.

The tolerance on the secondary lid lug holes has been changed from (+1/8", -0) to (+1/32" -0). With the specified shackle sizes (27 tons WLL for primary lugs, and 1.5 tons WLL for secondary lugs), the hole sizes are within 10% of the pin sizes. This is an acceptable condition based on the recognized industry standards. See for example ASME BTH-1-2011 paragraph 3-3.3.5.

1-7 Provide a reference to the WMG, Inc., approved quality assurance program on the drawings.
Drawings should provide a reference to the NRC approved quality assurance program. This information is required to determine compliance with 10 CFR 71.31 and 10 CFR 71.37.

Response:

General Note 25 has been added to the drawing WMG-150B-DW-004 to read:

This drawing has been generated in accordance with WMG's Quality Assurance Program (NRC Approval Number 0954).The design, fabrication, testing, examination, and document control of the WMG 150B Cask project is subject to WMG's Quality Assurance Program.

1-8 Clarify, on the drawings, which lugs will be used to lift the cask, primary lid, secondary lid, and which lugs will be rendered inoperable during each part of the lifting operations.

Staff is concerned that the wrong lug may be used for lifting operations. Indicate which lugs will be rendered inoperable during lifting operations in Section 7 of the

application and on the drawings.

This information is required to determine compliance with 10 CFR 71.33 and 10 CFR 71.45(b)(2).

Response:

The primary lid lugs (Item 211) are designed and analyzed for lifting the entire cask. These lugs may be used for lifting the primary lid, as well as the combination of the primary and secondary lids. The secondary lid lifting lugs (Item 226) are designed for lifting the secondary lid only. In order to ensure that the secondary lid lugs (Item 226) may not be accidently used for lifting the cask, or the combination of primary and secondary lids, marking on the secondary lid stating "Use these lugs for lifting the Secondary Lid only" has been added. See the SAR drawing Sheet 4.

During the transportation of the package both the primary and the secondary lid lifting lugs will be covered by the upper impact limiter. Therefore, the provisions of 10 CFR 71.45(b)(2) are not applicable.

1-9 Clarify lifting lug details on the body of the package.

Sheet 7 of the licensing drawings shows lugs that appear to be attached directly to the package body, but is unclear how the heat shield, wire wrap, etc., will be modified in this area to accommodate the lug.

This information is required to determine compliance with 10 CFR 71.33 and 10 CFR 71.45.

Response:

Note 27 has been added to the SAR drawing to indicate that the heat-shield (Item 116) and the wire wrap (Item 115) will be cut around the tie-down lugs to fit.

Chapter 2 Structural and Materials Evaluation

2-1 Provide a detailed description of the lead pouring process used for this application. Discuss whether qualified procedures and personnel are utilized. Discuss whether trace elements may exist, as introduced during the pour, in addition to those which may be acceptable under ASTM B29 specification. Provide justification why ASTM A543, Type B, Classes 1 and 2 materials are not susceptible to liquid metal embrittlement (LME) when in contact with liquid lead. Provide history, experience, and available research literature.

Drawing WMG-150B-DW-004-P71, sheet 1 of 8, note 14, states that the lead pour will be continuous and the lead integrity will be ensured by a gamma scan. No other specific information is provided concerning the reliability of the steel shell following the lead pour and literature suggests that plain carbon and low-alloy steels may be embrittled by exposure to liquid lead (LME).

This information is required to determine compliance with 10 CFR 71.33(a)(5)(iii), and 71.39.

Response:

Detailed description of the lead-pouring process is included in the new document WMG-150B-AR-129S-P71 (Reference 2-40 of the SAR). The liquid metal embrittlement of ASTM A543 steel has been addressed in this document. It has been concluded that under the controlled lead-pouring process that will be used for the fabrication of the WMG 150B cask, ASTM A543 is not susceptible to liquid metal embrittlement (LME).

An additional requirement has been added in the specification of ASTM A-543, Type B, Class 1, material to inspect the surfaces per [MIL] T9074-BD-GIB-010/0300, Section B.3.6 (see Note 28 on drawing WMG-150B-DW-004-P71, Rev.1). This will eliminate the presence of surface cracks - one of the necessary conditions for LME.

2-2 Include, in the evaluation, stresses that are incurred by the pouring of lead into scenarios for both normal conditions of transport (NCT) and hypothetical accident conditions (HAC).

Lead pouring and subsequent shrinkage when cooling introduces stresses into the package design that should be included under NCT and HAC.

This information is required to determine compliance with 10 CFR 71.71, and 10 CFR 71.73.

Response:

A new document WMG-150B-AR-130S-P71 (Reference 2-41 of the SAR) has been created. It has been shown in this document that under the controlled lead-pouring process used for the fabrication of the WMG 150B cask, the only component that will experience stresses due to lead shrinkage are the inner shell and the bolting ring. The process of lead-pour, cool-down, lead thickness examination, and closure of the assembly by outer base-plate will take weeks to complete. It has been shown in analyses that because of the lead creep the fabrication stresses will reduce to levels that are an order of magnitude smaller than those calculated using elastic properties of the structural components.

In the NCT and HAC analysis results provided in the SAR, the thermal stresses are very conservatively accounted for by using the appropriate temperature dependent coefficients of thermal expansion, and elastic modulus, of steel and lead. It has been concluded in the document that the fabrication stresses due to lead pouring process are very small and are adequately compensated in the conservative analyses of the NCT and HAC events.

2-3 Provide a traceable evaluation to demonstrate that the LS-DYNA finite element analysis (FEA) model is properly benchmarked for predicting rigid body decelerations of the package under free-drop analyses.

To benchmark the FEA model for the drop analyses, the application references, and relies on, the Model No. 3-60B package designed and analyzed by Energy*Solutions*. Calibration of the Model No. 3-60B package is based on a vitrified high level waste cask that was physically drop-tested by BAM. However, since the WMG-150B package is not owned by Energy*Solutions*, it is unclear to the staff what specificities of the BAM tests and the Energy*Solutions'* benchmark evaluation, which could be proprietary, are applicable and can be used for benchmarking the WMG-150B FEA model.

Response:

A new proprietary document WMG-150B-AR-131S-P71 (Reference 2-42 of the SAR) has been created. This document benchmarks the WMG LS-DYNA modeling technique's results with the test results of vitrified high level waste (VHLW) cask,

performed by BAM and Sandia National Laboratories (SNL). The digital test data have been obtained from SNL. The results of the analyses show that the WMG modeling techniques predict the rigid body acceleration of the cask conservatively for the side drop, and within 1% for the slap-down, test results. The trace of the acceleration time-history show an excellent agreement, and the pulse duration during both tests are remarkably similar.

The proprietary document WMG-150B-AR-110-P71 (Reference 2-25 of the SAR) is still included in the SAR submittal because it provides an additional benchmarking of the WMG analysis techniques. Thus, the WMG LS-DYNA drop analyses techniques have now been benchmarked with:

- Test Results (WMG-150B-AR-131S-P71), and
- An Established Modeling Technique (WMG-150B-AR-110-P71)

2-4 Provide missing references and files and ensure that they are correctly annotated in the application and on the supplied CDs. Provide a summary table of references and their corresponding names and locations on the CDs provided to staff for their review.

Reference 2-23 is labeled as Reference 3-8 on the CD's. Additionally, References 119-9 and 119-7 mentioned in Reference 2-24 cannot be found on the CDs or are mislabeled. Additional missing references include 1-4, 2-27, Appendix B (Section 8), WMG-150B-ES-002-P71 (Section 8), and ANSYS files used in Reference 2-24 for conducting increased and reduced pressure analysis, and bolt tightening. Please ensure and confirm that all references mentioned in the application, as well as the references contained within, are also provided.

This information is required to determine compliance with 10 CFR 71.31(a)(1), 10 CFR 71.71, and 10 CFR 71.73.

Response:

All the references data associated with the SAR submittal are provided on new DVDs and Hard-Drives. The summary of these medium are listed as follows.

Medium	Contents
DVD-1	Non-Proprietary References
DVD-2a	Non-Proprietary Data Associated with References
DVD-2b	Non-Proprietary Data Associated with References
DVD-3	Proprietary References
DVD-4	Proprietary Data Associated with References
HD-1	Non-Proprietary ANSYS Input & Output Data
HD-2	Proprietary LS-DYNA Input & Output Data

The list of individual references and their data, if any, are included in the accompanying document titled, *Reference/Data Guide* (included in DVD-1 also). This document identifies the references/data and their location on the supplied medium.

Observations

2-5 Provide additional clarification and justification regarding the overall package weight, content to package weight, and package aspect ratio used in ANSYS/LS-DYNA modeling and the safety factors obtained from ANSYS/LS-DYNA modeling.

The WMG-150B package weighs 62,000 lbs and is expected to carry a 15,500 lbs payload (for a total gross weight of 77,500 lbs.) The aspect ratio (overall length to overall width) of the WMG-150B package, its overall weight, its contents weight to cask weight ratio, and its construction materials, are dissimilar either to the vitrified high level waste cask used for drop testing at BAM or to the Model No. 3-60B package.

Moreover, since the WMG-150B model is calibrated to another model, i.e., the 3-60B package, and not to an actual drop test, staff is concerned with the potential for error propagation. This is already apparent in the application, where the WMG-150B modeling technique is quoted, in Reference 2-15, to come within 5% of the values presented in the safety analysis report for the Model No. 3-60B. Moreover, the WMG-150B application states, in Section 2.7.1.3, "Corner Drop," that the smallest factor of safety for all components is 1.03, with some other components having a safety factor of 1.05. Therefore, the corner drop analysis, conducted for the WMG-150B package, could have a factor of safety less than 1.

Therefore, staff is concerned with the reliability of the methodology used in the application for the WMG-150B package

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

Response:

A new benchmark analysis, as described in the response of Comment No. 2-3 has been performed. The results of the VHLW cask drop tests have been compared with those from the WMG LS-DYNA model analysis results (Reference 2-42). It has been shown that the WMG modeling techniques provides results that are conservative for some drop orientations and accurate for others. The VHLW package has similarities with the WMG 150B package, as listed below.

Attribute	Comment
Impact Limiters	Both packages have dumb-bell shape impact limiters at the two ends to protect the cask during the HAC drop test.
Foam Material	Both packages use General Plastic Manufacturing Company's rigid-cell polyurethane foam.
Foam Density	WMG 150B cask uses denser foam (23 lb/ft^3 density) compared to VHLW package (17 lb/ft^3 density) in order to accommodate higher package mass (77,500 lbs. vs 52,400 lbs.).
Relative Stiffness	In both packages the casks are much stiffer than the impact limiters such that the cask and impact limiters can be dynamically un-coupled. Therefore, the analysis technique is not sensitive to the package geometry.

The WMG analysis technique has also been calibrated with the results of another analyzed cask and it has been shown that the results compare within 5% of the other technique (Reference 2-25).

As explained in the SAR, the impact limiter reactions are calculated from the foam stress-strain properties that have a tolerance of ±10% on the specified properties. The largest of all the results encompassing the temperature range, as well as the material properties tolerances have been used in the stress recovery phase of the ANSYS analysis, making the results very conservative. An additional conservatism has been employed by increasing the impact limiter reaction from those obtained from the LS-DYNA analysis for use as input in the ANSYS analysis, as shown below.

Orientation	LS-DYNA Result (Output)	ANSYS Analysis (Input)	% Difference
End Drop	6.1305×10^6 lbs.	6.5×10^6 lbs.	+6.0%
Side Drop	2.1384×10^6 lbs.	2.3×10^6 lbs.	+7.6%
Corner Drop	2.1821×10^6 lbs.	2.3×10^6 lbs.	+5.4%
Reference 2-7, Paragraph 5.1.8			

Thus it can be seen that the input to ANSYS analyses have been additionally increased by a minimum of 5.4% for the stress-recovery analysis.

2-6 Provide and update contents to canister impact calculations.

Section 1.2.2.3 of the application indicates that contents density varies from 0.5g/cc to 12g/cc. A single 55 gallon drum with these specified densities could weigh more than 10,000 lbs. However, Section 2.7.1.10 of the application assumes that two 5,000 lb drums are shored. In the HAC drop scenarios, the contents could impact a lid at a slightly oblique angle and at an off centered location, as the package overall makes contact with an unyielding surface. Lids, bolts, and the bottom plate could be damaged by such a scenario, in addition to any lead shielding in the vicinity. Cumulative damage should be examined, as the lids, bottom plate, and bolts may be damaged first by the package impact followed by the impact of contents.

This information is required to determine compliance with 10 CFR 71.73.

Response:

Will be provided later.

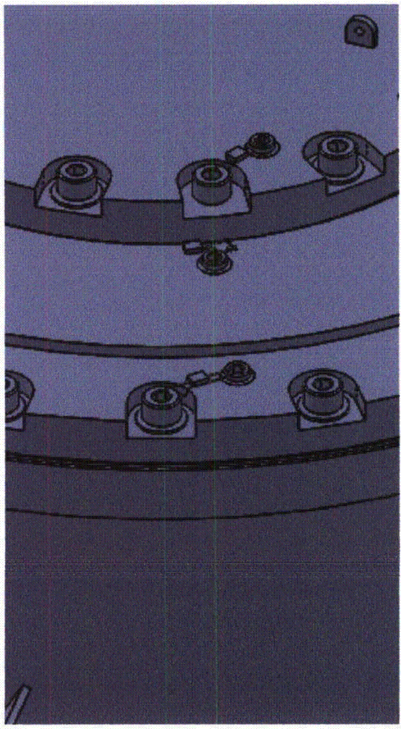
2-7 Specify the use of tamper resistance seals on the licensing drawings and provide details as to how they function.

Tamper resistance devices are mentioned in the application, but no details are provided on their use and operation.

This information is required to determine compliance with 10 CFR 71.33 and 10 CFR 71.43(b).

Response:

The tamper resistant seals, employed in the WMG 150B package, are shown on Sheet 3 (Items 238 and 239). They are specified as commercial grade cable seals, similar to Dickey Manufacturing Company's Defender 1.5 Cable seals with the minimum breaking strength of 500 lbs. These seals are connected between one each of the primary and secondary lid bolts and the pressurization ports as shown in the following sketch.



Step 7.1.2.8 in Section 7 has been added to read:

Install security seals on the primary lid, secondary lid, and the test port as shown in the SAR drawing.

2-8 Provide details, configuration, and material specifications for the shoring material used for contents packaging.

Shoring is mentioned in 2.7.1.10 of the application with regards to the packaging of canister contents but no details have been provided with regards to the material the shoring is made of or its configuration. This information should be described in the application and on the licensing drawings.

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

Response:

Will be provided later.

2-9 Provide and clarify the wire wrap details and calculations used to attach the stainless steel heat shield to the outer shell of the canister.

Wire wrap is mentioned on the plans; however, the spacing of the wire, and the tack weld spacing are not specified. Staff is concerned with the heat shield ability to stay in place in the HAC fire scenario, for the reduced external pressure loading under NCT, and the fatigue life of unobservable tack welds.

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

Response:

Note 27 has been added to the SAR drawing that provides the details of the heat-shield (Item 116) and the wire wrap (Item 115) attachment to the cask body. The wire wrap (Item 115) is helically wound at 12" pitch around the cask body. It is spot-welded every 12" longitudinal length. The heat-shield (Item 116) is wrapped around the cask body and is welded on the edges. There will be no welds between the outside of the wire wrap and the heat-shield.

During the HAC fires test and the reduced external pressure loading conditions, the heat-shield will grow radially outwards and will not impart any loading on the wire wraps. During the transportation of the package, there is no credible mode other than its own inertia that will apply any loading on these wire-wraps. Since the inertia loading is insignificant, there will not be any fatigue damage to the tack welds.

2-10 Incorporate actual welded conditions into the finite element analyses.

Several components such as lifting lugs and plates appear to have been modeled in ANSYS and LS-DYNA, for both NCT and HAC, with full penetration welds. However, plans and calculations show otherwise: see lifting lug item 201, on sheet 7, as an example.

This information is required to determine compliance with 10 CFR 71.45, 10 CFR 71.71, and 10 CFR 71.73.

Response:

Will be provided later.

2-11 Provide details and calculations on the impact of vibrations, incident to travel, on the package.

Staff is concerned with possible fatigue issues that can arise from the dynamic response of the package, incident to NCT, regarding tie down lugs, lifting lugs, and bolts.

This information is required to determine compliance with 10 CFR 71.71.

Response:

Will be provided later.

2-12 Provide additional analyses of the package orientations used for drop evaluations for both NCT and HAC.

Package orientations used in Reference 2-7 appear to be incomplete. Reversed package orientations of those shown in Figures 1-d through 1-g should also be included in the analyses to accommodate the scenario where the bottom end of the package (opposite end of where the lids are located) strikes first. Both cold and hot scenarios should be examined for all package orientations.

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

Response:

Will be provided later.

2-13 Evaluate additional package components for the puncture scenario.

Puncture, as described in 10 CFR 71.73, was not considered with respect to the outer stainless steel shield. Specifically, a glancing blow by the bar described in the puncture test could tear the shield and create a thermal "hot spot" for the HAC thermal scenario.

In addition, primary lifting lugs, secondary lift lugs, impact limiter lifting lugs, upper and lower guide plates, primary and secondary lid, and tie down lifting lugs have not been examined for a similar scenario in which these devices may be separated from the package body.

Staff is concerned that glancing blows and direct impact by the bar mentioned in the puncture test may also damage the lead shielding in those areas. The vent port region should also be examined for a direct impact as localized stresses may be observed.

This information is required to determine compliance with 10 CFR 71.73.

Response:

Will be provided later.

2-14 Perform a water immersion analysis.

Section 2.7.6 of the application states that a water immersion test (10 CFR 71.73(c)(6)) is not necessary since a value of 25 *psig* was used for the external test mentioned in Section 2.6.4 of the application. However, a value of only *20 psia* was used in both Section 2.6.4 and Reference 2-24 of the application. 10 CFR 71.73(c)(6) specifies that an equivalent amount of water to produce *21.17 psig* is adequate, which equates to
35.87 psia, the value that should be used in this calculation.

This information is required to determine compliance with 10 CFR 71.73.

Response:

Will be provided later.

2-15 Describe and provide the dimensions of the sealing surface and of the O-ring grooves.

A sealing surface is mentioned in Section 7.1.1.2.4 of the application, but the surface itself is not defined or clearly identified in the drawings.

This information is required to determine compliance with 10 CFR 71.33(a)(5).

Response:

The details of the sealing surface and O-ring grove geometry are shown on sheet 6 of the SAR drawing. Note 10 has been modified to specify that all sealing surfaces will be finished to meet the sealing requirements of Section 8.0.

2-16 Verify and clarify the dimensions of the impact limiters. The Impact limiter analysis in Reference 2-25 does not appear to use the same impact limiter dimensions as those specified on the licensing drawings.

Impact limiters, as analyzed in Reference 2-7, do not appear to incorporate the lug recesses shown at the lifting lugs in the finite element analysis and on the drawings. In addition, the height of the recesses of the impact limiters at the lifting lugs on the drawings does not indicate how deep they have to be (see Primary Lift Lug Fit-Up detail sheet 7 of 8 of the drawings). This could affect HAC drop evaluations.

This information is required to determine compliance with 10 CFR 71.33 and 71.73.

Response:

Will be provided later.

2-17 Provide the validation and verification results for ANSYS 15 results.

Reference 2-27 describes the validation and verification results for ANSYS 14.0.3. However, many, if not most, results are based on ANSYS 15 results.

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

Response:

The verification of ANSYS/LS-DYNA Version 15.0 has been performed on two operating systems Windows 8.0 and Windows 8.1. The Windows 8.0 V&V document is included as Reference 2-27 and that of Windows 8.1 is included as Reference 2-39 on DVD-1. ANSYS Version 14.0.3 V&V document is included as Reference 2-23 on DVD-1.

2-18 Include the lifting lugs and backing angle into the impact limiter analysis.

It does not appear that the lifting lugs and backing angle were used in the LS-DYNA analysis of impact limiters (Reference 2-25).

This information is required to determine compliance with the requirements of 10 CFR 71.71 and 10 CFR 71.73.

Response:

The details of the impact limiter lifting lugs and the backing angle are now provided in the SAR drawing. The lifting lugs and the backing angles are located away from the impact zones of the impact limiters. They will have no effect on the overall response of the impact limiters in any orientation during the HAC drop tests. Therefore, they have been omitted in the LS-DYNA models of the impact limiters. The modeling simplifications and the rationale for neglecting the minor components in the LS-DYNA analyses are included in Section 4.1 of Reference 2-7.

The analyses in Reference 2-25 are the benchmark analyses and not those of the WMG 150B Cask.

2-19 Provide stresses in the seal components for NCT and HAC conditions.

Stress summaries are provided for several components under NCT and HAC. However, stresses found in the inner bearing rings, primary lid seal ring, secondary lid seal ring and inner O-rings, have not been provided.

This information is required to determine compliance with the requirement of 10 CFR 71.71 and 10 CFR 71.73.

Response:

Will be provided later.

Chapter 3 Thermal Evaluation

3-1 Provide thermal models that adequately capture the thermal characteristics of the WMG-150B package during NCT and HAC.

The thermal models prepared by the applicant to perform the thermal evaluation during NCT and HAC did not include the contents of the WMG-150B package. Summary tables of temperatures did not include any limiting temperatures for the package's radioactive contents.

The information is required to determine compliance with 10 CFR 71.71 and 71.73

Response:

The finite element thermal model, used for the NCT and HAC event analyses, introduces the internal contents heat to the inside surfaces of the cask. While this assumption is conservative for the evaluation of the cask structure temperatures, it is not capable of predicting the waste temperature and the cask cavity temperatures, as pointed out by the staff.

The waste temperature and the average cavity temperature have been calculated using an analytical method. It is described in details in Section 3.3.2.1 for the NCT case and summarized in Section 3.4.3 for the HAC fire event. Tables 3-1 and 3-2 of the SAR list these temperatures in the rows titled *Cask Cavity* and *Waste Container* temperatures for the NCT and HAC events, respectively. They are also listed in the following table.

Item	Temperature (°F)	
	NCT	HAC
Cask Cavity	153.5	219
Waste Container	155.5	220.6

The limit on the waste container (radioactive contents) is dependent on the material of construction of the waste container – metal or HDPE. For the HDPE this limit is set to 250°F (HDPE melting temperature is 259°F). A note has been added in Table 3-2 to indicate this limit.

Chapter 4 Containment Evaluation

Observations

4-1 Provide the American Society of Nondestructive Testing (ASNT) certification level of the examiner for development and approval of helium and pressure change leakage rate testing procedures, considering that industry standards indicate that this should be performed by a Level III examiner.

The applicant described the leakage tests in Section 8.1.4 of the application for acceptance leak tests and Section 8.2.2 for periodic and maintenance leak test, without identifying the ANST Level of the examiner.

ANSI/ASNT CP-189-2006, "Standard for Qualification and Certification of Nondestructive Testing Personnel," which provides the minimum training, education, and experience requirements for nondestructive testing personnel, states that a nondestructive testing personnel Level III examiner has the qualifications to develop and approve written instruction for conducting the leak testing.

This information is required to determine compliance with 10 CFR 71.37, 10 CFR 71.87, and 10 CFR 71.119.

Response:

Will be provided later.

4-2 Clarify the scope of the containment boundary.

The applicant stated in Section 1.2.1.3 that the containment boundary consists of the inner steel shell of the cask body together with closure features comprised of the primary and secondary bearing and seal rings, inner O-rings, pressurization port, cask lids and cap screws and in Section 4.1.1 that the package "containment vessel" is defined as the inner shell of the shielded transport cask and the primary and secondary lids, together with the associated O-rings.

1) The applicant should clarify (i) whether the containment boundary includes the baseplate and the joining welds or not, (ii) the location of the inner O-rings, and (iii) if the cap screws serve as the containment boundary. The applicant should provide a complete and clear description of the containment boundary.

2) Revise Figure 2-1, or add another figure, to clearly demonstrate, on the figure, that the containment boundary completely encloses the package cavity.

This information is required to determine compliance with 10 CFR 71.33 and 71.51.

Response:

Will be provided later.

4-3 Provide descriptions of (1) the characteristics of the sealed metal cavity-filler canister, (2) the corresponding installation and removal procedures, and (3) the metals suitable as the cavity-filler canister in the leak test.

The applicant stated in Section 8.1.4.2 Test Procedure that (optional) the sealed metal cavity-filler canister may be inserted into the package cavity in the leakage tests to reduce the volume of tracer test gas required to conduct the tests. The applicant noted that the cavity-filler canister should not obstruct the pressurization port

penetration. The canister metal must be chemically compatible with the cask liner and the test gas.

The applicant needs to provide more information on (1) the characteristics of this sealed metal cavity-filler canister, (2) the installation and removal procedures, and (3) the list of the canister materials to ensure that the canister material will not interact with or be penetrated by the test gases (helium) and will not thermally expand to cover the drain opening during the leak tests.

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

Response:

Will be provided later.

Chapter 5 Shielding Evaluation

5-1 Justify how using MORSE-SGC with the SAS3 interface from SCALE is conservative for calculating dose rates of the WMG-150B package with the proposed contents.

MORSE-SGC is a shielding analysis code originally developed in the 70's that uses the Monte Carlo method to solve particle transport problems. In a previous meeting with the applicant, staff cautioned the applicant on the use of such a legacy shielding code, as it is no longer supported by its developer (ORNL) and any errors are no longer reported or corrected. Staff noted that SAS3 requires the user to determine the biasing scheme outside the code and manually enter it and that the convergence of the calculations has to be carefully examined. More important to staff is the fact that there is no information available for SAS3 benchmarking, except a sample problem presented in NUREG/CR-0200. The applicant was reminded that it would need to provide all validation and verification information, as applicable to this package design, for staff to even consider the use of this code in an application. Staff also reminded the applicant that SAS3 has been shown to underestimate the dose rate by a factor of almost 3 and that RAIs were generated on that topic for another applicant.

The applicant states in Section 5.0 of the SAR that the "MORSE results were benchmarked with MCNP for the most limiting shielding case." However, this benchmark result was not provided in the SAR, nor was there any further discussion of the details of this benchmark or how this calculation was performed. In addition, it is not clear what the "limiting shielding case" is, not withstanding, whether benchmarking this limiting case establishes that other cases with different geometries and materials that may not be limiting are benchmarked. As such, it is not clear whether dose rates calculated with SAS3 can be assured to be below regulatory limits.

The staff requests that the applicant provide validation and verification information appropriate to this specific application for the MORSE-SCG code using SAS3 or the applicant should provide the details of the MCNP benchmarking case and justify that this benchmark is applicable to other non-limiting cases.

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

Response:

WMG revised the shielding analysis to use MCNP6. A new document was created WMG-150B-AR-132S-P71 to document the MCNP6 shielding analysis and it is included as Reference 5-7 of the SAR. Section 5 of the SAR has been revised accordingly and WMG-150B-AR-132S includes the analysis and hardcopies of input and output files from all the MCNP case runs. Electronic copies of all case inputs and outputs including the weight windows input files (wwinp), which are required to reproduce the results are provided.

5-2 Provide a description of the contents that is sufficient to enable an adequate evaluation of the package.

The current content descriptions in the application address some properties of the contents, such as form, but do not address other important aspects such as the radionuclides in the contents. The shielding evaluation only addresses a small Cobalt-60 source, however the types of contents that the applicant proposes to ship (resins, filters, filter media) will contain other gamma emitting nuclides other than Co-60. Section 1.2.2 of the SAR states: "The activity of all radionuclides shall not exceed 3,000 A2 and shall be less than 100 curies of Co-60 or equivalent, subject to

the shielding limitations (Chapter 5) determined in accordance with Attachment 7-1 in Chapter 7." Although the staff has found describing maximum contents in terms of A2 acceptable for beta and alpha emitting nuclides, which in general do not challenge the package shielding, the staff does not accept this practice for gamma emitting nuclides (see Regulatory Issue Summary 2013-04, available on the NRC public website: http://pbadupws.nrc.gov/docs/ML1303/ML13036A135.pdf)

Thus, the application should discuss other non-Co-60 gamma emitting nuclides, provide limits for these nuclides, and provide evaluations for these radionuclides supporting the Co-60 equivalency in Attachment 7-1. This equivalency appears to equate only total energy per second to that of Co-60. However, energy per second alone does not take into account the effectiveness of the shielding for any particular gamma. Higher energy gammas will be less likely to be stopped by the shield than lower energy gammas. For all nuclides intended to be shipped, the applicant should justify that the energy per second equivalency is bounded by the Co-60 analyses.

In addition due to the nature of the content, allowing no neutron emitters would be far too restrictive as it is likely that there will be some neutron emitting contaminants and the applicant should provide a very small limit that is bounding to the content, but not challenging to the package shielding.

This information is needed to confirm compliance with 10 CFR 71.31(a), 71.33(b), 71.35(a), 71.47, and 71.51.

Response:

The revised shielding analysis report, WMG-150B-AR-132S, includes details of the type and form of contents including isotopic content and distribution for the proposed cask contents. The bounding source term is presented and clearly justified. The Co-60 Equivalency calculation has been revised to correct for higher energy gamma photons when warranted.

The applicant has provided a limit for neutron emitters by limiting the cask contents to fissile excepted per 10 CFR 71.15 as started in sections 1.1, 1.2 and 5.2 of the SAR

Observations

5-3 Justify assuming a uniform source distribution for modeling the package.

The applicant analyses assume a uniform distribution. There is no basis given in the SAR for this assumption, and non-uniformity could lead to a non-conservative dose rates. Provide a basis for this assumption. Discuss the possibility for reconfiguration and how contents are ensured to maintain uniformity at all times.

This information is needed to confirm compliance with 10 CFR 71.47 and 71.51.

Response:

The source was assumed to be uniformly distributed within the package based on current practices, historic data and current regulatory guidance. As a practical matter all the material shipped in Type B casks is higher activity material which is typically 10 CFR Part 61 Class B and C waste. Shippers are required to load the packages in a uniform manner in order to comply with the NRC CABTP and disposal site criteria. The BTP defines relatively uniform isotopic concentrations as within a factor of 10. Historic dose rate data shows that disposal liners shipped in Type B packages are much more uniform in nature. These packages typically have maximum contact dose rates within a factor of

1.3 to 2.0 of the average. More homogeneous waste forms commonly referred to as blendable waste forms, including ion exchange resins, are very uniform and typically have maximum dose rates within 30% of the average. Waste forms such as cartridge filters and irradiated hardware, where the package can contain a collection of discrete items, can be less uniform, but are still within a factor of 2.0 of the average. The CABTP limits blending concentrations of primary gamma emitters to within a factor two, which is consistent with the empirical data cited above. If one considers the dose rates at a standoff distance of 1 foot or 1 meter from the disposal liner, the observed dose rates are even more uniform.

Therefore, based on empirical data, current practices and current regulatory guidance, the source was assumed to be uniformly distributed within the package. It should be noted that the effects of concentrating the source material were analyzed under hypothetical accident conditions.

5-4 Explain how the densities of shielding materials assumed in the shielding analysis bound the actual density of shielding materials in the WMG-150B package.

As stated in SAR Section 5.1.1, "The material densities for the shielding analysis were taken from the default materials provided with the SCALE package for Carbon Steel (7.82 g/cc), Stainless Steel (7.94 g/cc) and Lead (11.34 g/cc) as appropriate." The Bill of Materials in Drawing WMG-150B-DW-004-P71 specifies the materials used for shielding, but it is not apparent that the density of these materials is bounded by those used in the shielding analysis. The applicant should discuss how they ensure that the densities used are bounded by those of the actual package fabrication.

This information is needed to confirm compliance with 10 CFR 71.47 and 71.51.

Response:

Section 5 was revised in its entirety to reflect the MCNP analysis. The revised shielding analysis report, WMG-150B-AR-132S, and section 5 include details of the materials used. The ASTM composition for the A543 steel was analyzed and a sensitivity analysis was performed with MCNP to verify that the materials specifications used for standard carbon steel are bound the results for A543 steel. It should be noted that the standard carbon steel results were in very good agreement with the A543 cases and bounded the results by about 0.2%. Therefore, the material specifications for the trace impurities in the steel have no significant impact on results as long as the materials are both modelled at 7.87 g/cc, which is the ASTM spec for A5453 steel used in the cask.

5-5 Justify the binning of the Co-60 photons for use in the MORSE code.

As stated in SAR Section 5.2.1, "The gamma photons per second were then binned to conform to the SCALE standard 18 gamma energy groups for input into the SAS3 program as summarized in Table 5-2." Table 5-2 shows nearly all of the gamma energy going into the bin from 1 to 1.33 Mev. As these are propagated through the SAS3 code, the average bin energy will be used, somewhere around 1.165MeV, and since Co-60 has 2 gammas emitted nearly 100% of the time, 1 at 1.173 and 1 at 1.332 MeV, the will both be under represented. As such, the applicant should justify this binning of the Co-60 gamma photons and discuss how it adequately accounts for the Co-60 gammas. The applicant should discuss any additional measures that were taken to ensure that the Co-60 gammas were represented accurately or conservatively.

This information is needed to confirm compliance with 10 CFR 71.47 and 71.51.

Response:

Section 5 was revised in its entirety to reflect the MCNP6 analysis. The revised shielding models input the Co-60 gamma photons at their discrete source energies and no binning of source photons was done.

Chapter 7 Operating Procedures

Observations

7-1 Indicate when the welds, and the exterior part of the package, are inspected prior to each pre-loading.

The application indicates when lid bolts, seals, and interior portions of the package are inspected for each preloading, but does not mention the inspection of the exterior parts of the package and of all accessible welds.

This information is required to determine compliance with 10 CFR71.85 and 71.87.

Response:

Will be provided later.

Chapter 8 Acceptance Tests and Maintenance Program

8-1 Provide a quantitative value of the damage mentioned for the package components, as outlined in the maintenance program in Section 8.2 of the application.

Quantify severe corrosion, pitting, thread damage to bolts, etc., in terms of section loss, as mentioned in Section 8.2 of the application, for bolts, bolt holes, washers, and O-rings and when such items must be replaced, as a function of section loss, in the maintenance program.

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

Response:

Quantitative values for determining damage or section loss of the cask components listed in SAR Section 8.2 will be determined by physical measurements and the use of gauges. The results of the measurements or tests using gauges will be compared to the original specifications identified in drawing WMG-150B-DW-004-P71 and ASME B1.2 as applicable. Discrepancies will be dispositioned as identified in the Table below. The Table below is included in Section 8.2 right below the inspections performed prior to each use of the cask.

Examples of inspections performed on a periodic/annual basis:

Component	**Inspection Method** (Visual, Measurement)	**Condition** (Any corrosion, pitting, cracking, gouges, scratches, nicks, thread damage)	**Condition** (Section loss, out of tolerance as measured against BOM)	**Action**
Lift Lugs	V & M	X	X	Engineering Evaluation, Rework,
Bolt	V & M (No Go Lo/Hi gauge test IAW Section 6 of ASME B1.2)	X	X	Replace
Bolt Hole	V & M	X	X	Engineering Evaluation, Rework
Washer	V & M	X	X	Replace
"O" Ring	V & M	X	X	Replace
"O" Ring Sealing Surface	V & M	X	X	Engineering Evaluation, Rework

8-2 Provide acceptance criteria for foam testing per WMG, Inc., specification. Provide evidence that the as-poured foam density will be consistent with the acceptance test density. Confirm that all foam impact-limiting materials will have the mechanical properties bounded by the structural analyses used in the application at the maximum and minimum temperatures of NCT.

The applicant proposes to use foam "Type FR-3700 or FR-6700 or equivalent" with the foam being procured based on WMG specifications ES-002-P71.

Staff has always been opposed to vague wording, such as "equivalent" or "similar," in safety analysis reports (SARs). What is "equivalent" to one applicant may not be "equivalent" for another applicant. All materials must have specified characteristics in accordance with recognized Codes and Standards, particularly for "important to safety" components. Defining "equivalency" by some critical characteristics meeting or exceeding those specified for the designated material is not acceptable for staff because it does not provide the means to determine how "equivalency" will be confirmed.

An understanding of the specific acceptance criteria and basis for evaluation is critical for all important to safety components. For components and materials that are not fabricated per acceptable consensus standards, the basis for the design is needed.

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

Response:

In order to be more coherent and address the NRC staff comments, the foam specification document WMG-150B-ES-002-P71, Rev.0 (Reference 8-1) has been revised to Rev.1. In the revised document the staff comments are addressed as follows.

- The foam material has been categorically specified as General Plastic Manufacturing Company's LAST-A-FOAM Type FR-3700, closed-cell polyurethane foam. 'Or equivalent' has been removed from this document, as well as from the SAR Section 2.2.1.
- Acceptance criteria for foam testing are described in Section 3.2 (density), Section 3.3 (compression properties), and Section 3.4 (flame retardantcy).
- In Section 3.2.1 the foam density is specified to be 23 ± 1 lb/ft^3, i.e. between 22 and 24 lb/ft^3. One sample from each batch is tested in order to ensure that the density of each batch is within the specified tolerance (Section 3.2.3). Additionally, the mass of the lower and upper impact limiters are recorded and compared with the corresponding estimated masses based on 22 lb/ft^3 (min.) and 24 lb/ft^3 (max.) foam densities (Section 3.2.4). These measures will ensure that the foam density is within the specified tolerance.
- The specification requires that the test samples meet the specified compressive stress-strain properties with a tolerance of ± 10% at various strain values at 75 ± 5°F (Section 3.3.1). The specified stress-strain properties have been obtained from General Plastic Manufacturing Company's published data. They are listed in Table 1 and plotted in Figure 1. Using the manufacturer's published data, WMG has documented the foam compressive stress-strain properties at the maximum and minimum NCT temperatures in WMG-150B-AR-105-P71 (Reference 5 of the specification). For the analysis purposes, both nominal +10% and nominal -10% properties at the maximum and minimum NCT temperatures

have been used. Thus, the structural analyses of the impact limiters in the SAR, made of the foam, procured under these specifications, are bounded by both the temperature variation and the specified property tolerance.

8-3 Revise the application to clarify that the seal manufacturer, seal part / drawing number, seal core, jacket, and lining materials, as well as specific material combinations of those materials, surface finish range, and minimum and maximum seal and groove dimensions (or dimensions with tolerances) are seal parameters that are subject to NRC approval.

The applicant proposes to use its own Commercial Grade Dedication process to procure seals, while mentioning only two critical seal parameters, in Section 8.1.5 of the application, i.e., 10 hours at 380°F and 1,000 hours at 160°F. Each seal manufacturer proposes specific seal designs to meet the reliability, sealing requirements, and life and recovery of the package seals. Specific seal materials and combinations of seal materials ensure there will be no chemical, galvanic, or other reactions. In addition, the surface finish can impact the performance of the seal. These parameters, as well as the seal and groove dimensions, are all part of the seal / groove design which is an important to safety component not subject to change without NRC approval.

An understanding of the specific acceptance criteria and basis for evaluation is critical for all important to safety components. For components and materials that are not fabricated per acceptable consensus standards, the basis for the design is needed.

This information is required to determine compliance with 10 CFR 71.33, 71.43(d), 71.51(a)(1) and (2).

Response:

In order to satisfy this concern, WMG developed specification document WMG-150B-ES-003-P71, Rev.0 (Reference 8-2). SAR Section 8 has also been revised to address this RSI. The SAR Drawing (WMG-150B-DW-004-P71) has been revised to the Seal Plate Groove details.

8-4 Describe in detail the maintenance leak testing procedures of the package.

Maintenance leak testing should be described according to ANSI N.14.5.

This information is required to determine compliance with 10 CFR 71.51 and 71.93(b).

Response:

The detailed maintenance leak testing procedures have been included in Section 8.2.2 after "General Requirements".

8 | 7 | 6 | 5 | 4 | 3 | Revision Block | 1

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Security-Related Information
Figure Withheld Under 10 CFR 2.390

B

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Prepared: [signature]
Date: 4/28/2015
Reviewed: [signature]
Date: 4/28/2015

WMG

Title: General Arrangement & Details
Rev: 1

Size: B | Scale: NTS | Dwg No: WMG-150B-DW-004-P71 | Sheet: 1 of 8

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Bill of Materials

Revision Block

Rev:	Description:	Approved By:	Date:

Security-Related Information
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Title	General Arrangement & Details		Rev 1
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Security-Related Information
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Prepared: Date: 04/28/2015 Reviewed: Date: 4/28/2015	WMG
Title: General Arrangement & Details	Rev: 1
Size: B Scale: NTS Dwg No: WMG-150B-DW-004-P71	Sheet: 3 of 8

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Revision Block

Security-Related Information
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Prepared: Date: 04/28/2015			WMG
Reviewed: Date: 4/28/2015			
Title: General Arrangement & Details			Rev 1
Size B	Scale NTS	Dwg No WMG-150B-DW-004-P71	Sheet 4 of 8

8	7	6	5	4	3	Revision Block	1

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Security-Related Information
Figure Withheld Under 10 CFR 2.390

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Prepared: Bethany Duncan Date: 04/28/2015 Reviewed: Date: 4/28/2015			WMG
Title: General Arrangement & Details			Rev 1
Size: B	Scale: NTS	Dwg No: WMG-150B-DW-004-P71	Sheet: 5 of 8

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Security-Related Information
Figure Withheld Under 10 CFR 2.390

Prepared: Bethany Duncan Date: 04/28/2015 Reviewed: [signature] Date: 4/28/2015			WMG
Title: General Arrangement & Details			Rev 1
Size: B	Scale: NTS	Dwg No: WMG-150B-DW-004-P71	Sheet: 6 of 8

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D

C

Security-Related Information
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B

A

Prepared: Date: 04/28/2015			WMG
Reviewed: Date: 4/28/2015			
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D

C

Security-Related Information
Figure Withheld Under 10 CFR 2.390

B

A

Prepared: Bethany Denman Date: 04/28/2015 Reviewed: [signature] Date: 4/28/2015	WMG
Title: General Arrangement & Details	Rev 1
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Reference & Data Guide Table

Reference No.	Document No.	Document Referenced	Location	
			Document	Data
Section 1				
SAR Drawing	**WMG-150B-DW-004-P71, Rev.1**		DVD-1	N/A
Section 2				
2-7	**WMG-150B-AR-111-P71, Rev.0**		DVD-3	DVD-4 & HD-2
		3. (SAR Drawing)	DVD-1	N/A
		5. (Same as 2-27)	DVD-1	N/A
		6. (Same as 2-25)	DVD-3	DVD-4 & HD-2
		7. (Same as 2-11)	DVD-1	N/A
2-11	**WMG-150B-AR-105-P71, Rev.0**		DVD-1	N/A
2-14	**WMG-150B-AR-112-P71, Rev.0**		DVD-1	N/A
		112-4 (Same as 2-20)	DVD-1	N/A
		112-5 (SAR Drawing)	DVD-1	N/A
2-20	**WMG-150B-AR-122-P71, Rev.0**		DVD-1	N/A
2-21	**WMG-150B-AR-113-P71, Rev.0**		DVD-1	DVD-2a

		113-2 (SAR Drawing)	DVD-1	N/A
		113-5 (Same as 2-20)	DVD-1	N/A
		113-6 (Same as 2-31)	DVD-1	HD-1
		113-9 (Same as 2-23)	DVD-1	N/A
2-23	**WMG-150B-AR-099-P71, Rev.1**		DVD-1	N/A
2-24	**WMG-150B-AR-119-P71, Rev.0**		DVD-1	HD-1
		119-2 (SAR Drawing)	DVD-1	N/A
		119-9 (Same as 2-23)	DVD-1	N/A
		119-11 (Same as 2-31)	DVD-1	HD-1
2-25	**WMG-150B-AR-110-P71, Rev.0**		DVD-3	DVD-4 & HD-2
		8. (Same as 2-27)	DVD-1	N/A
2-27	**14-040-IH-AR-109-P71, Rev.0**		DVD-1	N/A
2-29	**WMG-150B-AR-116-P71, Rev.0**		DVD-3	DVD-4 & HD-2
		2. (Same as 2-27)	DVD-1	N/A
		3. (Same as 2-25)	DVD-3	DVD-4 & HD-2
		4. (SAR Drawing)	DVD-1	N/A
		5. (Same as 2-7)	DVD-3	DVD-4 & HD-2

2-31	**WMG-150B-AR-120-P71, Rev.0**		DVD-1	HD-1
		120-4 (Same as 2-7)	DVD-3	DVD-4 & HD-2
		120-8 (Same as 2-23)	DVD-1	N/A
		120-11 (Same as 2-24)	DVD-1	HD-1
		120-12 (Same as 2-35)	DVD-1	N/A
2-32	**WMG-150B-AR-125-P71, Rev.0**		DVD-1	DVD-2a
		1. (SAR Drawing)	DVD-1	N/A
		4. (Same as 2-39)	DVD-1	N/A
		5. (Same as 2-7)	DVD-3	DVD-4 & HD-2
		9. (Same as 2-20)	DVD-1	N/A
2-33	**WMG-150B-AR-115-P71, Rev.0**		DVD-1	N/A
		1. (SAR Drawing)	DVD-1	N/A
		3. (Same as 2-7)	DVD-3	DVD-4 & HD-2
2-34	**WMG-150B-AR-114-P71, Rev.0**	1. (SAR Drawing)	DVD-1	N/A
		3. (Same as 2-7)	DVD-3	DVD-4 & HD-2
2-35	**WMG-150B-AR-121-P71, Rev.0**		DVD-1	N/A
		121-2 (SAR Drawing)	DVD-1	N/A

		121-4 (Same as 2-20)	DVD-1	N/A
2-36	**WMG-150B-AR-126-P71, Rev.0**		DVD-1	DVD-2a
		1. (SAR Drawing)	DVD-1	N/A
		3. (Same as 2-35)	DVD-1	N/A
		5. (Same as 2-39)	DVD-1	N/A
		8. (Same as 2-20)	DVD-1	N/A
2-39	**14-040-IH-AR-127-P71, Rev.0**		DVD-1	N/A
2-40	**WMG-150B-AR-129S-P71, Rev.0**		DVD-1	N/A
		1. (Same as 2-41)	DVD-1	DVD-2a
2-41	**WMG-150B-AR-130S-P71, Rev.0**		DVD-1	DVD-2a
		1. (SAR Drawing)	DVD-1	N/A
		2. (same as 2-40)	DVD-1	N/A
		4. (Same as 2-39)	DVD-1	N/A
2-42	**WMG-150B-AR-131S-P71, Rev.0**		DVD-3	DVD-4
		1. (Same as 2-25)	DVD-3	DVD-4 & HD-2
		3. (Same as 2-39)	DVD-1	N/A
Section 3				

3-2	**WMG-150B-AR-123-P71, Rev.0**		DVD-1	DVD-2b & HD-1
		123-13 (SAR Drawing)	DVD-1	N/A
		123-14 (Same as 2-23)	DVD-1	N/A
3-8	**WMG-150B-AR-099-P71, Rev.1**	Same as 2-23	DVD-1	N/A
3-11	**WMG-150B-AR-124-P71, Rev.0**		DVD-1	DVD-2b
		1. (SAR Drawing)	DVD-1	N/A
		3. (Same as 3-2)	DVD-1	HD-1
		5. (Same as 2-39)	DVD-1	N/A
Section 5				
5-7	**WMG-150B-AR-132S-P71, Rev.0**		DVD-3	HD-2
Section 8				
8-1	**WMG-150B-ES-002-P71, Rev.1**		DVD-1	N/A
8-2	**WMG-150B-ES-003-P71, Rev.0**		DVD-1	N/A