Safety Analysis Report for the West Valley Melter Package

SARWVMP-01

Revision 1

April 2015
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USNRC Docket Number 71-9797

Submitted by:

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West Valley Demonstration Project
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[Under IEWO M14-WV-0001]
&
CH2M Hill-B&W West Valley, LLC
[Under Contract DE-EM0001529]

Responses to the U.S. Nuclear Regulatory Commission Requests for Additional Information on the Safety Analysis Report for the West Valley Melter Package (SARWVMP-01)

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Acronyms and Abbreviations

ARF	airborne release fraction
ASME	American Society of Mechanical Engineers
AWS	American Welding Society
B&PV	Boiler and Pressure Vessel Code
CFR	Code of Federal Regulations
DOE	Department of Energy
DR	damage ratio
FEA	finite element analysis
G	force due to gravity
GMP	grouted melter package
HAC	hypothetical accident conditions
LDCC	low density cellular concrete
LPF	leak path factor
LST	limited service temperature
NCT	normal conditions of transport
NRC	Nuclear Regulatory Commission
PNNL	Pacific Northwest National Laboratory
QADS	quick and dirty shielding
RF	respirable fraction
RTV	room temperature vulcanizing
SAR	safety analysis report
RAI	request for additional information
RSI	request for supplemental information
UT	ultrasonic testing
WPS	weld procedure specification
WVDP	West Valley Demonstration Project
WVMP	West Valley Melter Package

Units

G	acceleration due to gravity
kips	1,000 pounds force
ksi	1,000 pounds per square inch
hr	hour
μm	micro meters
psi	pounds per square inch

INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) is reviewing the U.S. Department of Energy (DOE) request for a special package authorization for the West Valley Melter Package (WVMP), a Type B(U) radioactive material transportation package Model Number 9797 containing the melter from the West Valley Demonstration Project (WVDP). DOE submitted the Safety Analysis Report (SAR) WVMPSAR-01 for a special package authorization to the NRC for review on October 16, 2014 (reference 1).

In connection with its review, NRC submitted on November 12, 2014 three requests for supplemental information (RSIs) along with five observations on the SAR (reference 2). On December 2, 2014, DOE provided responses to the RSIs and observations and related changes to the SAR (reference 3).

On February 5, 2015 NRC submitted a Request for Additional Information (RAI) (reference 4). The DOE responses to this request are provided in the following format:

Number: The NRC number is specified.

Subject: A brief statement of the subject of the RAI is listed.

Basis: The basis for the RSI or observation as described by NRC is reproduced in its entirety.

DOE response: The DOE response addresses the RAI, providing explanatory information on the basis for the response.

Changes to the SAR: This section describes changes made to the SAR.

References are cited where appropriate, with a reference list provided at the end of the responses. Attachment 1 is a complete copy of Revision 1 of the SAR with changes marked by vertical lines.

RAI Number: 2-1 (Chapter 2, Structural Evaluation)

Subject: Tie-down configuration description and analysis

RAI: Provide a detailed description and analysis for the tie-down configuration that will be used to secure the package to a trailer and/or rail car, including the corresponding free body diagrams that indicate all points of force application and all points of restraint.

The current analysis for one of the options determines the stress in the attachment plates and welds based on overturning that does not include a full static analysis. Moments are summed about a rotation point to determine the reaction force and direction on the attachment plate required to stop rotation. The horizontal component of this force is approximately 1500 kips, shared by two attachment plates. The horizontal force applied to the center of gravity of the package is 10G, or 3,900 kips. There is a force deficit of 2,400 kips to balance the forces in this direction that is not accounted for.

It is also unclear how the 5G lateral force is restrained in that horizontal direction. Again, the restraining force on the attachment plate is determined through a rotational analysis, but the lateral forces do not balance.

Additionally, the staff is unclear as to the definition of a "sling angle penalty" (the 0.707 factor) that was used to compute the lateral restraining force. This appears to be associated with the angle of the tension member, but no free body diagram or other description is provided.

This information is required to demonstrate compliance with 10 CFR 71.45(b).

DOE response: The WVMP will be tied down for two modes of transportation, one configuration for heavy haul truck and another for rail transport. Information has been added to Section 2.5.2 to clarify this point.

The submitted analysis in chapter 2 evaluates two securement options: (1) using shear blocks at the package base and cable ties to the removed lift lug positions, and (2) only using the corner bumpers for shear and vertical restraint.

The analysis used rigid body mechanics to evaluate a 10G/2G case and then a 5G/2G case, and superposition of the two cases to arrive at a bounding restraint load. It is bounding because the vertical load is added twice.

It is unclear where the reviewer is finding a 1500 kip horizontal component. If referring to the 1632 kip value for the "using upper restraint location," then that value is only the horizontal component at the top. The balance of the horizontal force is carried by shear blocks at the bottom. This value was not computed in this case, because it is bounded by the analysis case of "Using lower restraint locations". The reviewer is correct in that the 0.7071 factor is a penalty factor for cables running at an angle other than 0° or 90°.

Regarding force balance, the two cases evaluated are (1) using four bottom restraint locations and upper tie tie-downs and (2) just using the four bottom corners. The forces computed represent the maximum value at any of the corners, since the 10G/5G/2G directions can be +/-. The analysis is considered to be complete and clear.

Changes to the SAR: The tie down section was revised to show tie-down methods used in road transport and in rail transport. A new figure was added to depict both arrangements. The old figure 2-5 (now 2-6) was revised to show shear and compression restraint terms to match the calculations.

The calculations were expanded to show intermediate steps and also includes a force balance check. The only numerical change made was that the conservatism of including the vertical load again in the 5G lateral calculations was removed. New forces are slightly lower as a result.

The following portions of the SAR have been revised to address this RAI:

Chapter 2, pages 2-16 through 2-23.

RAI Number: 2-2 (Chapter 2, Structural Evaluation)

Subject: Strain acceptance limit for hypothetical accident condition

RAI: Justify the strain acceptance limit of 56% for the hypothetical accident condition (HAC).

The staff believes there is an error in Section 5.2, "Acceptance Criteria," of Appendix 2.12.2 (Calculation No. M-CLC-A-00497) for the strain limit. In this calculation, the applicant computes the limiting triaxial strain, ε_L, using equation 5.6 from ASME B&PV Section VIII, Division 2, which states:

$$\varepsilon_L = \varepsilon_{Lu} \cdot \exp\left[-\left(\frac{\alpha_{sl}}{1+m_2}\right)\left(\left\{\frac{(\sigma_1+\sigma_2+\sigma_3}{3\sigma_e}\right\} - \frac{1}{3}\right)\right]$$

In the above equation, ε_{Lu} is determined from Table 5.7 of Section VIII, as the maximum of $0.60\left(1.00 - \frac{F_y}{F_u}\right)$ and $2ln\left[1 + \frac{E}{100}\right]$ for ferric steel, but the applicant uses the following equation to determine this value:

$$\varepsilon_{Lu} = \max\left\{0.75\left(1-\frac{F_y}{F_u}\right), 2\cdot\ln\left[1+\frac{E}{100}\right]\right\} = \max\left\{0.75\left(1-\frac{38}{70}\right), 3\cdot\ln\left[1+\frac{21}{100}\right]\right\} = 57\%$$

This equation mixes values for ferric and stainless steel from Table 5.7, then replaces the constant 2 with 3 in the second equation when actual numbers are input into the equation. Thus, the value of 57% is higher than it should be.

Furthermore, in the final computation of ε_L, the applicant uses 100% for ε_{Lu} (shown below) instead of the value that was computed to arrive at a triaxial strain limit of 56%, which appears to be too large by a factor of over 2.

$$\varepsilon_L = 100\% \cdot \exp\left[-\left(\frac{2.2}{1+0.27}\right)\left(\left\{\frac{2}{3*1}\right\}-\frac{1}{3}\right)\right] = 56\%$$

This information is required to demonstrate compliance with 10 CFR 71.51(a).

DOE response: Terms applicable to stainless steel got mixed into the equation. This error has been corrected.

Changes to the SAR: The following portions of the SAR have been revised to address this RAI:

Appendix 2.12.2, sheets 17 through 19.

RAI Number: 2-3 (Chapter 2, Structural Evaluation)

Subject: Welded joint analysis

RAI: Justify the analysis for the welded joints that attach the steel plates that comprise the walls, top, and bottom of the package.

In accordance with Drawing No. 4005-DW-001, the welded joints between the plates that comprise the top, bottom, and walls of the package are 1 inch groove partial penetration welds with a 5/16 inch covering fillet weld in the inside. Table 6-10 of Appendix 2.12.2 states that the 4 inch and 6 inch steel walls are modeled with "three nodal layers through thickness." Figure 6-11 of Appendix 2.12.2 shows two layers of elements in the 4 inch steel plate and 3 layers of elements in the 6 inch plate. Both of these explanations indicate that the connection, modeled as a full penetration weld, will have significantly more calculated strength than the as-built package with partial penetration welds.

As an example, the capacity of a 1 inch groove weld, approximately 144 inches long, with a 70 ksi weld rod, is 3,000 kips (0.3x70x144x1, in accordance with the Steel Construction Manual, 13th edition). Each corner consists of two groove welds and a 5/16 inch fillet weld which results in a capacity of approximately 6,800 kips per corner. The corner drop results in a force 53,430 kips (137G) on the package which is very close to the capacity of all 8 corner welds, assuming they carry the load equally. An appropriate analysis is needed to demonstrate the structural integrity of the welds and ultimately the performance of the package under HAC.

This information is required to demonstrate compliance with 10 CFR 71.51(a).

DOE response: The AISC value of 0.3*70 is a normal condition allowable, not a capacity. A lower bound shear capacity would be at least twice that value. In terms of bending strength, the 1" groove welds top and bottom and reinforcing fillet will achieve 80% (6 inch plate) to 90% (4 inch plate) of the strength of a full penetration weld.

The modelling technique did connect nodes together, but the underlying element (continuum shell was used, not the conventional shell element) only has translational degrees of freedom, thus shear and axial is only transmitted. The bending strength in the element is derived from an underlying shell theory. And since the plate stops at the weld joint, and a new plate starts, the plate's bending strength transfer only happens through tensile/compressive loads on the weld. So the model behavior is representative of actual conditions.

Changes to the SAR: Model variations were investigated, including (1) reducing the number of connected nodes, and (2) replacing the connected nodes with connector elements that reflect actual weld area. The results were included in a revised Appendix 2.12.2 calculation.

The following portions of the SAR have been revised to address this RAI:

Chapter 2, pages 2-34 and 2-35.

Appendix 2.12.2, sheets 21-24.

RAI Number: 2-4 (Chapter 2, Structural Evaluation)

Subject: Results of flat side down drop test in normal conditions of transport.

RAI: Explain the results of the flat side down (hard impact) drop test in normal conditions of transport (NCT) for which the calculated shear stress exceeds the shear yield strength of the connector pins by almost 50%.

In Section 6.10.4 of Appendix 2.12.2, the applicant reports, with no qualifying comment, shear stresses of 31,800 psi in the connector pins, which are almost 50% higher than the reported allowable shear stress of 21,600 psi. For this same scenario, the applicant also reports 4 bolts in excess of the stress interaction requirement.

This information is required to demonstrate compliance with 10 CFR 71.51(a).

DOE response: An explanation should have been included in the text to the SAR for stress conditions that were above the allowable. The high stress occurs in just two of the 24 pins, and is a high frequency spike that does not cause a safety issue.

Changes to the SAR: The FEA output was filtered in order to arrive at the structurally significant output values. As part of RAI 2-5 resolution, the shear pin diameter was increased to 2.5 inch diameter, which keeps all NCT and HAC loads within capacity.

The following portions of the SAR have been revised to address this RAI:

Chapter 2, pages 2-4 and 2-5.

Appendix 2.12.2, sheet 86.

RAI Number: 2-5 (Chapter 2, Structural Evaluation)

Subject: Impact limiter shear pin loads

RAI: Clarify the statement in Appendix 2.12.2 on sheet 85, "The loads on the shear pins that attach the impact limiter to the shock absorbers are not explicitly checked in the HAC drops."

Appendix 2.12.2 states: "The loads in the shear pins that attach the impact limiter to the shock absorbers are not explicitly checked in the HAC drops. The FEA model for the shear pins is constructed to represent accurate load versus displacement relations, so that behavior of the pins is assessed implicitly through impact limiter displacements. The only role these pins play is to keep the impact limiter in place during and after the NCT. The construction of the impact limiter and the way it's nested inside the GMP shock absorbers is such that the impact forces tend to self-energize the impact limiter to remain in place."

Section 2.1 of the application states that the 2 inch by 9 inch plate (secured to the shock absorbers by the connector pins) provides structural redundancy to the front wall bolts. The staff agrees that, in several drop scenarios, the impact forces tend to keep the impact limiter in place, and thereby keep the plate in place; however, there are several scenarios in which this is not the case. If the connector pins fail, the impact limiter is no longer providing redundant structural support, and failure of the door bolts could cause significant gaps in the perimeter and face seals.

As an example, for the NCT flat side down drop (1 foot), the applicant reports shear stresses in the connector pins in excess of the allowable shear stress (see RAI 2-4). This scenario generates 76Gs of force to the package. The HAC flat side down drop (30 feet) generates 546Gs of force, which is over 7 times that of the same NCT configuration with no reported stress analysis of the connector pins.

For the HAC CG over side edge scenario, all bolts are reported to fail under the 137G load. In the NCT CG over side edge scenario, the connector pins are loaded to 94% of the shear capacity for a 50G load. Therefore, it is not unreasonable to assume that the connector pins could fail under the load increase of 274%. With the reported failure of the bolts, this could cause significant gaps in the door seal.

Additionally, the connector pins are welded in place by means of a ½ inch groove weld. Assuming the weld is all around, the area of the weld is approximately 1 square inch and the capacity of each weld is 21 kips. Further analysis is needed to ensure the structural integrity of these welds for NCT (including shock and vibration) and HAC tests and conditions.

This information is required to demonstrate compliance with 10 CFR 71.51(a).

DOE response: The FEA model of the shear pin included a force limit based on the stress-strain behavior of the material. If the shear pin ultimate strength is exceeded, then the model results would reflect that condition by showing motion corresponding to a lack of (or reduced) constraint on the 2"x9" steel. The motion of the 2"x9" plates was tracked in all cases. The applicant sees no need to track the load output in the shear pin for HAC cases, as there is no acceptance criteria being imposed onto any single pin other than that the group of 24 pins maintain position of the 2"x9" plates of the impact limiter keep the door in place.

The shear pin weld is only present to keep the pins in place for the onset of the HAC impact. The shear pins have a head on one side and a weld on the other, except for the bottom row. Once the NCT or HAC drop is initiated, the pins are only tasked with shear restraint to keep the IL positioned up against the door. As part of the NRC review resolution, shear pin loads are extracted from the HAC simulations and shown to be acceptable, and only slightly higher than the shear loads occurring in the NCT drop condition.

Changes to the SAR: The FEA analysis results for connector pin shear loads were added to Appendix 2.12.2. The pin diameter was increased to 2.5 inch to allow a clean defense the pin capacity.

The following portion of the SAR has been revised to address this RAI:

Appendix 2.12.2, sheet 86.

RAI Number: 2-6 (Chapter 2, Structural Evaluation)

Subject: Gaps resulting from CG over front corner drop scenario

RAI: Provide both face seal gaps and perimeter seal gaps for the locations reported in the CG over front corner drop scenario. In addition, confirm that the gaps are consistent or bounded by the assumptions used in the containment analysis.

In Appendix 2.12.2, for the HAC CG over front corner drop, the face seal gap is reported for location numbers 5 and 6 with no corresponding perimeter seal gap. Additionally, the perimeter seal gap is reported for location numbers 7 and 8 with no corresponding face seal gap. The two gaps together will determine the actual opening in the door, which should be consistent with, or bounded by, the assumptions, e.g., leak path factor, used in the containment analysis.

This information is required to demonstrate compliance with 10 CFR 71.51(a).

DOE response: Figure 6-91 of Appendix 2.12.2 shows face gaps and edge gaps along two of the four sides, Figure 6-92 shows face gaps at the full set of locations around the perimeter. Figure 6-93 shows perimeter gaps at the full set of locations around the perimeter. Locations 5, 6, 7, and 8 are called out specifically because they are the higher gaps.

Changes to the SAR:

The following portions of the SAR have been revised to address this RAI:

Appendix 2.12.2, sheets 124-128.

RAI Number: 2-7 (Chapter 2, Structural Evaluation)

Subject: Use of Power Spectral Density curve

RAI: Justify the use of the Power Spectral Density curve (Figure 6-2 of Appendix 2.12.2) from SG-100, Appendix F, for determining the normal condition of transport vibration environment.

For the Power Spectral Density to be representative of the package, the weight must be similar. The Transportation Shock and Vibration Literature Review (PNNL-22514, June 6, 2013), prepared for the Department of Energy by Pacific Northwest National Laboratory, indicates that "no studies were found that evaluated a rail transportation cask or other cargo similar in weight of a commercial light-water reactor used nuclear fuel rail transportation cask, about 300,000 lbs." In fact, the largest transportation package that was studied weighed 220,000 lbs, which is much less than the WVMP weight of 390,000 lbs.

This information is required to demonstrate compliance with 10 CFR 71.71(c)(5).

DOE response: Using a Power Spectral Density curve that applies to less massive equipment should be understood to be conservative. Per PNNL-22514, the data used to currently characterize shock and vibration appears to overestimate the impacts.

Changes to the SAR: The PNNL-22514 statement has been added to Appendix 2.12.2 to indicate the Power Spectral Density curve used is conservative.

The following portion of the SAR has been revised to address this RAI:

Appendix 2.12.2, sheet 33.

RAI Number: 2-8 (Chapter 2, Structural Evaluation)

Subject: Package condition after test sequence

RAI: Provide a comprehensive summary of the condition of the package after the test sequence, and address the extent to which components have been damaged and relate the package condition to the acceptance standards. In addition, confirm that the condition of the package after the test sequence is consistent with, or bounded by, the assumptions, e.g., damage ratio and leak path factor, used in the containment analysis.

Section 2.7.8 of the application discusses damage to the package, such as status of bolts, face seal displacement and concrete crush, following certain HAC tests and conditions, but does not properly aggregate the damage to the various components to describe the overall condition of the package following the entire test sequence. For instance, simply reporting the maximum face seal gap and maximum perimeter seal gap and comparing them to their respective available lengths does not adequately assess the condition of a "breach path" in the door seal. The face seal gap and its associated perimeter seal gap are needed to adequately assess the condition of the door seal. The seal gap alone is still not sufficient. The condition of the concrete, the status of the bolts and connector pins, etc., need to be combined to properly describe the condition of the package after the HAC test sequence, in order to adequately assess the package performance with respect to containment and shielding regulations.

This information is required to demonstrate compliance with 10 CFR 71.51(a).

DOE response: Section 2.7.8 is a summary of damage for HAC. The structural analysis shows that concrete will be damaged and seal gaps will exist. For HAC, chapter 4 considers a leak path factor of 1, irrespective of the gap established in chapter 2. The relevant information in terms of containment is the concrete crush, which is already reported in section 2.7.8.

Changes to the SAR: A table has been added to summarize results for all HAC drop events evaluated. A discussion of additional damage from pin drop was also included.

The following portions of the SAR have been revised to address this RAI:

Chapter 2, 2-44 through 2-46.

RAI Number: 2-9 (Chapter 2, Structural Evaluation)

Subject: Areas of noncompliance and equivalent safety

RAI: List all areas for which the West Valley Melter Package is not in compliance with 10 CFR Part 71. Describe the mitigating actions that have been taken to provide an equivalent level of safety for these areas of non-compliance.

The application has been submitted under the "special package authorization" provision of 10 CFR 71.41(d) which states that the applicant shall demonstrate that the overall level of safety in transport for these shipments is at least equivalent to that which would be provided if all the applicable requirements had been met. The applicant submitted a checklist that indicates compliance with all regulatory requirements pertaining to the structural evaluation of the package; however, the staff has noted several areas for which the package design is not in compliance.

For example, the regulations state that the test conditions for NCT and HAC must be based on the ambient temperatures, preceding and following the test, constant at -20°F and 100°F. Because the applicant has no fracture toughness testing data on the 6 inch and 4 inch thick carbon steel plates, the applicant established a limited service temperature (LST) of 3°F. This is not in compliance with 10 CFR 71.71 or 10 CFR 71.73, but can be accepted under 10 CFR 71.41. In order to make a safety determination, the staff requires a justification for all areas not in compliance with the regulations.

This information is required to demonstrate compliance with 10 CFR 71.41(d).

DOE response: Information has been added to the SAR to better address cases where the WVMP provides a level of safety equivalent to the applicable requirements.

In regard to the ambient temperature requirements, the WVMP is not in compliance with 10 CFR 71.71 or 10 CFR 71.73 for NCT and HAC ambient temperatures of -20°F and 100°F. Due to material property limits, an LST of 3°F was established, and supported by analysis, to show equivalent safety. This matter is documented in Appendix 2.12.2.

Changes to the SAR: The following portions of the SAR have been revised to address this RAI:

Executive Summary, page ES-2.

Chapter 1, pages 1-1 through 1-3, 1-24 through 1-33.

Chapter 2, pages 2-1, 2-3, 2-13, 2-31, and 2-32.

Chapter 4, pages 4-5 and 4-6.

Chapter 5, page 5-1.

Chapter 7, page 7-1.

Chapter 8, pages 8-1, 8-4, 8-9 through 8-18.

RAI Number: 2-10 (Chapter 2, Structural Evaluation)

Subject: Fracture toughness for steel plate

RAI: Provide either a technical justification for not performing the required fracture toughness testing or provide the following: (i) fracture toughness testing data for WVMP 516 Grade 70, 4, and 6 inch plate material, (ii) welding procedure qualification record fracture toughness testing data, and (iii) fracture toughness testing data for welding material used.

Appendix 1.3.5, Table 1, of the application states that ASME Code Section III, Subsection ND, Table ND-2311-1, exempts impact testing for the WVMP plate material. Contrary to the applicant's position that fracture toughness testing can be exempted in accordance with Section III, Table ND-2311-1, the table only exempts 516 Grade 70 that is 2.5 inch and below in thickness with an LST above 0°F. While the WVMP LST is listed as 3°F, the material thickness is 6 inch and 4 inch.

In addition, the staff notes that even when fracture toughness testing is exempted in accordance with Table ND-2311, ND-2311(a)(8) specifically states that the exemptions listed in Table ND-2311-1 do not apply to weld metal and welding procedure qualification impact testing.

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

DOE response: The package was designed and procured to meet AWS D1.1. The LST has been adjusted to match. The application shows an equivalent level of safety to meet the 10 CFR 71.33(a)(5) requirements.

Changes to the SAR: The SAR was revised to show equivalent safety in Chapter 1 and Chapter 2 with analysis to support an equivalent level of safety to meet 10 CFR 71.33(a)(5) requirements.

The associated changes appear in the revised SAR as follows:

Chapter 1, pages 1-1 through 1-3, 1-24, and 1-25.

Chapter 2, pages 2-13, 2-25, 2-31, 2-32, 2-34, 2-35, and 2-44 through 2-46.

Chapter 8, pages 8-9 and 8-10.

RAI Number: 2-11 (Chapter 2, Structural Evaluation)

Subject: Fracture toughness for bolting material

RAI: Provide fracture toughness testing data for the bolting material that meets the requirements of Table ND-2333-1.

Appendix 1.3.5, Table 1, of the application indicates that the WVMP package is compliant with ASME Section III, ND-2128, for bolting material. In accordance with ND-2333, bolting material requires impact testing that meets the requirements of ND-2333-1. ND-2311(a)(2) exempts bolting below a nominal size of 1 inch; however, the closure bolts for the container lid are 1.5 inch diameter. The staff was unable to find impact testing data for the WVMP bolting.

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

DOE response: The package was designed and procured to meet AWS D1.1. The application shows equivalent level of safety to meet 10 CFR 71.33(a)(5).

The closure bolts are not credited because the impact limiter provides retention duties during NCT and HAC. All other bolted penetrations are less than 1 inch and are not credited for containment during NCT or HAC.

Changes to the SAR: Chapters 1, 2, 4, and 8 have been revised. The associated changes appear in the revised SAR as follows:

Chapter 1, pages 1-1 through 1-3, 1-24, and 1-25.

Chapter 2, pages 2-13, 2-25, 2-31, 2-32, 2-34, 2-35, and 2-44 through 2-46.

Chapter 4, pages 4-2 through 4-6.

Chapter 8, pages 8-9 and 8-10.

RAI Number: 2-12 (Chapter 2, Structural Evaluation)

Subject: Ultrasonic test reports for plate material

RAI: Provide UT reports that show that the plate material that was used for the package meets the requirements of ASME Code Section III, Subsection NB.

The WVMP package demonstrates equivalent safety with base materials approved by ASME and ASTM specifications, as applicable. Appendix 1.3.5, Table 5, of the application indicates that a base metal UT was performed on the WVMP plate material in accordance with ASME Section III, Subsection NB. However, no UT reports for this testing were provided.

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

DOE response: The package was designed and procured to meet AWS D1.1 for an IP-2 package. The application shows equivalent level of safety to meet 10 CFR 71.33(a)(5).

Changes to the SAR: Chapters 1, 2, 4, and 8 have been revised. The associated changes appear in the revised SAR as follows:

Chapter 1, pages 1-1 through 1-3, 1-24, and 1-28.

Chapter 2, pages 2-13, 2-25, 2-31, and 2-32.

Chapter 4, pages 4-2 through 4-6.

Chapter 8, page 8-13.

RAI Number: 2-13 (Chapter 2, Structural Evaluation)

Subject: Welding procedure specifications

RAI: Provide a list of the WPSs that were used to weld the WVMP package, and identify the welding procedures used to weld each joint.

Appendix 1.3.5, Table 5, of the application lists the welding filler materials used to weld the WVMP package; however, it is not identified which welding procedure specifications, listed in the WVDP Site Welding Manual, WVDP-352, were used to perform the welding on the WVMP package.

In addition, the staff notes that E71T-8 weld filler material was used according to Table5, but none of the procedures listed in WVDP-352 specifies E71T-8 as a weld filler material.

This information is required to demonstrate compliance with 10 CFR 71.31(c).

DOE response: To demonstrate equivalent safety to 10 CFR 71.31(c) for the WVMP, the following WPSs were listed in the Weld Record Report and contained in the WVMP work package:

- WPS 7.032, R3, 1/17/03, Pre-Qual, FCAW, E71T-1;
- WPS 2.108, R1, 2/8/95, Pre-Qual, SAW, EA1;
- WPS 1.076, R3, 5/8/02, Pre-Qual, SMAW, E7018;
- WPS 7.046, R1, 9/2/04, Pre-Qual, FCAW, E81T-1; and
- WPS 4.010, R7, 5/24/04, PQR 1.1.007, GTAW, ER70S-3.

All WPSs were prequalified/qualified in accordance with AWS D1.1. Appendix 1.3.5, Table 6 identifies weld attributes for partial penetration welds on the 4" and 6" joints.

Changes to the SAR: Chapters 1 and 8 have been revised. The associated changes appear in the revised SAR as follows:

Chapter 1, pages 1-24 through 1-33.

Chapter 8, pages 8-9 through 8-18.

The following welding procedure specifications used in in the West Valley Melter Package were provided to NRC.

- WPS 7.032, R3, 1/17/03, Pre-Qual, FCAW, E71T-1;
- WPS 2.108, R1, 2/8/95, Pre-Qual, SAW, EA1;
- WPS 1.076, R3, 5/8/02, Pre-Qual, SMAW, E7018;
- WPS 7.046, R1, 9/2/04, Pre-Qual, FCAW, E81T-1; and
- WPS 4.010, R7, 5/24/04, PQR 1.1.007, GTAW, ER70S-3.

The weld maps and welding log for these WPS were also provided.

Filler material E71T-8 was not found in Table 5 or used in the SAR.

RAI Number: 2-14 (Chapter 2, Structural Evaluation)

Subject: Use of AWS D1.1 consistent with ASME Code Section III, Subsection ND

RAI: Identify the sections or paragraphs of the application showing that the use of AWS D1.1 is consistent with the requirements of ASME Code Section III, Subsection ND.

The applicant states, in several locations in SAR Appendix 1.3.5, that its use of AWS D1.1 is equivalent to the requirements of ASME Code Section III, Subsection ND; however, the staff found several inconsistencies.

This information is required to demonstrate compliance with 10 CFR 71.31(c).

DOE response: The package was designed and procured to meet AWS D1.1. The application shows equivalent level of safety to meet 10 CFR 71.31(c) requirements.

Changes to the SAR: Chapters 1 and 8 were revised as noted previously. The associated changes appear in the revised SAR as follows:

Chapter 1, pages 1-24 through 1-33.

Chapter 8, pages 8-9 through 8-18.

RAI Number: 3-1 (Chapter 3, Thermal Evaluation)

Subject: Natural convection heat transfer

RAI: Provide calculation results (tables, figures, etc.) to demonstrate that, during an HAC fire, the omission of natural convection heat transfer in the package air pocket is conservative.

Page 3-24 of the application states that the inclusion or omission of natural convection in the air pocket inside the WVMP package gave mixed results for changes in the maximum calculated temperatures and pressure. Therefore, the reported results are those calculated without natural convection.

However, the applicant did not provide results for the case when natural convection is included. The applicant needs to provide results for both cases in tabulated and graphic form for the staff to determine the adequacy of the analysis assumptions.

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

DOE response: The additional results, including natural convection, were reported in the revised calculation note supporting Rev 0A of the SAR in Appendix 3.5.4 but were omitted from Chapter 3 since they were not the bounding pressure. The results from the calculation in Appendix 3.5.4 have been incorporated into the text of Chapter 3.

Changes to the SAR: The associated changes appear in the revised SAR as follows:

Chapter 3, pages 3-24 through 3-31.

RAI Number: 4-1 (Chapter 4, Containment Evaluation)

Subject: A_2 values used in evaluation

RAI: Address the following comments (a) through (e), as appropriate, for each of the isotopes in the table below, or revise the A_2 values in Table 1 of calculation package X-CLC-G-00121. The subsequent calculations in calculation package X-CLC-G-00121 may also need to be revised.

(a) Provide additional justification for the A_2 value used in the calculation. For the specific isotope, the A_2 value used in the calculation was different from the A_2 value in 10 CFR Part 71, Appendix A, Table A-1.

(b) Provide additional justification for the A_2 value used in the calculation. The A_2 value for this isotope was not in 10 CFR Part 71, Appendix A, Table A-1; address why a value from 10 CFR Part 71, Appendix A, Table A-3 was not used.

(c) Provide additional justification for the A_2 value used in the calculation. It appears this A_2 value was from 10 CFR Part 71, Appendix A, Table A-3; a brief justification for the value chosen should be provided.

(d) Provide additional justification for the A_2 value used in the calculation. The isotope that was cited in the second column of the table below was not included in Table 1 of calculation package X-CLC-G00121.

(e) Clarify if the isotope should be Rn-222 rather than Rn-22.

Isotope	A2 (Ci/A2) from Table 1 of calculation package X-CLC-G-00121	A2 (Ci/A2) from Table A-1 of 10 CFR 71	NRC comment to be addressed
Y-90	unlimited	8.1	(a)
Nb-95m	included with Zr-95	not in Table A-1	(b)
Ba-137m	included with Cs-137	not in Table A-1	(b)
Hg-206	5.40E-01	not in Table A-1	(c)
Tl-206	Include with Bi-210m	not in Table A-1	(d)
Tl-207	5.40E-01	not in Table A-1	(c)
Tl-208	included with U-232	not in Table A-1	(b)
Tl-209	included with U-232	not in Table A-1	(b)
Tl-210	5.40E-01	not in Table A-1	(c)
Pb-210m	included with Th-229	not in Table A-1	(b)
Pb-211	5.40E-01	not in Table A-1	(c)
Pb-212	included with U-232	5.4	(a)
Pb-214	included with Rn-222	not in Table A-1	(b)
Bi-209	included with Pb-210	not in Table A-1	(b)
Bi-210	included with Pb-210	16	(a)

Isotope	A2 (Ci/A2) from Table 1 of calculation package X-CLC-G-00121	A2 (Ci/A2) from Table A-1 of 10 CFR 71	NRC comment to be addressed
Bi-211	included with Ra-223	not in Table A-1	(b)
Bi-212	included with U-232	16	(a)
Bi-213	included with Th-229	not in Table A-1	(b)
Bi-214	included with Rn-222	not in Table A-1	(b)
Bi-215	5.40E-01	not in Table A-1	(c)
Po-210	included with Pb-210	0.54	(a)
Po-211	2.40E-03	not in Table A-1	(c)
Po-212	included with Pb-212	not in Table A-1	(b)
Po-213	included with Th-229	not in Table A-1	(b)
Po-214	included with U-230	not in Table A-1	(d)
Po-215	included with Ra-223	not in Table A-1	(b)
Po-216	included with U-232	not in Table A-1	(b)
Po-218	included with Rn-222	not in Table A-1	(b)
At-215	2.40E-03	not in Table A-1	(c)
At-217	included with Th-229	not in Table A-1	(b)
At-218	2.40E-03	not in Table A-1	(c)
At-219	2.40E-03	not in Table A-1	(c)
Rn-217	2.40E-03	not in Table A-1	(c)
Rn-218	included with U-230	not in Table A-1	(d)
Rn-219	2.40E-03	not in Table A-1	(c)
Rn-220	included with U-232	not in Table A-1	(b)
Rn-22	1.10E-01	not in Table A-1	(e)
Fr-221	included with Th-229	not in Table A-1	(b)
Fr-223	5.40E-01	not in Table A-1	(c)
Ra-224	included with U-232	0.54	(a)
Ra-225	included with Th-229	0.11	(a)
Ac-225	included with Th-229	0.16	(a)
Ac-228	included with Ra-228	1.4	(a)
Th-228	included with U-232	0.027	(a)
Th-231	included with U-235	0.54	(a)
Th-234	included with U-238	8.1	(a)
Pa-233	included with Np-237	19	(a)
Pa-234	5.40E-01	not in Table A-1	(c)
Pa-234m	included with U-238	not in Table A-1	(b)
U-235m	unlimited	not in Table A-1	(b)
U-237	included with Pu-241	not in Table A-1	(b)
Np-239	included with Am-243	11	(a)

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

DOE response: For (a) through (e) the A_2s have been revised, as appropriate, with a bases provided for the value used for each isotope.

In addition, as a confirmatory type calculation, an attachment was added to the X-CLC-G-00121 which uses RadCalc 4.1 and calculates the A2s contained in the: (1) Spout Glass; (2) Heel Glass; (3) Refractory Glass; and (4) Surface Contamination, with the RADCALC4.1 determined values then used as the input re-calculating each of the NCT and HAC releases. A comparison of the 10 CFR 71hand calculated A_2s vs. those from Radcalc 4.1, shows the released A2 values to be virtually the same, with no difference for the NCT roll-up, and an ever so slightly more conservative value for the hand-calculated value for the HCT roll-up.

Changes to the SAR: The associated changes to the Appendix 4.6.2 calculation appear on the following pages:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 12-16 and 75 through 84.

RAI Number: 4-2 (Chapter 4, Containment Evaluation)

Subject: Airborne release fractions and respirable fractions

RAI: Clarify the following regarding the airborne release fraction and respirable fraction in calculation package X-CLC-G-00121.

Calculation package X-CLC-G-00121, Section 2, "Background," states that "Airborne Release Fraction (ARF) is the fraction that is aerosolized, normally assumed to be 10 μm or less (Ref. 4)," and "Respirable Fraction (RF) is the fraction of the airborne material that is respirable (inhaled into the lungs)."

From the DOE Handbook, it appears the phrase, "Normally assumed to be 10 μm or less (Ref. 4)," should modify the RF rather than the ARF.

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

DOE response: Calculation package X-CLC-G-00121 has been revised to clarify the definitions of airborne release and respirable fraction and to demonstrate equivalent safety to meet 10 CFR 71.51(a)(1) and (2).

Changes to the SAR: Calculation package X-CLC-G-00121, Section 2, *Background*, now states:

"Airborne Release Fraction (ARF) is the fraction that is aerosolized.

The Respirable Fraction (RF) is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-μm Aerodynamic Equivalent Diameter (AED) and less (Ref. 4)."

The follows portions of the SAR were changed:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 5 and 18.

RAI Number: 4-3 (Chapter 4, Containment Evaluation)

Subject: Clarify leak path factors

RAI: Provide additional information to clarify the third bullet of Section 5.3.1, and the third and fourth bullets of Section 5.4.1 in the calculation package X-CLC-G-00121. The subsequent calculations in the calculation package X-CLC-G-00121 may also need to be revised.

In the third bullet of Section 5.3.1, it is not clear what each of the two numerical values that make up the leak path factor (LPF) represent or how each value ties to Reference 12 of the calculation package X-CLC-G-00121. The values in the third bullet of Section 5.3.1 do not appear to be consistent with the values used in Tables 4, 5, and 6 of calculation package X-CLC-G-00121. Both the third bullet of Section 5.3.1 and the third bullet of Section 5.4.1 appear to describe a combined leak path factor associated with the intact melter multiplied by the WVMP shell; yet, the numerical leak path factors are different in the two bullets. The fourth bullet of Section 5.4.1 describes a leak path factor that represents no credit for the WVMP; yet, the third bullet of Section 5.4.1 appears to take credit for the WVMP shell.

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

DOE response: Calculation package X-CLC-G-00121 has been reorganized to show equivalent safety with 10 CFR 71.51(a)(1) and (2). Since pressurization does not occur inside the melter (pressure stays < 2 psig within melter) only two LPF values will be used within this calculation package X-CLC-G-00121.

Changes to the SAR: The following portions of the calculation package were changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-0, sheets 19 through 21.

RAI Number: 4-4 (Chapter 4, Containment Evaluation)

Subject: Justify damage ratios

RAI: Provide justification for the damage ratios (DR) based on the structural and thermal HAC analysis results and in Sections 5.4.2.1, 5.4.2.2, and 5.4.3 of calculation package X- CLC-G-00121.

It is not clear how the damage ratios provided in Sections 5.4.2.1, 5.4.2.2, and 5.4.3 of the calculation package X-CLC-G-00121 were derived, based upon the structural analysis of the HAC conditions. It is also not clear if the damage ratios considered the predicted maximum temperature of the low density cellular concrete (LDCC) during the HAC fire from Table 3-2 of the application.

This information is required to determine compliance with 10 CFR 71.51(a)(2).

DOE response: Revised Section 5.4.1 Glass during HAC to the following:

- Borosilicate glass is internal to the melter. For a release to occur a fraction of the borosilicate glass matrix must be damaged DRHAC GLASS = 3E-4. (Ref. 14) (For further details see Table 4-HAC Inputs Table, column a).

- The glass particles < 20 μ are conservatively equated to be releasable as aerosols "ARF x RF"HAC GLASS = 1E-3 (Ref. 14). (See Table 4-HAC Inputs Table, column e, with further explanation of derivation provided in the Table has associated text block).

- Based on the thermal analysis (Chapter 3), the melter internal temperature/pressure will not significantly increase during HAC; therefore, contributions from glass are limited to those from impact. That is, glass releases from maximum temperature/pressure (inside the melter), nor will decomposition/de-watering result in any addition releases from inside the melter. (For further details see Table 4-HAC Inputs Table, Note 2).

Section 5.4.2.1 external to the melter during HAC was revised to the following:

"For HAC, three different release contributions were determined.

Impact

- The first release is the result of impact of the LDCC external to the melter with ARF_{LDCC} = 1E-3 and the RF_{LDCC} = 1E-1 (See Table 4-HAC Inputs Table, columns f & g). Note: the ARF and RF values applied for LDCC from impact (no increased temperature or pressure) are the same for both HAC & NCT, as well as for LDCC internal to and external to the melter.

- The fraction of external LDCC under impact for HAC is based on the structural analyses (Ref. 16), which shows the maximum $DR_{external}$ LDCC impact =35%, (For additional details see Table 4 HAC Inputs Table, column b).

Maximum Temperature/Pressure (Release of Existing Fines)

- The second is the result of the thermal analysis (Chapter 3,pg 3-5 Table 3-2) which concluded the maximum temperature of the external LDCC could reach 693^{0}F, which results in an ARF_{LDCC} HAC maximum temperature/pressure = 1E-1 and RF_{LDCC} HAC maximum temperature/pressure = 7E-1 based on Ref. 4, pg. 4-9, (See Table 4-HAC Inputs Table, columns h and i, as well as Table 4-HAC Inputs Table, note 1 and 2).

Decomposition/De-watering

- The third release is the result of LDCC decomposition/de-watering which results in an ARF_{LDCC} HAC decomp/de-watering = 6E-3 and RF_{LDCC} HAC $_{LDCC}$ decomp/de-watering = 1E-2 based on Ref. 4, pg. 4-48 and pg. 4-61. (See Table 4, HAC-Inputs Table, columns j, and k).

- The fraction of external LDCC affected for decomp. /de-watering is conservatively assumed to be $DR_{external}$ LDCC decom/de-watering = 1 (For details see Table 4-HAC Inputs Table, column d)."

Changes to the SAR: The following portions of the calculation package were changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-0, sheets 19 through 27.

RAI Number: 4-5 (Chapter 4, Containment Evaluation)

Subject: Clarify respirable fraction values

RAI: Provide additional information to clarify the difference between the respirable fraction (RF) values in the first and third bullets of Section 5.4.2.2 of calculation package X-CLC- G-00121.

The first bullet states the RF is equal to 1, while the third bullet states the RF is not applied.

This information is required to determine compliance with 10 CFR 71.51(a)(2).

DOE response: Additional information has been added to clarify the difference between the respirable fraction (RF) values used in Section 5.4.2.2 of calculation package X-CLC-G-00121. The 3rd bullet of Section 5.4.2.2 was deleted and the following bullet added to Section 2:

- DR, ARF, RF and LPF are reduction factors. If they are not explicitly discussed, mathematically they can be considered to have a value of 1 (i.e., a value of 1 means no reduction).

Changes to the SAR: The following portion of the calculation package was changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheet 6.

RAI Number: 4-6 (Chapter 4, Containment Evaluation)

Subject: Clarify "ER" term

RAI: Clarify if the "ER term" in calculation package X-CLC-G-00121 is synonymous with the acronym, "EF," escape fraction.

The "ER term" is used on page 6 of 99, and on page 13 of 99, in calculation package X- CLC-G-00121, but the acronym has not been defined. The acronym "EF," is used on page 4 of 99, page 5 of 99, and page 17 of 99, of calculation package X-CLC-G-00121

DOE response: To demonstrate an equivalent level of safety to 10 CFR 71.51(a)(1) and (2), ER has been changed to escape fraction (EF) on sheets 4, 6, 71-73 of the calculation package X-CLC-G-00121.

Changes to the SAR: The following portions of the SAR and calculation package were changed to address this RAI:

Chapter 4, pages 4-1 and 4-6.

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 4, 6, 71-73.

RAI Number: 4-7 (Chapter 4, Containment Evaluation)

Subject: Clarify damage ratio values

RAI: Clarify the use of DR = 0.001 and uncontained airborne release fraction (ARF) LDCC = 7.5×10^{-3} in Table 3 of calculation package X-CLC-G-00121. The subsequent calculations in calculation package X-CLC-G-00121 may also need to be revised.

Table 3 states that the DR of glass is 0.001, while the first bullet of Section 5.4.1, as well as the value used in Tables 12,13, and 14, states the DR is equal to 0.01. Table 3 states that the uncontained ARF LDCC is equal to 7.5×10^{-3}, but this value is not described in Section 5.4.2.

This information is required to determine compliance with 10 CFR 71.51(a)(2).

DOE response: The HAC inputs were made consistent the first bullet of Section 5.4.1 as well as the value used in in the corresponding tables. The value used in Section 5.4.2 for ARF HAC-LDCC-EXTERNAL has been changed to 1E-3, with the effecting release HAC-LDCC-EXTERNAL, confirmed to be using the correct value.

Changes to the SAR: The following portions of the calculation package were changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 6-9, 11, and 21.

RAI Number: 4-8 (Chapter 4, Containment Evaluation)

Subject: Clarify use of leak path factors

RAI: Clarify the use of the leak path factor (LPF) values in Tables 7 and 8 of calculation package X-CLC-G-00121. The subsequent calculations in calculation package X-CLC- G-00121 may also need to be revised.

The values used in Tables 7 and 8 (LPF_{melter} multiplied by LPF_{WVMP}) do not appear to be consistent with the value in the fifth bullet of Section 5.3.2.2 of the same calculation package which describes one value.

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

DOE response: To ensure LPFs are consistent and correct values are applied for all releases within calculation package X-CLC-G-00121 only the following values will be used:

LPF_{MELTER}=0.1 and 1

LPF_{WVMP}= 1.

Changes to the SAR: The following portion of the calculation package was changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheet 21.

RAI Number: 4-9 (Chapter 4, Containment Evaluation)

Subject: A_2 value for low-density cellular concrete

RAI: Clarify the use of LDCC inside the Melter, equal to 2.03 x 10^{-10} in Table 11 of calculation package X-CLC-G-00121. The subsequent calculations in calculation package X-CLC- G-00121 may also need to be revised.

In Table 11 of calculation package X-CLC-G-00121, the summation of the release in terms of A_2 of the LDCC inside the Melter is equal to 2.03 x 10^{-10}, whereas in Table 7 of calculation package X-CLC-G-00121 the summation is equal to 1.08 x 10^{-8}.

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

DOE response: Table 11 in the calculation package has been revised to ensure it is correctly pulling from Table 7.

Changes to the SAR: The following portion of the calculation package was changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheet 21.

RAI Number: 4-10 (Chapter 4, Containment Evaluation)

Subject: Consistency in airborne release fractions

RAI: Clarify the use of the ARF value in Table 18 of calculation package X-CLC-G-00121. The subsequent calculations in calculation package X-CLC-G-00121 may also need to be revised.

The value used in Table 18 does not appear to be consistent with the value in the fourth bullet of Section 5.4.2.1 of the same calculation package.

This information is required to determine compliance with 10 CFR 71.51(a)(2).

DOE response: Table ARFLDCC $_{\text{EXTERNAL}}$ for impact was changed to be consistent with Section 5.4.2.1. (ARF will equal 1E-3).

Changes to the SAR: The following portions of the calculation package were changed to address this RAI:

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 20, 22, 78, 79, and 82.

RAI Number: 4-11 (Chapter 4, Containment Evaluation)

Subject: Leak path factor and containment boundary temperatures

RAI: Provide additional information to address how the WVMP LPF, used in the NCT and HAC containment analysis, is appropriate for the containment boundary temperatures reached during the thermal NCT hot and HAC analysis.

It appears that the maximum predicted temperature of the containment boundary Type 516 steel plates, referred to as "Container" in Table 3-1 (with insolation, 100°F ambient) of the application slightly exceeds the structural temperature limit (200°F) in Table 3-5 of the application during NCT hot conditions. Section 4.2 of the application did not address how the WVMP LPF used in the NCT containment analysis incorporated the thermal analysis results.

It appears that the maximum predicted temperature of the containment boundary Type 516 steel plates, referred to as "Container" in Table 3-2 of the application exceeds the average steel plate temperature limit (800°F) in Table 3-5 of the application during HAC conditions. Section 4.3 of the application did not address how the WVMP LPF used in the HAC containment analysis incorporated the thermal analysis results.

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

DOE response: Conservatively the effects of all maximum temperatures were equated to their corresponding increase in pressure. The LPF_{WVMP} has been revised and is now set equal to 1 (i.e., no reduction credit is given to the WVMP).

Changes to the SAR: The following portions of the SAR and calculation package were changed to address this RAI:

Chapter 4, pages 4-2, 4-3, 4-5, and 4-6.

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 28-30, 34-40, 46, 69, 70, and 77-83.

RAI Number: 4-12 (Chapter 4, Containment Evaluation)

Subject: Clarify whether sealant is credited in containment analysis

RAI: Clarify, in Section 4.1.2 of the application, if the room temperature vulcanizing (RTV) is credited in the containment analysis.

Section 4.1.2 of the application states that the gaskets of the five gasketed ports and the gasket of the bolted side door are not credited in the containment analysis, but it is not clear if the perimeter joint sealed with RTV is credited in the containment analysis.

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

DOE response: Calculation package X-CLC-G-00121 has been revised to ensure that in all cases LPF_{MELTER}=0.1 and 1 LPF_{WVMP} = 1. With these changes, the RTV is not credited in the containment analyses.

Changes to the SAR: The following portions of the SAR and calculation package were changed to address this RAI:

Chapter 4, pages 4-2, 4-3, 4-5, 4-6, and 4-7.

Appendix 4.6.2, calculation package X-CLC-G-00121, sheets 10, 18, 28-30, 34-40, 46, 57, 69, 70, 77-83,

RAI Number: 4-13 (Chapter 4, Containment Evaluation)

Subject: Taking H-3 into account

RAI: Clarify if the calculations in Appendix 4.6.3 of the application take into account the H-3 in Table 1 of Appendix 4.6.2 of the application. Alternatively, provide a justification for not including that isotope in the combustible gas generation calculations.

In Table 1, "WVMP Radionuclide Content on October 1, 2013," of Appendix 4.6.3 calculation package F-CLC-G-00040, the isotope H-3 was not included in the combustible gas generation calculations. Table 1, "WVMP Radionuclide Content and A_2 Values," of Appendix 4.6.2 of the application, lists the H-3 isotope under surface contamination, but it is not clear in the application if it is a combustible gas.

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

DOE response: Tritium was considered in the gas generation calculations. Refer to Sheet 33 of F-CLC-G-00040. Table 1 of Appendix 4.6.3 sheet 10 shows the content of the box at time t = 0 after closing. Any available tritium would have been dissipated, without any time for new tritium to be produced.

Note to Appendix 4.6.3 calculation package F-CLC-G-00040 explains why H-3 is not included in Table 1.

Changes to the SAR: None.

RAI Number: 5-1 (Chapter 5, Shielding Evaluation)

Subject: Use of QADS for calculating absorbed dose rates

RAI: Justify how using QADS is conservative for calculating dose rates of the package with the proposed contents.

QADS is a fairly old point kernel computer code for computing absorbed dose rates outside the package. However, QADS has not been formally compared to more modern methods such as those used in KENO or MCNP. As such, it is not clear whether dose rates calculated with QADS can be assured to be below regulatory limits.

This is especially an issue with the dose rate at 2 meters, calculated to be 7.5 mrem/hr at the bottom location versus a regulatory limit of 10 mrem/hr. In addition, the staff has performed calculations with MAVRIC showing that QADS can be both conservative and non-conservative, depending on the geometry and materials in question.

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

DOE response: The QADS results are generally conservative when compared to measured dose rates on the package. New Appendix 5.5.4 has been added to Chapter 5 showing a comparison of QADS results with the measured dose rates.

Changes to the SAR: The following changes were made to the SAR:

Chapter 5, pages 5-10 and 5-12.

RAI Number: 5-2 (Chapter 5, Shielding Evaluation)

Subject: Apparent discrepancies in QADS input

RAI: Explain the apparent discrepancies with the input used in QADS input file "spout.in." In the input file "spout.in," the maximum z values in bodies 11 and 12 extend into the "wdc" and "edc" zones (void) through the "stl" zone (carbon steel) and into the "ldc" zone (concrete). Most likely, these overlapping areas should not be treated as voids but should be the steel and concrete. It may be that the maximum z values should be 105.7275, similar to the maximum z value in body 10. Bodies 2 and 9 also overlap slightly, so the zones "ref" and "spt" should either be: (a) "2 -9" and "9", or (b) "2" and "9 -2". Both zones are void, so either fix would be appropriate.

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

DOE response: The input in file "spout.in" is indeed incorrect.

Bodies 11 and 12 which define cells "wdc" (west discharge cell) and "edc" (east discharge cell) should extend in the z-direction from -35.56 cm to 84.455 cm. The effect of this error is to make the roof of these cells too thin. Modifying the cell description in QADS reduces the maximum dose rate at the top of the package under NCT by a factor of 250 or more depending on distance from the surface.

The effect of overlap between bodies 2 and 9 also has no significant effect with the corrected geometry.

Changes to the SAR: The following change was made to address this RAI:

> Chapter 5, Appendix 5.5.2, Engineering Calculation N-CLC-G-00153, an errata page was added to Appendix 5-1 with the following information: "The input for bodies 11 and 12 had the incorrect height. The definition of region "ref" should be 2 - 9."

RAI Number: 5-3 (Chapter 5, Shielding Evaluation)

Subject: Justify uniform source distribution

RAI: Justify assuming a uniform source distribution for modeling in QADS.

The applicant's dose rates obtained by modeling with QADS 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.

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

DOE response: The assumption of uniform distribution within the source regions is based on the nature of the process that generated the sources. Glass is uniformly mixed in the melter, and examination of glass from a similar melter showed no stratification of the radioactive material in the glass (reference 5-5, *Characterization of DWPF Melter One Glasses*, WSRC-TR-2003-00477, Rev 0, A.D. Cozzi and J.M. Pareizs, Westinghouse Savannah River Company, Aiken, South Carolina, October 2003.) Reference 5-5 was provided to NRC with the SAR.

Changes to the SAR: The following portion of the SAR was revised to address this RAI:

Chapter 5, page 5-6.

RAI Number: 7-1 (Chapter 7, Package Operations)

Subject: Describe torque values for preparation for transport

RAI: Describe, in Section 7.1.3 of the application, the torque values for the five gasketed ports and bolted side door of the containment boundary.

Section 7.1.2 of the application describes torque values for the gasketed ports and bolted side door from the loading in 2004. Provide confirmation, in Section 7.1.3 of the application, that these torque values are valid during the preparation of transport to ensure closure of the package.

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

DOE response: Prior to installation of the IL, re-application of the original torque (500 lb-ft) to the bolts associated with the bolted side door of the containment boundary will be conducted. Re-application of the original torque (35 lb-ft) to the bolts associated with the gasketed ports will also be performed.

Changes to the SAR: The following portion of the SAR was revised to address this RAI:

Chapter 7, page 7-5.

RAI Number: 8-1 (Chapter 8, Acceptance Tests and Maintenance Program)

Subject: Cited ASME Code sections

RAI: Clarify if the ASME Code Sections, cited in Section 8.1.2, "Container," and Section 8.1.4 of the application, are accurate.

The staff could not find the cited Sections EIII, and EII of the ASME Code. This information is required to determine compliance with 10 CFR 71.119.

DOE response: In both cases, the ASME Code section cited should have been Section III.

Changes to the SAR: The following portions of the SAR were revised to address this RAI:

Chapter 8, pages 8-3, 8-4.

REFERENCES

1. Letter from Bryan Bower, Director, West Valley Demonstration Project, to Pierre Saverot, U.S. Nuclear Regulatory Commission, subject: "Submittal of Safety Analysis Report for the West Valley Melter Package (SARWVMP-01) and Affidavit Concerning Request for Withholding Proprietary Information Contained in the Safety Analysis Report (Docket Number 71-9797)," dated October 16, 2014.

2. Letter from Pierre Saverot, U.S. Nuclear Regulatory Commission, to Daniel Sullivan, West Valley Demonstration Project, subject: "West Valley Melter Package Application – Request for Supplemental Information," dated November 12, 2014.

3. Letter from Bryan Bower, Director, West Valley Demonstration Project, to Pierre Saverot, U.S. Nuclear Regulatory Commission, subject: "Submittal of Responses to Requests for Supplemental Information and Observations on the Safety Analysis Report for the West Valley Melter Package (SARWVMP-01) (Docket Number 71-9797)," December 2, 2014.

4. Letter from Pierre Saverot, U.S. Nuclear Regulatory Commission, to Daniel Sullivan, West Valley Demonstration Project, subject: "West Valley Melter Package Application – Request for Additional Information," dated February 5, 2015.

Safety Analysis Report
for the
West Valley Melter Package

SARWVMP-01

Revision 1

April 2015
(Re-formatted 4/27/2015)

USNRC Docket Number 71-9797

Submitted by:

U.S. Department of Energy
West Valley Demonstration Project
10282 Rock Springs Road
West Valley, NY 14171

Prepared by:

Savannah River National Laboratory
[Under IEWO M14-WV-0001]
&
CH2M Hill-B&W West Valley, LLC
[Under Contract DE-EM0001529]

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RECORD OF REVISIONS

No.	Date	Purpose
0	October 2014	Initial issue for Nuclear Regulatory Commission review.
0A	November 2014	Incorporation of changes from initial Nuclear Regulatory Commission review and associated requests for supplemental information and observations.
1	April 2015	Incorporation of changes associated with Nuclear Regulatory Commission requests for additional information, including: (1) Updated table of contents. (2) Revised Executive Summary to better address equivalent level of safety. (3) Revised Chapter 1 to make it clear that the container was procured as an Industrial Packaging 2 (IP-2) package, that while the container is not leaktight it complies with leakage rate requirements, and that requirements used in construction of the packaging provide an equivalent level of safety to American Society of Mechanical Engineers (ASME) requirements. A revised Impact Limiter drawing was also included. (4) Revised Chapter 2 to make it clear that the package structure provides a level of safety equivalent to the performance requirements of 10 CFR 71 and added tables summarizing package damage from drops specified for normal conditions of transport and hypothetical accident conditions. (5) Revised Chapter 3 to report initial conditions and maximum temperatures and pressures with natural convection in the package air pocket as well as without natural convection. (6) Revised Chapter 4 to demonstrate that the package provides a level of safety equivalent to the containment requirements of 10 CFR 71 under normal conditions of transport and hypothetical accident conditions. (7) Revised Chapter 5 to add a new appendix that compares QADS model output to actual package dose rate measurements. (8) Revised Chapter 7 to include requirements for verifying torque of bolts used to secure gasketed ports and the bolted side door prior to shipment. (9) Revised Chapter 8 to make it clear the WMP provides a level of safety equivalent to applicable ASME Boiler and Pressure Vessel Code sections and updated Appendix 8.3.2 to make this point clear.

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EXECUTIVE SUMMARY

The purpose of this report is to analyze the West Valley Melter Package, a Type B(U) radioactive material transportation package Model Number 9797 containing the vitrification melter from the West Valley Demonstration Project, to support a request for special package authorization by the U.S. Nuclear Regulatory Commission. This report demonstrates the West Valley Melter Package meets the Commission's regulation at Title 10, Part 71 of the Code of Federal Regulations (10 CFR 71), *Packaging and Transportation of Radioactive Material*, with an equivalent level of safety to those requirements.

The West Valley Melter Package, shown in Figure ES-1, consists of the Grouted Melter Package and an Impact Limiter.

The Grouted Melter Package consists of the container with the melter encased in Low Density Cellular Concrete. The container was constructed in 2004 of welded steel plate with one side being a door secured with bolts and a neoprene gasket. Each corner contains a shock absorber. The Low Density Cellular Concrete, poured in 2013, completely encases the melter.

The Impact Limiter will be constructed of steel plate and foam filled steel tubing. It will be attached to the shock absorbers on door side of the Grouted Melter Package.

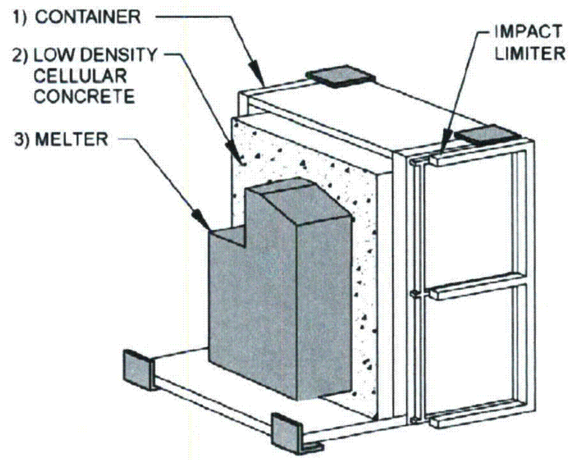


Figure ES-1. West Valley Melter Package Components

The residual radioactivity in the melter amounts to approximately 3,554 curies, with over 99.8 percent of this amount from cesium 137 and strontium 90 and their daughter products. There are approximately 82 grams of fissile material within the melter.

The melter consists of a stainless steel box structure approximately 10 feet on each side lined with refractory material. The melter contains radioactive material immobilized in borosilicate glass, which accounts for over 99 percent of the residual radioactivity. The melter weighs approximately 107,500 pounds (49,000 kilograms).

The melter was used from 1996 through 2002 to produce a homogenized mixture of high-level waste and borosilicate glass. During use, the primary pour spout became plugged with hardened glass and the secondary pour spout was used to complete the waste vitrification. After completion of waste vitrification, the melter was used to process low-activity flush solutions to reduce the radioactivity concentration in the molten material in the melter cavity. When processing was completed as much of the molten material was removed as practical. The melter now contains approximately 1,030 pounds (467 kilograms) of hardened glass, with approximately 218 pounds (99 kilograms) in the plugged primary pour spout.

Table ES-1 summarizes how the West Valley Melter Package meets the requirements of 10 CFR 71. This table is organized using NRC Regulatory Guide 7.9, *Standard Format and Content of Part 71*

Applications for Approval of Packages for Radioactive Material, which was closely followed in preparing this report.

Table ES-1. 10 CFR 71 Compliance Summary

Chapter	Subject	Compliance	Discussion
2	Structural Evaluation	Equivalent Level of Safety	Analyses of the West Valley Melter Package show it provides equivalent level of safety for Normal Conditions of Transport and Hypothetical Accident Conditions. The analysis shows only localized damage to the Low Density Cellular Concrete, container welds and minor face seal displacement under Hypothetical Accident Conditions.
3	Thermal Evaluation	Complies	The thermal evaluation demonstrates requirements are met using conservative analyses that did not consider the insulating values of the Impact Limiter.
4	Containment	Equivalent Level of Safety	Equivalent level of safety is demonstrated by package performance in accordance with requirements with release rates below regulatory limits under Normal Conditions of Transport and Hypothetical Accident Conditions.
5	Shielding Evaluation	Equivalent Level of Safety	The evaluation demonstrates provides equivalent level of safety for the applicable requirements.
6	Criticality Evaluation	Complies	The package is fissile exempt.
7	Package Operations	Equivalent Level of Safety	Operations are performed in accordance with approved procedures.
8	Acceptance Tests and Maintenance Program	Equivalent Level of Safety	The required acceptance tests provide equivalent level of safety.

1.0 GENERAL INFORMATION

This chapter provides an introduction to the Safety Analysis Report (SAR) and a general description of the West Valley Melter Package (WVMP) and its contents.

1.1 Introduction

1.1.1 Purpose

Key Terms and Acronyms in this Chapter	
CHBWV	CH2M Hill-B&W West Valley, LLC
GMP	Grouted Melter Package (consisting of the melter, LDCC inside the container, and the container)
IL	Impact Limiter
LDCC	Low Density Cellular Concrete
PBS	Polymeric Barrier System
WVDP	West Valley Demonstration Project
WVMP	West Valley Melter Package (consisting of the GMP with the IL installed)

The purpose of this SAR is to analyze the safety aspects of the WVMP, Model Number 9797, a Type B(U) radioactive material transportation package containing the vitrification melter from the West Valley Demonstration Project (WVDP). The WVMP is a fissile exempt package.

This SAR was prepared for a Special Package Authorization (SPA) from the U.S. Nuclear Regulatory Commission (US NRC) for use of the WVMP. Such special package authorization is required by the Commission's regulation per Title 10, Part 71 of the Code of Federal Regulations (10 CFR 71), *Packaging and Transportation of Radioactive Material*, §71.41(d) (reference 1-1) for a one-time shipment of radioactive material transportation packages.

1.1.2 Scope

This SAR demonstrates the WVMP complies with 10 CFR 71 or provides safety measures equivalent to those in the applicable regulations. The WVMP design includes an impact limiting component attached to an existing Grouted Melter Package (GMP) component. This SAR was prepared following the guidance provided in Regulatory Guide 7.9, *Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material* (reference 1-2), to facilitate US NRC staff review.

1.1.3 Background

The WVDP vitrification melter contains residual radioactivity associated with spent nuclear fuel reprocessing at the West Valley site. At the heart of the vitrification plant was the slurry-fed vitrification melter. The melter consisted of an electrically heated box structure approximately 10 feet on each side containing refractory material, with an outer shell of stainless steel. The vitrification melter was used from 1996 through 2002 to heat high-level waste slurry and glass forming chemicals to produce a molten homogeneous mixture that was poured into stainless steel canisters, where it hardened to produce a highly stable glass waste form.

In 2004, West Valley procured a specially designed container for the melter. This approximately 208,000 lb container consists of 6" thick sidewalls and 4" thick top and bottom. The container was procured as a 49 CFR 173.411 Industrial Packaging Type 2 (IP-2) package with the associated fabrication and quality assurance (QA) requirements (reference 1-3). The package was designed so that once the melter was loaded, and prior to shipment, the interstitial spacing within the melter and the spacing between the melter and the container would be filled with Low Density Cellular Concrete (LDCC). This provides securement of the melter within the container and impact limiting resistance in the event of an accident. In 2004 the melter was transferred into the container and placed into storage until 2013 when the LDCC was added.

In 2014, it was determined that the melter was required to be shipped in either a Type B certified package or under SPA granted by the US NRC. Since the melter was already in the GMP, an IP-2 package and encased in LDCC, it is necessary to submit an application to the US NRC for a SPA demonstrating an equivalent level of safety.

West Valley plans to ship the WVMP to the Waste Control Specialists (WCS) low-level waste facility in Texas for disposal using two modes of transportation. Heavy haul trailer will be used from West Valley to the closest suitable rail.

1.2 Package Description

1.2.1 Packaging

The WVMP is a rectangular shaped packaging 15'9" long by 12'7" wide by 12'6.5" high containing eight shock absorbers and an Impact Limiter (IL). The maximum fully loaded weight is approximately 390,800 lbs as discussed in Chapter 2 and the minimum empty weight is approximately 208,000 lbs (reference 1-4).

The containment feature is the WVMP's container. This containment is not leaktight, as discussed in Chapters 2 and 4, but demonstrates compliance with 10 CFR 71 leakage dose rates for normal conditions of transport (NCT) in 10 CFR 71.51(a)(1) and with hypothetical accident conditions (HAC) in 10 CFR 71.51(a)(2) (reference 1-1). The container is fabricated with SA516, Grade 70 carbon steel. It has a bolted side door recessed into the container secured with 32 ASTM A193-B7 1½-inch diameter bolts. This bolted side door has a neoprene gasket. The container was designed, constructed, and procured under the WVDP's Nuclear Quality Assurance (NQA)-1 program meeting the requirements of 49 CFR 173. A copy of the engineering drawing describing the container details (reference 1-3) appears in Appendix 1.3.2.

Figure 1-1 shows a cutaway view depicting the melter encased in LDCC within the container. The GMP is comprised of the container, the melter, and the LDCC.[1]

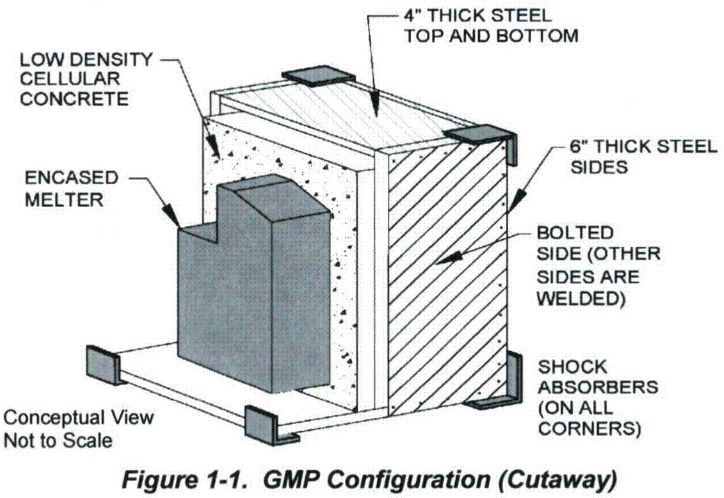


Figure 1-1. GMP Configuration (Cutaway)

To demonstrate equivalent

[1]The three figures included in this chapter are conceptual sketches. Refer to the engineering drawings in the appendix for details.

level of safety to 10 CFR 71 performance criteria for both structural and containment, an IL is attached to the bolted side door of the GMP as shown on Figure 1-2. This IL is comprised of 2" by 9" steel plates and foam-filled 6" by 10" tube steel. The GMP with the IL component in place forms the WVMP. A copy of the engineering drawing describing the IL (reference 1-5) appears in Appendix 1.3.3.

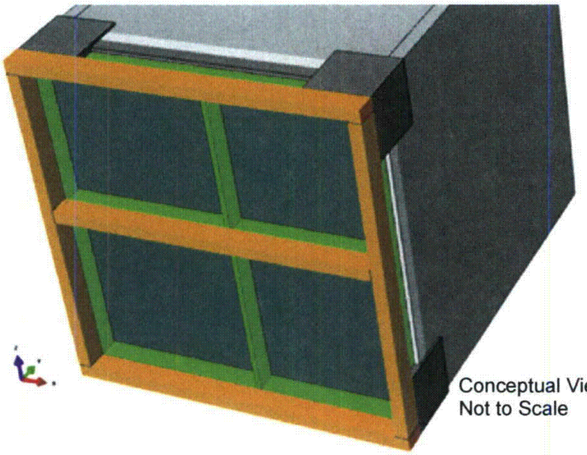


Figure 1-2. WVMP Showing the Impact Limiter

Figure 1-3 shows a cutaway view of the WVMP (the GMP with the IL in place).

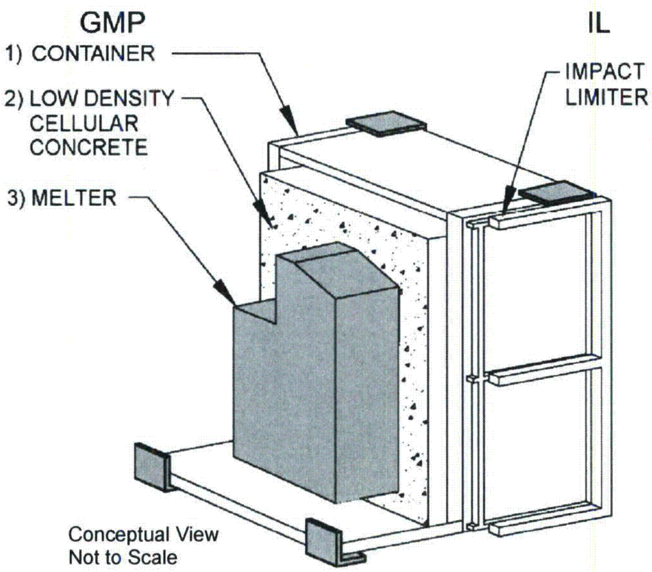


Figure 1-3. Components of the WVMP

Appendix 1.3.4 shows how the WVDP contractor's Quality Assurance Program (QAP) followed in construction of the packaging is comparable with the applicable regulatory requirements. Appendix 1.3.5 shows that American Welding Society (AWS) welding requirements used in construction of the packaging provide an equivalent level of safety with those of NUREG/CR-3019, *Recommended*

Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials (reference 1-6) and the ASME Boiler and Pressure Vessel Code, Subsection ND (reference 1-7).

The gamma shielding features of the WVMP include the 6" thick side walls of the container and the 4" thick top and bottom, made of SA516 carbon steel. The next gamma shielding feature is the LDCC, filling the annular space in the container. The innermost gamma shielding feature is the melter. The melter contains refractory brick, Inconel, and Type 304L stainless steel. The neutron dose is negligible.

The WVMP is fissile exempt. There are no criticality control features.

The WVMP design has no active heat transfer features.

The WVMP will be marked per 10 CFR 71.85(c), which states *"The licensee shall conspicuously and durably mark the packaging with its model number, serial number, gross weight, and a package identification number assigned by the NRC."*

1.2.2 Contents

Radionuclide Content

The melter contains four primary source terms consisting of (1) the heel contained within the melter cavity, (2) residual glass contained within the cracks, crevices and interstitial spacing associated to the refractory brick, (3) the plugged discharge port (pour spout), and (4) the surface contamination on the melter exterior. Each of these source terms was characterized independently utilizing available historical information, analytical results, and swipe sample results. The total activity associated with the melter is 3,554 curies. Total fissile (gram) content of the melter is 81.56 grams. Total number of A_2's associated to the melter is 214.9. Thermal decay heat associated to the melter is 9.2 watts. (reference 1-8)

Primary isotopes of concern consist of Cs-137 (Ba-137m) and Sr-90 (Y-90), which contribute greater than 99.8 percent of the total activity associated with the melter. Other nuclides present include actinides, other fission products, activation products, and other associated daughter products, with a combined contribution to total activity of less than 0.2 percent.

In characterizing the melter, a conservative approach was taken to ensure that the isotopic distribution and associated activity was bounded. Decay correction was incorporated in the final content.

The melter was characterized utilizing analytical data associated with the waste materials that were processed through it, swipe sample results within the vitrification cell, and swipe samples of the melter. When available, shard sample data were used which increase accuracy and reduce uncertainty.

The melter contains fissile radionuclides in the form of Pu-239, Pu-241, U-233, and U-235 with a bounding fissile content of 81.56 grams. Of the 81.56 grams of fissile material, 80.90 grams is contained within 467 kg of vitrified glass contained within the melter. The remaining 0.66 gram of fissile material is fixed to the outer surface of the melter body. Table 1-1, based on reference 1-8, gives a breakdown of the total activity by source term, quantify of fissile material by source term, activity of primary isotopes by source terms, and quantity of vitrified glass by source term.

Table 1-1. Source Term Totals

Activity Breakdown by Source Term						
Source Term	Total Activity (Ci)	Fissile Mass (g)	A2's	Decay Heat (W)	% of Total Activity	Mass of Vitrified Glass (kg)
Exterior Contamination (decay corrected)	1.436E+01	6.569E-01	2.136E+00	4.054E-02	0.404%	
Melter Spout (decay corrected)	1.793E+03	1.899E+01	8.244E+01	4.551E+00	50.445%	9.90E+01
Refractory (decay corrected)	6.300E+02	3.268E+01	6.713E+01	1.768E+00	17.725%	6.82E+01
Melter Heel (decay corrected)	1.117E+03	2.923E+01	6.315E+01	2.834E+00	31.426%	3.00E+02
Totals	**3.554E+03**	**8.156E+01**	**2.149E+02**	**9.194E+00**		4.67E+02
Activity Associated to Primary Isotopes						
	Exterior Surface	Spout	Refractory	Heel	Totals	
	Act (Ci)	Act (Ci)	Act (Ci)	Act (Ci)	Act (Ci)	% of Total Act
Cs-137	5.062E+00	8.566E+02	2.132E+02	5.419E+02	1.617E+03	45.487%
Ba-137m	4.778E+00	8.086E+02	2.012E+02	5.116E+02	1.526E+03	42.938%
Sr-90	2.213E+00	6.332E+01	1.068E+02	3.120E+01	2.035E+02	5.726%
Y-90	2.213E+00	6.333E+01	1.068E+02	3.121E+01	2.036E+02	5.727%
Total Activity of Primary Isotopes	1.427E+01	1.792E+03	6.280E+02	1.116E+03	3.550E+03	99.878%
Total Activity of Remaining Activity	9.400E-02	1.150E+00	2.000E+00	1.090E+00	4.334E+00	0.122%

Conservatism and Uncertainty

The source term estimate is a bounding estimate that is conservative in several respects, for example:

- The estimated mass of hardened glass in the bottom of melter cavity of 300 kg was conservatively based on an eight-inch depth of glass, where the best estimate of glass depth is 6.5 inches, which corresponds to approximately 192 kg at a glass density of 2.6 g/cm^3.
- The estimated mass of 99 kg in the plugged pour spout and pour chamber was conservatively based on assuming that the spout and pour chamber are completely full of hardened glass, which may not be the case.
- The calculated mass of residual glass associated with the refractory material of 68.2 kg was estimated using a conservative volume of material based on one percent of the actual

volume of refractory brick considering the results of visual inspection of the refractory condition after completion of vitrification.

- The amount of removable activity on the melter exterior was conservatively estimated using the maximum result from swipe samples taken from the exterior surfaces, which was approximately twice the average value (reference 1-8) and applying a conservative wiping efficiency of 10 percent.

Uncertainties associated with the inventory estimate are not discussed in the characterization report. The two primary sources of uncertainties are the residual glass mass estimates and the sample analytical data used in the calculations. The residual glass estimates are conservative as just discussed and the total residual glass mass of 467 kg is considered to be bounding. That is, the positive uncertainty in this value is essentially zero and the negative uncertainty is of the order of 25 percent (+0%,-25%).

The sample data uncertainties are reflected in analytical reports (reference 1-8). However, uncertainties in these data were not used in calculating the activity scaling factors since multiple results were available and they were consistent. Geometric averaging of scaling factors is a common practice throughout the commercial nuclear power industry in cases where more than one representative sample is available. This practice is incorporated into the Radman™ software used in the characterization, which has been reviewed and accepted by the US NRC (reference 1-9).

This practice is also consistent with NUREG/CR-6567/PNNL-11659, *Low-Level Waste Classification, Characterization, and Assessment: Waste Streams and Neutron-Activated Metals* (reference 1-10), which states that it "is important that waste generators utilize the most accurate scaling factors possible, so that reliable estimates of these nuclides [ones for which activity scaling factors are used] can be made."

In summary, the use of average values without regard for uncertainty in the analytical data to develop activity scaling factors is consistent with accepted practice and the conservatism in the glass mass estimating process bounds the uncertainty in the analytical data.

Considering the forgoing discussion, rounding down the total inventory estimate of 3,554 curies, including all daughter products, to 3,500 curies appropriately reflects the accuracy of the estimate. However, the 3,554 curie value is used in the analyses in the interest of conservatism.

Physical Description

The physical form of the contents is solid. The chemical form of the contents is oxide and non-reactive.

The melter content is comprised of a stainless steel outer housing and an exterior structural steel frame with the interior lined with refractory materials. See figure 1-4. The maximum envelope dimensions of the melter are 11'10" long by 10'9¾" wide by 10'5 ½" high. All external surfaces of the melter are coated with three layers of Bartlett's Polymeric Barrier System (PBS) contamination fixative. The interior of the melter contains refractory material, vitrified glass, and LDCC.

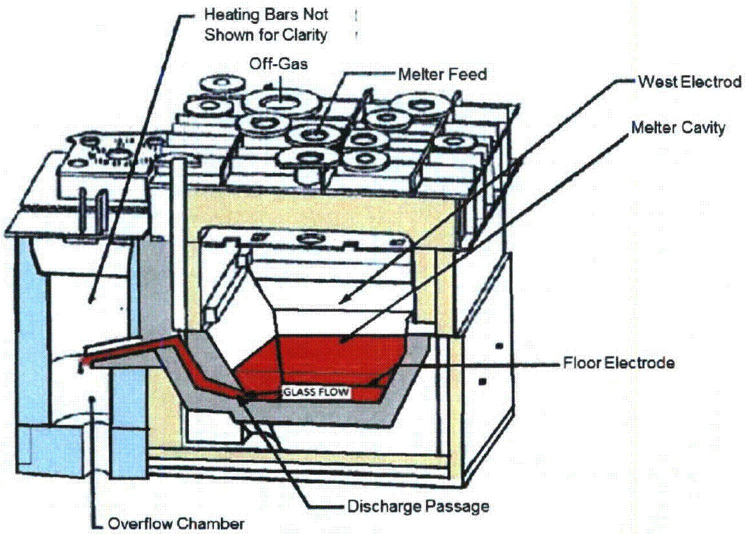


Figure 1-4. Melter

The content weight of the WVMP consisting of the melter, its refractory, and the residual vitrified glass is approximately 107,500 lbs. The WVMP's Maximum Normal Operating Pressure is 12 psi.

1.2.3 Special Requirements for Plutonium

The WVMP contains less than 20 curies of plutonium (reference 1-8). Consequently, there are no special requirements for plutonium related to this package.

1.2.4 Operational Features

All activities related to the WVMPs' final assembly, handling, loading, and transport will be performed in accordance with approved plans, procedures, and work planning instructions.

Prior to the WVMP leaving the WVDP site, an impact limiter will be installed to the bolted door side of the GMP which will render the door inoperable. The IL component will be procured, receipt inspected, and installed by the WVDP site. A copy of the engineering drawing showing the details of the IL is included in Appendix 1.3.3.

The WVMP will be marked per 10 CFR 71.85 (c), which states *"The licensee shall conspicuously and durably mark the packaging with its model number, serial number, gross weight, and a package identification number assigned by the NRC."* Tamper-indicating devices will be applied to the five gasketed ports, four on the top and one on the side of the package.

Radiation surveys of the package (on contact and at one meter from the surface) and non-fixed (removable) contamination surveys will be performed within 60 days of loading and prior to transport. The package exterior surface is expected to be free of removable contamination, and package exterior radiation levels will not exceed the limits specified in 10 CFR 71.47 at any time during transportation.

1.3 Appendix

This appendix contains the following information:

1.3.1 List of references

1.3.2 Engineering drawing for the container

1.3.3 Engineering drawing for the Impact Limiter

1.3.4 CHBWV Quality Assurance Program and Regulatory Requirements Matrix

1.3.5 ASME Code Requirements Equivalent Level of Safety Tables

APPENDIX 1.3.1 – REFERENCES

1-1 10 CFR Part 71, *Packaging and Transportation of Radioactive Material.*

1-2 *Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material*, Regulatory Guide 7.9, Revision 2, U.S. Nuclear Regulatory Commission, Washington, D.C., March 2005.

1-3 *WMG Certificate of Conformance, WVDP-TC-474, WVNSCO Purchase Order 19-104320-C-LH, West Valley Demonstration Project Melter DOT package, revised, WMG, Inc., Peekskill, New York, July 2013.* (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Request for Withholding*)

1-4 *West Valley Melter Container*, Drawing 4005-DW-001, Revision 7, WMG, Inc., Peekskill, New York, June, 2013. (PROPRIETARY – see Appendix 1.3.2)

1-5 *WVMP Impact Limiter*, Drawing R-R3-A-00063, Revision 0, Savannah River National Laboratory, Aiken, South Carolina, October 2014. (See Appendix 1.3.3)

1-6 *Recommended Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials*, NUREG/CR-3019, Monroe, R.E., H.H. Woo, and R.G. Sears, Lawrence Livermore National Laboratory, Livermore, California, March 1984.

1-7 *ASME Boiler and Pressure Vessel Code, Subsection ND*, American Society of Mechanical Engineers, New York, New York, 2004.

1-8 *West Valley Demonstration Project Waste Characterization of Vitrification Melter*, WVDP-577, Brandjes, C., CH2M Hill-B&W West Valley, LLC, West Valley, New York, September 2014. (provided)

1-9 *Acceptance for Referencing, RADMAN Topical Report (WMG-102, as Revised from WMG-101P)*, HPPOS-288 PDR-9306180293, U.S. Nuclear Regulatory Commission, Washington, D.C., http://www.nrc.gov/about-nrc/radiation/protects-you/hppos/hppos288.html (site visited September 12, 2014).

1-10 *Low-Level Waste Classification, Characterization, and Assessment: Waste Streams and Neutron-Activated Metals*, NUREG/CR-6567/PNNL-11659, U.S. Nuclear Regulatory Commission, Washington, D.C., August 2000.

1-11 Structural Welding Code – Steel, D1.1, American Welding Society, 2000

1-12 West Valley Melter Package (WVMP) — Comparison of AWS D1.1, Structural Welding Code and ASME Section III, Subsection ND Welding Requirements, SRNL-L4430-2015-00001, D.N. Maxwell, SRNL Material Science and Technology. March 2015, (provided)

APPENDIX 1.3.2 – ENGINEERING DRAWING FOR THE CONTAINER

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG Inc.			
West Valley Melter Container			
SIZE B	FSCM NO.	DWG NO. 4005-DW-001	REV 7
SCALE NTS		SHEET 1 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG inc.

West Valley
Melter Container

SIZE	FSCM NO.	DWG NO.	REV
B		4005-DW-001	7
SCALE NTS		SHEET 2 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG Inc.			
West Valley Melter Container			
SIZE B	FSCM NO.	DWG NO. 4005-DW-001	REV 7
SCALE NTS		SHEET 3 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG Inc.
West Valley
Melter Container

B		4005-DW-001	7
NTS		4 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG Inc.
West Valley
Melter Container

SIZE	FSCM NO.	DWG NO.	REV
B		4005-DW-001	7
SCALE NTS		SHEET 5 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG Inc.			
West Valley Melter Container			
SIZE B	FSCM NO.	DWG NO. 4005-DW-001	REV 7
SCALE NTS		SHEET 6 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG inc.
West Valley
Melter Container

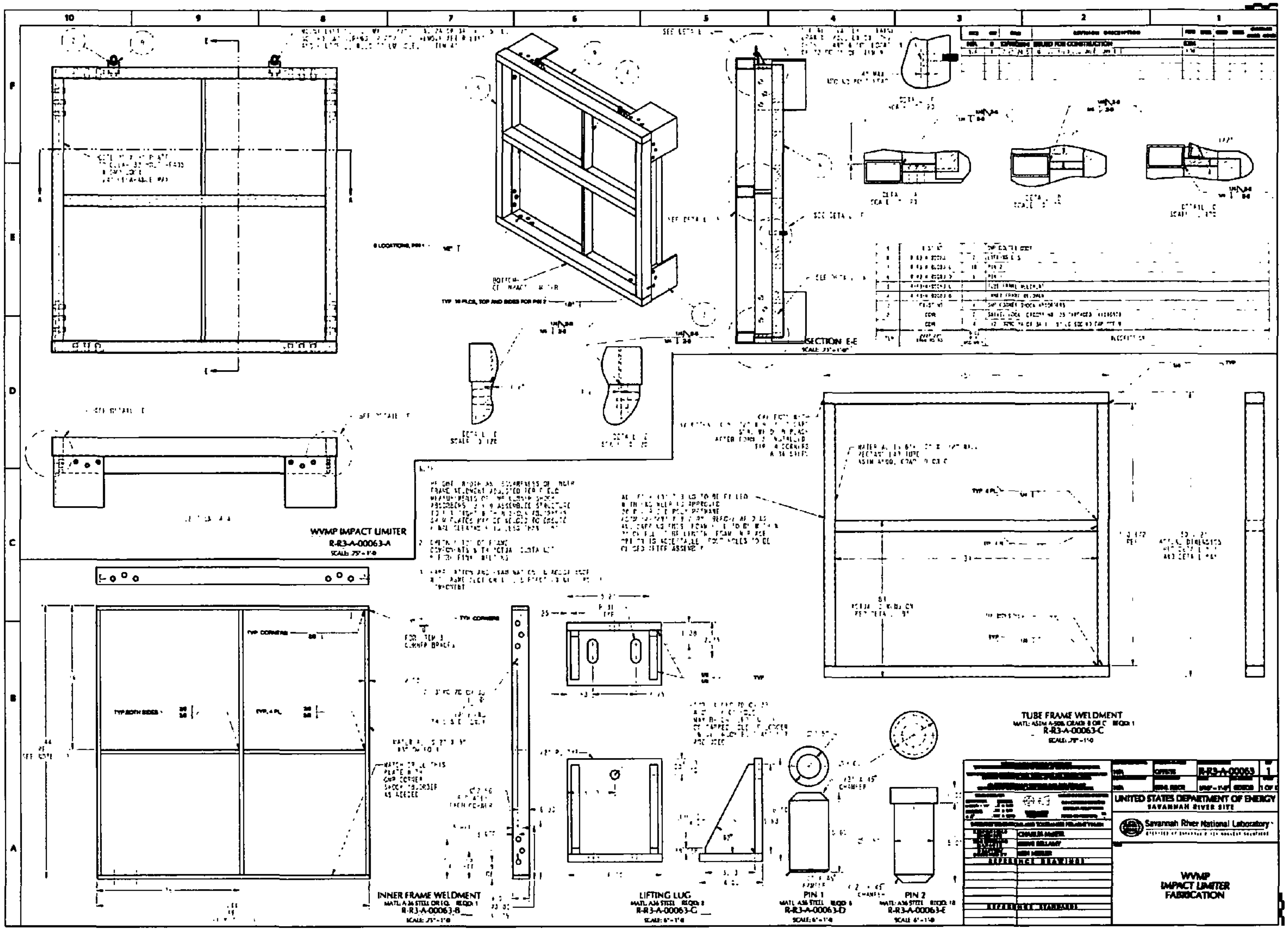
B		4005-DW-001	7
NTS		7 of 8	

Proprietary drawing withheld under 10 CFR 2.390,
Public Inspections, Exemptions, Requests for Withholding.

WMG Inc.
West Valley
Melter Container

B		4005-DW-001	7
NTS		8 of 8	

APPENDIX 1.3.3 – ENGINEERING DRAWING FOR THE IMPACT LIMITER



APPENDIX 1.3.4 – CHBWV QUALITY ASSURANCE PROGRAM AND REGULATORY REQUIREMENTS MATRIX

10 CFR 71 Subpart H	CHBWV QA Program WVDP-111	Description
1 (71.103) Quality Assurance Organization	Part A: Management §1.0 and Part C: Assessment §9.0	Defines the responsibilities for the establishment and implementation of the CH2M Hill-B&W West Valley, LLC (CHBWV) Quality Assurance Program (QAP). The organizational structure and the assignment of responsibility shall be such that quality is achieved and maintained by those who are assigned responsibility for performing the work, and the quality achievement is verified by persons not directly responsible for performing the work.
2 (71.105) QA Program	Part A: Management §1.0 – 3.0	The CHBWV QAP is comprised of WVDP-111, "CHBWV Quality Assurance Program", company-wide implementing documents, work control procedures, training procedures and other CHBWV documents. The company-wide and functional area or project-specific procedures, and other policies, plans and documents that are directly credited as being the implementing procedures for the QAP requirements are listed within this table.
3 (71.107) Package Design Control	Part B: Performance §6.0 Part E: Control of Software	It is CHBWV policy to design items and systems using sound engineering/scientific principles and appropriate standards. Design work, including changes, is incorporated with applicable requirements and design basis. Design interfaces are identified and controlled. Procedures describe the requirements and responsibilities established to plan, control, and verify design activities, including design input, design output, configuration and design changes, documentation, and technical interfaces consistent with the graded approach. The software quality control procedures also define the requirements governing the development, acquisition, maintenance and use of computer software.
4 (71.109) Procurement Document Control	Part A: Management §4.0 and Part B: Performance §7.0	Establishes the process by which procurement documents and their changes contain technical, quality, and safety requirements relative to the scope, nature, importance, complexity and desired reliability of the procured items or services, and that those requirements are independently reviewed prior to issuing the documents.
5 (71.111) Instructions, Procedures and Drawings	Part A: Management §3.0 Part B: Performance §5.0	Activities that can affect the quality, safety, or the environment of CHBWV products and services are prescribed by and performed in accordance with documented, management-approved procedures, instructions, checklists, and design documents.
6 (71.113) Document Control	Part A: Management §4.0	A program is established and implemented to control the preparation, review, approval, issuance, use, and revision of documents that prescribe activities, specify requirements, or establish design. Examples of document to be controlled include drawings, data files, calculations, specifications, computer codes, purchase orders and related documents, vendor-supplied documents, procedures, work instructions and data sheets.
7 (71.115) Control of	Part A: Management §3.0 Part B: Performance §7.0-8.0	Describes the process that CHBWV has developed to ensure that potential suppliers are evaluated prior to contract award and at intervals during the course of the

APPENDIX 1.3.4 – CHBWV QUALITY ASSURANCE PROGRAM AND REGULATORY REQUIREMENTS MATRIX

10 CFR 71 Subpart H	CHBWV QA Program WVDP-111	Description
Purchased Items and Services Commercial Grade Item Dedication	Part F: Commercial Grade Item or Service Dedication	contract. Procedures provide for the inspection of items either during manufacture or when received onsite. The scope of work which accompanies the purchase requisition provides all the required specifications, documentation and criteria for acceptance.
8 (71.117) Identification and Control of Items	Part B: Performance	CHBWV has defined a process for the control and maintenance of M&TE, calibrated instruments and the required documentation.
	§5.4 Implementation §5.4.2 – Identification and Control of Items	It is CHBWV policy to perform work under suitable conditions using approved instructions, procedures, or other appropriate means. Items are identified and controlled to ensure their proper use, and are maintained to prevent their damage, loss or deterioration. When specified, items shall be identified from the initial receipt and fabrication of items up to and including installation and use. When codes, standards, or specifications include specific identification or traceability requirements (such as identification or traceability of the item to applicable specification and grade of material; heat, batch, lot, part, or serial number; or specified inspection, test, or other records), implementing departmental procedures shall provide such identification and traceability control methods. Quality Assurance is responsible for verifying proper identification and traceability of received items and documentation.
	§7.0, Procurement §7.3.3 – QA Responsibility §8.0, Inspection & Acceptance Testing §8.1 – Introduction	It is the policy of CHBWV that the status of inspection and test activities shall be identified on the items or in documents traceable to the item to ensure that required inspections and tests have been performed, and to assure that items which have not passed the required inspections and tests are not inadvertently installed, used, or operated.
9 (71.119) Control of Processes	Part A: Management §2.0 Part B: Performance §5.0	CHBWV identified those activities that must be controlled as special processes and shall be performed by qualified personnel using approved procedures, drawings, checklists, travelers, or other appropriate means to specify requirements (i.e. welding, brazing, soldering, nondestructive assay, etc.).
10 (71.121) Inspection	Part A: Management §2.0 Part B: Performance §8.0	Establishes the requirements and responsibilities for specifying, planning, performing, and documenting receipt inspection, independent assessments, surveillances and peer verification.

APPENDIX 1.3.4 – CHBWV QUALITY ASSURANCE PROGRAM AND REGULATORY REQUIREMENTS MATRIX

10 CFR 71 Subpart H	CHBWV QA Program WVDP-111	Description
11 (71.123) Test Control	Part B: Performance §5.0	CHBWV has established and implemented procedures to perform inspections and acceptance testing of engineered systems, components, or parts according to the intended use of the items as specified in approved design specifications.
12 (71.125) Control of Measuring & Test Equipment	Part B: Performance §5.0 and 8.0	Describes the program which is established and implemented to control the calibration, maintenance, and use of equipment used for data collection and process monitoring of work including environmental data collection activities.
13 (71.127) Packaging, Handling, Shipping and Storage	Part B: Performance §5.0	Defines the requirements and states the responsibilities for the handling, shipping, packaging, and storage of items to prevent damage, deterioration, or loss. Controlled storage requirements are identified for those items needing an added level of protection from environmental environments (i.e. moisture, heat, etc.)
14 (71.129) Inspection, Test and Operating Status	Part B: Performance §5.0 and 8.0	Establishes the measures used to mark, label or tag items to indicate the status of inspections and tests performed. Procedures provide for the identification of items to preclude use of items that are in need of inspection or calibration, etc.
15 (71.131) Control of non-conforming Items	Part A: Maintenance §3.0 Part B: Performance §8.0	It is the policy of CHBWV on items that do not conform to specified requirements be controlled to prevent inadvertent installation or use. Controls provide for identification, documentation, evaluation, segregation when practical, disposition of nonconforming items, and for notification to affected organizations. The implementation of these requirements is through written procedures.
16 (71.133) Corrective Action	Part A: Maintenance §3.0	Establishes significance, assigns responsibilities and authorities, defines requirements, and provides for proper identification, documentation, control, evaluation, and resolution of identified issues through the development and tracking of deficiencies or improvements.
17 (71.135) Quality Assurance Records	Part A: Maintenance §2.0, 4.0 Part B: Performance §5.0	CHBWV integrates the requirements of documents and records processes into implementing procedures for the timely preparation, issuance, control and revision of documents that specify requirements of prescribed processes or quality-affecting activities.
18 (71.137) Audits	Part A: Maintenance §2.0 Part C: Assessment §10.0	Establishes the method for scheduling, planning, performing, reporting, and closing Quality Assurance (QA) and other program or activity audits.

Assigning CHBWV Quality Levels

The CHBWV quality level system provides graded quality assurance application. This system assigns quality levels based upon increasing levels of quality as the severity of incidents of safety, health, and environmental impact increase. With activities clearly identified by quality level, existing CHBWV procedures and practices provide a mechanism and process for the graded application of quality assurance. The quality level system is used to assure that each system is designed, procured, fabricated, installed, and operated in accordance with the appropriate design and operational codes and standards.

The quality level system evolved over the years from the initial Safety Classification System which was evaluated to determine if the Quality Level program met the graded approach to quality assurance. It resulted in combining Service Classes into the Quality Level definitions, leaving a dual classification system: Safety Class and Quality Level. The new system emphasized up-front planning, involving engineers in key process steps; timely decision-making; and consideration of resources, priorities, and risk bases. Moreover, it allowed for a graded approach to implementation.

This "graded approach" allows the level of effort needed for the WVDP to satisfy the multitude of directives. It ensures that the highest level of effort will be provided for work that has the greatest impact on safety, health, and the environment.

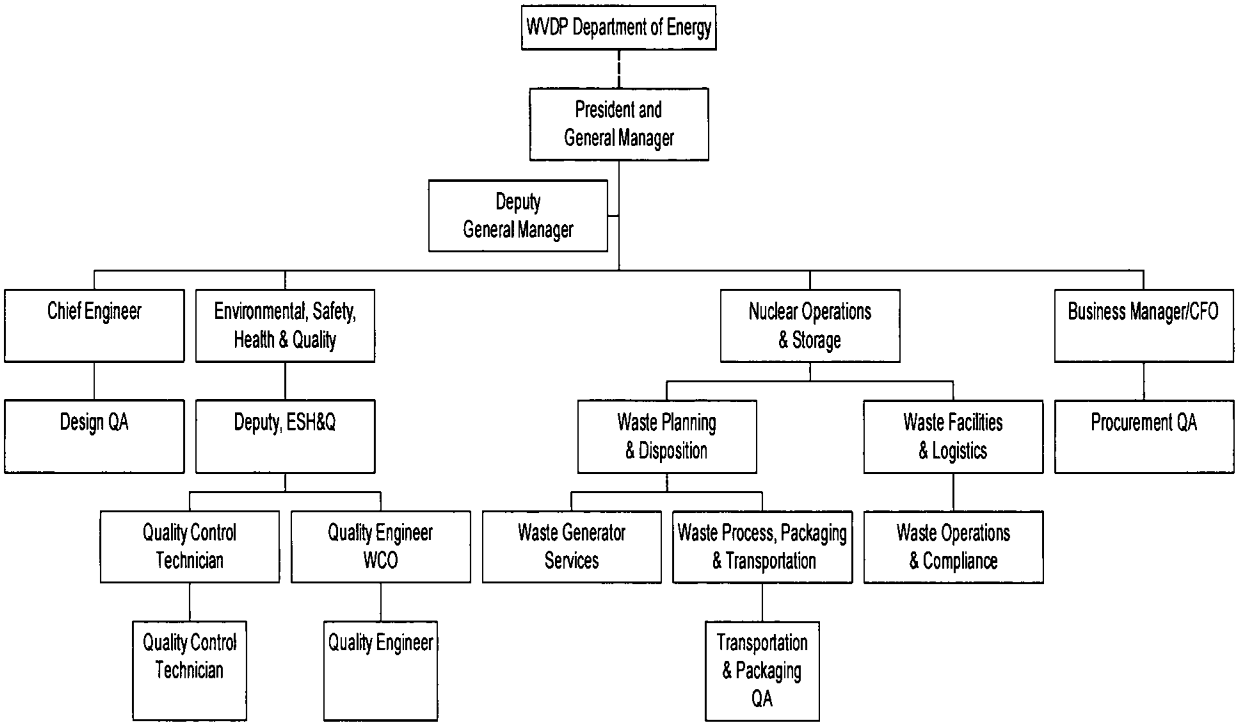
Comparison of NUREG/CR-6407 and CHBWV Classification Categories

NUREG/CR-6407 Safety Designation	Importance to Safety	CHBWV Safety Designation
A	Critical to safe operation	B
B	Major impact on safety	C
C	Minor impact on safety	N

Safety Assessment of Packaging Features

Package Components	Quality Level - NREG Type B (Normal Form)	NQA-1
Melter	B	B
LDCC	A	C
Side door	A	C
Bolts	A	C
Impact limiter	A	B
Container	A	C
Lifting lugs	B	B

CHBWV Organization Chart



The QA organization monitors the activities by performing QA surveillances on packaging and shipping activities, receipt inspections and shipping documentation review and approval. In addition, QA is responsible for reviewing and approving procedures and procurement documents.

The CHBWV Deputy ESH&Q/Quality Assurance Manager is responsible for ensuring the maintenance of the Quality Assurance Manual as well as for providing training and certification of QA personnel at CHBWV. Supplier evaluations, surveillances and audits are performed in accordance with approved procedures.

APPENDIX 1.3.5 – ASME CODE REQUIREMENTS EQUIVALENT LEVEL OF SAFETY TABLES

The container was procured as a 49 CFR 173.411 Industrial Packaging Type 2 (IP-2) package with the associated fabrication and quality assurance (QA) requirements (reference 1-3). The container was fabricated in accordance with American Welding Society (AWS) Structural Code D1.1 (reference 1-11).

The WVMP provides an equivalent level of safety with the requirements of NUREG/CR-3019, *Recommended Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials* (reference 1-6) and the ASME Boiler and Pressure Vessel Code, Subsection ND (reference 1-7) as detailed in this appendix. The letter report *West Valley Melter Package (WVMP) — Comparison of AWS D1.1, Structural Welding Code and ASME Section III, Subsection ND Welding Requirements*, provides detailed comparison (reference 1-12).

The fabrication and examination for the IL construction is per ASME Code, Section III, Subsection NF, in accordance with NUREG/CR 3854, Table 4-1.

Table 1. Material Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-2121	Materials shall be restricted to those listed in Tables 1A, 1B and 3.	The WVMP demonstrates an equivalent level of safety. SA516-70 and SA-36 are listed in Table 1A and within the permitted thickness. The ASME(SA) and ASTM(A) material specifications are identical.
ND-2221	Coupon and specimen location shall be as required by the material specification. Note that the ASME/ASTM material specification (Sect. II Part A Specification SA 20/A 20M-89, Section 11.2 states; the longitudinal axis of the tension test specimens shall be transverse to the final rolling direction of the plate).	The WVMP demonstrates an equivalent level of safety. Per the Certified Material Test Reports (CMTRs), coupons were taken in accordance with ASTM A516/ASME SA516.
ND-2128	Bolting material to be listed in Table 3.	The WVMP demonstrates an equivalent level of safety. ASTM 193-B7 is in Table 3.
ND-2130	Material CMTRs to be supplied.	The WVMP demonstrates an equivalent level of safety. CMTRs for SA-516, SA-36, and Bolts were supplied.
ND-2311	Pressure retaining material shall be impact tested, unless LST is set above Table ND-2311-1 values.	The WVMP demonstrates an equivalent level of safety. Appendix 2.12.2 analysis justifies LST = 3°F for 6 inch thick.
ND-2400	Welding Materials ASME Subsection ND requires fracture	The WVMP demonstrates an equivalent level of safety. Although the filler metal CMTRs verifying tensile, chemistry, and impact testing are not

Table 1. Material Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
	toughness testing. ASME Section III, Subsection ND requires filler material testing for tensile and chemistry.	available, the weld filler material used met the AWS 5.XX Specification as specified in the applicable AWS D1.1 welding procedure specification. Moreover, the filler material specifications for both ASME (SFA) and AWS (A5.XX) are identical and require impact testing for the FCAW, SMAW, and SAW consumables when purchased to the applicable specification. Lowest service temperature was set to 3°F to address the lack of fracture toughness testing.
ND-2440	Suitable storage and handling of electrodes flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.	The WVMP demonstrates an equivalent level of safety. AWS D1.1, Section 5.3 covers, in detail, the storage and handling requirements of welding consumables and electrodes. Compliance was verified through the quality program and CWI oversight.

Table 2. Design Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-3100	Loading and Design Criteria are specified.	The WVMP demonstrates an equivalent level of safety. The loads are per the CFR and are consistent with ND-3100. The design criteria are per ND-3100.
ND-3300	Design Requirements are specified.	The WVMP demonstrates an equivalent level of safety. The Stress Limits used in Chapter 2 structural analysis are in compliance with RG 7.6 and consistent with ND-3300.
ND-3350	Weld Joint requirements: The walls of the rectangular GMP are fabricated of single slabs. The only structural welds are on the corner joints. ND-3350 is targeted to circular vessels constructed of pieced plates. The best match to the corner joint is ND-3350, Category D.	The WVMP demonstrates an equivalent level of safety. The corner joints feature partial groove welds on both inside and outside edges with reinforcing fillets on the inside. ND-3350 permits partial groove welds. Weld joints meet the requirements of AWS D1.1 prequalified joint designs. The weld attributes on the 4 inch and 6 inch base material are in Table 6.

Table 3. Fabrication Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-4100	Material control requirements are specified. This includes material examination, repair of discontinuities, material identification and weld preparation. Welding material shall meet the requirements of ND-2400. Reference Table 1.	The WVMP demonstrates an equivalent level of safety. Base material examination, repair of discontinuities, weld preparation, and material identification meet the requirements of AWS D1.1. AWS D1.1 provides a level of assurance, combined with the CWI overview, that the correct material was used in the fabrication of the WVMP.
ND-4200	Forming, fitting, and aligning requirements are specified.	The WVMP demonstrates equivalent level of safety. These requirements are focused on circular vessels. There are no features of the GMP sensitive to tolerance or fit-up beyond those already controlled by material specifications and construction drawings. Weld joint requirements are already discussed in ND-3350.
ND-4300 and ND-4400	Welding Qualifications are specified. *ASME Section III, Subsection ND* requires qualification of procedures and personnel to be performed in accordance with ASME Section IX and additional requirements specified in ND-4300.	The WVMP demonstrates an equivalent level of safety. The welding procedure specifications (WPS) were performed in accordance with AWS D1.1 prequalified/qualified procedures as applicable, with one exception. WPS 2.108 is prequalified for use with ASTM A36 base material and requires a 150° F minimum preheat. The procedure was used to weld joints on base material A/SA516 that required a minimum preheat of 225° F. The disposition is to use as is based on the following: both materials are grouped as AWS prequalified materials, both are approved for use in the specified joint detail of AWS D1.1(B-U3c-S), and the filler material used (SFA 5.23, Classification EA1) meets the base metal/filler material strength relationships for SA516. Reference Table 5, ND-4600, for preheat disposition. Welders were qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.
ND-4600	Preheat, interpass and post-weld heat *treatment are specified.*	The WVMP demonstrates an equivalent level of safety. An appropriate level of preheat was performed in accordance with the AWS D1.1 applicable prequalified WPS requirements. Reference Table 5, ND-4600. The weld attributes on the 4 inch and 6 inch base material are in Table 6.

Table 4. Examination Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND-5200		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-5230	Radiography is not required when the weld joint is not a full penetration weld.	The WVMP demonstrates an equivalent level of safety. Visual and magnetic particle examinations (VT/MT) were performed, post weld, on all welded joints in accordance with AWS D1.1 requirements except welds 37 and 38. These welds were not examined, are not load bearing, and were dispositioned accordingly. Reference NCR No. (1)04-002. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
ND-5280	Based on Storage Tanks to WVMP similarity. Bottom-to Sidewall, Roof to sidewall joints shall be examined visually. Alternatively, MT or PT may be substituted.	The WVMP demonstrates an equivalent level of safety. Visual and magnetic particle examinations (VT/MT) were performed, post weld, on all welded joints in accordance with AWS D1.1 requirements except welds 37 and 38. These welds were not examined, are not load bearing, and were dispositioned accordingly. Reference NCR No. (1)04-002. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
ND-5340 and ND-5350	Acceptance standards for MT and VT are specified.	The WVMP demonstrates an equivalent level of safety. There are slight differences in the acceptance criteria with AWS D1.1 allowing a larger and greater number of rounded indications as compared to ASME Section III, ND requirements. However, the differences are insignificant and the AWS D1.1 acceptance criteria have proven to provide an adequate level of safety. Visual and magnetic particle examination performed the results were acceptable The weld attributes on the 4 inch and 6 inch base material are in Table 6.
ND-5500	ASME Section III, Subsection ND requires NDE personnel certification in accordance with SNT-TC-1A.	The WVMP demonstrates an equivalent level of safety. Documents contained in the welding documentation package revealed NDE personnel certification to SNT-TC-1A, proper eye examination, certified welding inspector (CWI) credentials and examinations meeting the applicable requirements of AWS D1.1

Table 5. Welding Requirements NUREG & AWS/WVMP Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
Base Materials – *ND-2000 (except ND-2300 and ND-4100)* NUREG/CR-3019 and ASME Subsection ND require fracture toughness testing. ND-2121(a) - Pressure retaining material shall conform to the requirements of one of the specifications for materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1..... ND 2121(e) - Welding and brazing materials used in manufacture of items shall comply with an SFA specification in Section II, Part C, except as otherwise permitted in Section IX, and shall also comply with the applicable requirements of this Article. ND2531 - Plates shall be examined in accordance with the requirements of the material specification.	Base Materials Used – SA/A36, A572 grade 50/60 (sub. A633 E/C), SA/ASTM516 grade 70 – Thickness (1/8" 1/2", 1", 2", 4" 6") Welding Materials Used – E71T-1 (spec. A5.20), ER70S-3 (spec. A5.18), E81T1-A1M (spec. A5.29), E7018 (spec. A5.1), and EA1 (spec. A5.23) Visual examination prior to welding.	The WVMP demonstrates an equivalent level of safety. Base material approved by ASME and AWS, same SA (ASME specification designation) and ASTM specifications applicable. Base materials prior to welding receive a visual examination based on AWS D1.1. Receipt inspection reports for the SA/A516 six inch material documents MT examination. SFA Specifications required in Section III are identical to AWS A5 specifications. Lowest service temperature was set to 3°F to address the lack of fracture toughness testing. The WVMP accepts gaps in the containment boundary (from analysis in Chapter 2) under HAC and released damaged material (see Chapter 4). Additional fractures or gaps do not increase or decrease the release fraction or the packages ability to meet 10 CFR 71 release criteria.
Welding Materials – *ND-2400* NUREG/CR-3019 and ASME Subsection ND require addressing fracture toughness. ASME Section III, Subsection ND requires filler material testing for tensile and chemistry. Suitable storage and handling of electrodes flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.	Welding Materials Used – E71T-1 (spec. A5.20), ER70S-3 (spec. A5.18), E81T1-A1M (spec. A5.29), E7018 (spec. A5.1), and EA1 (spec. A5.23) AWS D.1.1 Section 5.3 covers in detail the storage and handling requirements of welding consumables and electrodes.	The WVMP demonstrates an equivalent level of safety Filler metal CMTRs verifying tensile, chemistry, and impact testing are not available. The weld filler material used met the AWS 5.X Specification as documented in the applicable AWS D1.1 welding procedure specification. However, The filler material specifications for both ASME (SFA) and AWS (A5.XX) are identical and require impact testing for the FCAW, SMAW, and SAW consumables when purchased to the applicable specification. Storage and handling of welding materials requirements are met. Compliance was verified through the quality program and CWI oversight. The WVMP accepts gaps in the

Table 5. Welding Requirements NUREG & AWS/WVMP Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
		containment boundary (from analysis in Chapter 2) under HAC and released damaged material (see Chapter 4). Additional fractures or gaps do not increase or decrease the release fraction or the packages ability to meet 10 CFR 71 release criteria.
Joint Preparation – *ND-4200* ASME Section III, Subsection ND specifies weld requirements based on weld type.	Weld Joint/Welds - Complete/partial joint penetration v-groove, fillet and plug welds.	The WVMP demonstrates an equivalent level of safety. Weld joint preparation, groove type, weld type, and welding profiles used in the fabrication met the AWS D1.1 prequalified joint designs. The corner joints feature partial groove welds on both inside and outside edges with reinforcing fillets on the inside. ND-3350 permits partial groove welds. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
Welding – *ND-4400* ASME Section IX approved welding processes. Welding preparation and welding profile requirements.	Welding Processes – FCAW, GTAW, SMAW, and SAW	The WVMP demonstrates an equivalent level of safety. The WVMP used approved welding processes. Welding preparation, fabrication, and weld profiles met the requirements of AWS D1.1. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
Qualification Procedure/Personnel – *ND-4300* ASME Section III, Subsection ND requires qualification to be performed in accordance with ASME Section IX and additional requirements specified in ND-4300.	Welding Procedure Specifications – Prequalified and qualified.	The WVMP demonstrates an equivalent level of safety. The welding procedure specifications (WPS) were performed in accordance with AWS D1.1 prequalified/qualified procedures as applicable, with one exception, WPS 2.108, R1. WPS 2.108 is prequalified for use with ASTM A36 base material and requires a 150° F minimum preheat. The procedure was used to weld joints on base material A/SA516 that required a minimum preheat of 225° F. The disposition on the base material is to use as is based on the following: both materials are grouped as AWS prequalified materials, both are approved for use in the specified joint

Table 5. Welding Requirements NUREG & AWS/WVMP Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
	Welder Performance *Qualifications – Performed in* accordance with ASME Section IX.	detail of AWS D1.1(B-U3c-S), and the filler material used (SFA 5.23, Classification EA1) meets the base metal/filler material strength relationships for SA516. Reference Table 5, ND-4600, for preheat disposition. AWS D1.1 requires qualification for processes and materials of certain types and also allows the use of prequalified procedures. The FCAW, SMAW, and SAW processes used in this application are prequalified; the GTAW process used is qualified in accordance with the appropriate section of AWS D1.1,, "Certain welding processes in conjunction with certain related types of joints have been thoroughly tested and have a long record of proven satisfactory performance. These WPSs and joints are designated as prequalified and may be used without tests or qualification." The essential and nonessential variables and mechanical testing of the AWS prequalified and qualified WPSs are equivalent to ASME Section IX. The welder performance qualifications were performed in accordance with ASME Section IX mandated in ASME Section III, ND-4300 and is allowed by AWS D1.1 when approved by the Engineer. The Engineer is defined as a duly designated individual who acts for, and in behalf of, the Owner on all matters within the scope of the code.
Heat Treatment – *ND-4600* Except as otherwise permitted in ND-4622.7, all welds, including repair welds, shall be post weld heat treated.	Prequalified preheat requirements - 225^0 F for minimum thickness greater than 2 ½" and PWHT if specified by engineer and/or purchase requirements.	The WVMP demonstrates an equivalent level of safety. An appropriate level of preheat was performed in accordance with the applicable AWS D1.1 prequalified welding procedure with the exception to the welds made using WPS 2.108, R1, that required a minimum preheat

Table 5. Welding Requirements NUREG & AWS/WVMP Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
		of 225°F. These welds according to the WPS were made using a minimum preheat of 150°F. The welds are expected to function as designed with no cracking issues due to the following: • At minimum a 150° F preheat was performed. • Welding Processes (FCAW and SAW multiple electrodes) used produce a high deposition rate with high heat input which produces a slow cooling rate, permitting hydrogen diffusion. • Low hydrogen consumables were used – AWS A5.20 and A5.23 Electrode Specifications. • Low to medium restraint. • Post weld visual and magnetic examinations were acceptable. Also, these welds are reinforced by the shock absorbers and had little influence on the structural analysis (referenced Chapter 2). No PWHT documentation was available. No PWHT is credited in the WVMP. The WVMP accepts gaps in the containment boundary (from analysis in Chapter 2) under HAC and released damaged material (see Chapter 4) I. Additional fractures or gaps do not increase or decrease the release fraction or the packages ability to meet 10 CFR 71 release criteria.

Table 6. WVMP Weld Attributes for the Partial Penetration Welds on the 4" and 6" Thick Joints

Weld #	Dwg #	Item#	"T"(1)	Joint Type(2)	Final Inspection VT/MT CWI Report(3)	WPS(s)(4)	WPS Critical Variables (AWS D1.1)(5)				
							Process	Material	Filler Matl./Spec (6)	Preheat (Min.)	PWHT
4	4	1 - 4	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
6	4	1 - 4	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
7	4	1 - 3	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
8	4	1 - 3	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
9	5	2 - 3	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
10	5	2 - 3	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
20	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 / SFA 5.23	225°F / 150°F (8)	No Record
21	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 / SFA 5.23	225°F / 150°F (8)	No Record
22	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 /	225°F / 150°F (8)	No Record

Table 6. WVMP Weld Attributes for the Partial Penetration Welds on the 4" and 6" Thick Joints

Weld #	Dwg #	Item#	"T"(1)	Joint Type(2)	Final Inspection VT/MT CWI Report(3)	WPS(s)(4)	WPS Critical Variables (AWS D1.1)(5)				
							Process	Material	Filler Matl./Spec (6)	Preheat (Min.)	PWHT
									SFA 5.23		
23	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 / SFA 5.23	225°F / 150°F (7)	No Record

NOTES:

(1) T = Thickness

(2) SB = Single Bevel; BS = Both Sides; DoB = Depth of Bevel; FiC = Fillet inside Corner

(3) Reference NDE Report Number VT-35-04.

(4) Welding Procedure Specification (WPS).

(5) Welds performed by qualified welders for the procedures listed.

(6) Filler material specifications are acceptable by both the AWS D1.1 and Section IX of the ASME Boiler and Pressure Vessel Code and match the base material requirements for strength and ductility.

(7) Base material used for welds number 20, 21, 22, and 23 is SA516. One of the WPSs used for making these welds (WPS - 2.108, Revision 1) state that welding is to be performed on A36 base material only. The disposition is to use as is based on the following; both materials are grouped as AWS prequalified materials, both are approved for use in the specified joint detail of AWS D1.1 (B-U3c-S), and the filler material used (SFA 5.23, Classification EA1) meets the base metal/filler material strength relationships for SA516.

(8) Welds 20, 21, 22 and 23 had welds specified with two WPS. One specifies 225°F and other specified 150°F preheat. These welds are reinforced by the welded on shock absorbers and had little influence on the structural analysis (see Chapter 2 analysis). Reference Table 5, Heat Treatment NB-4600.

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2.0 STRUCTURAL EVALUATION

This chapter describes the structural evaluation of the West Valley Melter Package (WVMP) and how this exclusive use Type B package provides an equivalent level of safety with the performance requirements of 10 CFR 71 (Reference 2-1).

2.1 Description of Structural Design

2.1.1 Discussion

The WVMP consists of two components the Grouted Melter Package (GMP) and the Impact Limiter (IL), shown in Figure 2-1. The GMP consists of a 13'5" long by 12'4" wide by 12'4" high container which contains the vitrification melter with the volume between the two filled with Low Density Cellular Concrete (LDCC). The second component to the WVMP is the externally mounted IL. With the IL, the WVMP is 15'9" long 12'7" wide by 12'6.5" high, with a total weight of 390,800 lbs.

Key Terms and Acronyms in this Chapter

FEA	Finite Element Analysis
GMP	Grouted Melter Package (consisting of the melter and LDCC inside the container)
HAC	Hypothetical Accident Conditions
IL	Impact Limiter
LDCC	Low Density Cellular Concrete
MNOP	Maximum Normal Operating Pressure
NCT	Normal Conditions of Transport
PBS	Polymeric Barrier System
RTV	Room Temperature Vulcanizing
WVMP	West Valley Melter Package (consisting of the GMP with the IL installed)

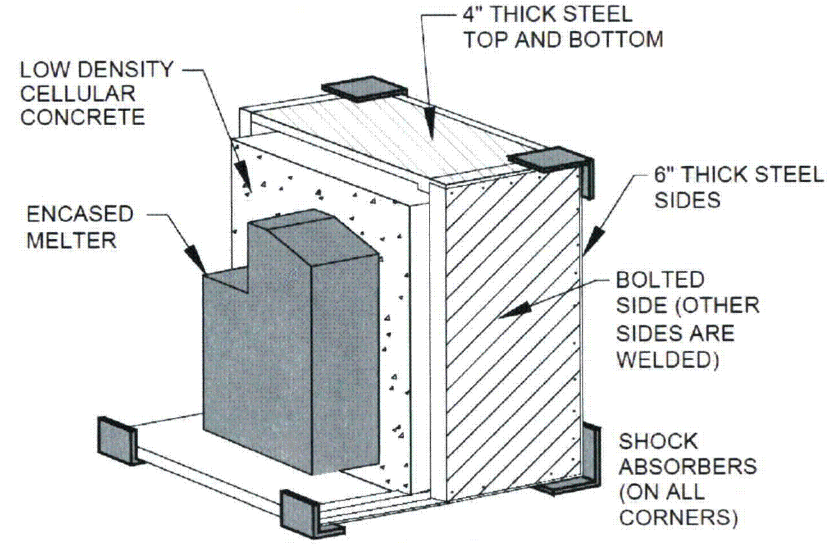
The Melter

The melter is comprised of a stainless steel housing with an exterior structural steel frame all residing on a structural steel support beam structure. Part of the melter interior is fabricated with Inconel 690 to handle the high vitrification temperature and for abrasion resistance to the glass frit. The interior of the melter is lined with refractory materials. The dimensions of the melter envelope are 11'10" long by 10'9¾" wide by 10'5½" high. The melter was modified prior to placing it in the container. The modifications included:

- Heating electrodes were removed to reduce overall size, and
- All exterior surfaces of the melter equipment and its frame were coated with Bartlett's Polymeric Barrier System (PBS) contamination fixative.

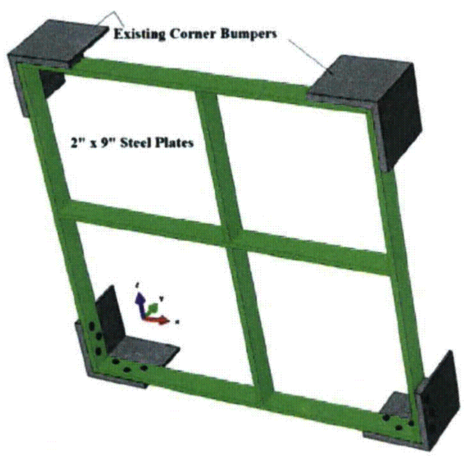
Container

The outer structure in which the melter resides is a rectangular-shaped steel walled container with sacrificial shock absorbers welded to all eight corners. The material of construction is American Society of Mechanical Engineers (ASME) SA516 Grade 70 carbon steel plate for the 6" thick side walls, 4" thick top and bottom plates, 6" thick back plate, and the 6" thick bolted side door. The shock absorbers are 27" by 27" and are made of A36 carbon steel plate. The 27" length of the shock absorbers consists of 18" of 1" thick plate that overlaps the container and 9" of 3" plate that extends past the container. All plate-to-plate joints at corners of the container are groove welded on each side of the joint, with an additional fillet weld on the inside corner joints. The bolted side door was bolted in place after insertion of the payload, using 32, 1.5" diameter ASTM A193 B7 bolts, evenly spaced around the perimeter. The interstitial space between the melter and GMP was filled with LDCC to form a monolith that fits tightly and securely inside the GMP. The LDCC maintains positioning of the melter and absorbs shock loads to minimize structural demands on the melter. Figure 2-1 shows the GMP.

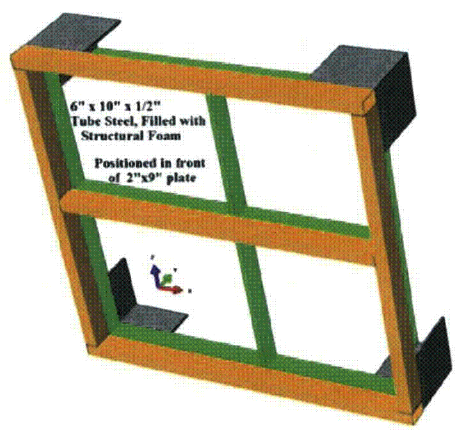


Conceptual Sketches
Not to Scale

Grouted Melter Package



2" by 9" plates of IL (to secure wall)



6" by 10" Tube Steel of IL (for Crush)

Figure 2-1. Components of the WVMP

Impact Limiter

The IL component is added to the bolted side door of the WVMP. The IL consists of a window frame-like structure of 2" by 9" structural plate (ASTM A36) that fits inside and is attached by welded pin connections to the 9" shock absorber extensions. This 2" by 9" plate prevents access to the front wall bolts and provides structural redundancy to the front wall bolts. The IL also includes

6" by 10" structural tube steel framework positioned in front of and welded to the 2" by 9" plates. The tube steel volume is filled with a rigid, closed-cell, 20 lb/ft^3 density polyurethane foam. The function of the rigid foam is to work with the structural tubing to cushion impacts that are prescribed in Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC). The IL is shown in Figure 2-1. The engineering drawing appears in Appendix 1.3.3.

Table 2-1 lists the WVMP components and their function.

Table 2-1. WVMP Components and Structural Functions

Component		Function for NCT and HAC
IL	2" x 9" Plates	Provide structural support to aid in maintaining position of side door under free-drop conditions
	6" x 10" Tube Steel	Energy absorption in door-side down drops. Size and strength chosen to reduce impact G-loads to minimize LDCC crush
LDCC		Maintain the position of the melter within the container, absorb energy, and reduce the shock loads imposed on the melter
Container		Structural support to maintain LDCC configuration (confinement). Absorbs impact energy.

2.1.2 Design Criteria

Design criteria for the WVMP are derived from the following Regulatory documents:

- 10 CFR 71.41 through 71.51, and
- 49 CFR 173, *Shippers – General Requirements for Shipments and Packagings* (reference 2-2).

Design criteria for the WVMP are also consistent with the following Regulatory Guides (RGs):

- RG 7.6, *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels* (reference 2-3);
- RG 7.8, *Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material*, (reference 2-4); and
- RG 7.11, *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)*, (reference 2-5).

Equivalent level of safety of the WVMP with the design criteria is demonstrated by analysis.

Normal Conditions of Transport

The design criteria for the WVMP structural components are based on the criteria of RG 7.6. The allowable tensile stresses under normal conditions are:

Primary membrane stresses, Pm < Sm

Primary membrane + bending stresses, Pm + Pb < 1.5 Sm

Shear stresses limited to 60% of tensile stress limits (per Mises Stress Theory)

Where, ***Sm*** = Design stress intensity per ASME *Boiler and Pressure Vessel Code* (B&PVC, reference 2-6), II-D, Tables 2A and 2B.

For the ASME SA516 Grade 70 structural steel plates comprising the container, the normal conditions allowable stresses are:

Pm < Sm = 23,200 psi [Up to 200°F]

Pm + Pb < 1.5Sm = 34,800 psi [Up to 200°F]

The 200°F condition bounds the NCT range of temperature established in Chapter 3. Per ASME II-D, Mandatory Appendix 2, the basis for the above criteria is the lesser of the following:

- One-third the specified minimum tensile strength at temperature (70,000/3 = 23,300 psi for ASME SA516), or
- Two thirds the specified minimum yield strength at temperature (2 × 34,800/3 = 23,200 psi for ASME SA516)

Sacrificial structures are shown to satisfy similar structural criteria in order to prevent excessive deformation (e.g., strain limits for foam), geometric instability (e.g., buckling), brittle fracture (including cold temperature conditions), and high temperature effects (annealing, softening, creep).

The WVMP performance under NCT and HAC loading conditions is evaluated at its actual weight. Consideration of minimum package or component size is not applicable.

HAC Criteria for GMP Container

HAC events are classified as a Level D Service Load. The structural criteria are per ASME B&PV Code, Section III, Appendix F-1341.23 (Plastic Analysis) and Appendix F-1331.1 (Elastic Analysis).

Primary membrane stresses, Pm < 0.7Su

Primary local , Pl < 0.9 **Su** (F 1341.23 plastic analysis)

< 150% Pm (F1341.23 elastic analysis)

Maximum Strains: Per ASME III-App F-1322.5, not to exceed material spec limits

Where, **Su** = Engineering Ultimate Strength of the material

For static HAC load events (e.g., internal/external pressure), elastic analysis was used with the following design criteria for the SA516-70 structure is (from -20°F to 800°F)

Pm < 0.7 × Su = 0.7 × 64,300 psi = 45,000 psi	[Up to 800°F]
Pl < 1.5 × Pm = 1.5 × 45,000 psi = 67,500 psi	[Up to 800°F]

For dynamic events (drops, puncture), plastic analysis was used, with the design criteria per ASME III Appendix F-1341.23. As derived in Appendix 2.12.2, the F 1342.23 criteria are implemented by imposing the following strain limits:

- 70% Stress Limits = 2.7% true strain, averaged through thickness, and over a general region.
- 90% Stress Limits = 11% true strain, averaged through thickness, and local.
- Maximum Strain Limit = 21% (to satisfy Appendix F-1322.5, accounts for multi-axial stresses. Value derived in Appendix 2.12.2 per ASME VIII-2 methods)

Bolting

The tensile and shear stresses in the 32 bolts attaching the bolted side door and the bolts for the five small circular plugs are evaluated (Appendix 2.12.2) during NCT and HAC analyses. The combined stress condition is compared to bolt yield and shear-out yield limits to establish bolt integrity. The 32 side door bolts had inadequate strength and number to survive all the HAC events, so the IL was added. The IL applies direct bearing stress onto the exterior surface of the door, eliminating the load path through the bolts; this makes the bolts redundant. The stress limits applied in this analysis are:

NCT Conditions: 2/3 Bolt Yield

HAC Conditions: MIN {Bolt Yield at Temperature, 70% Ultimate} (Drop condition, or HAC Fire)

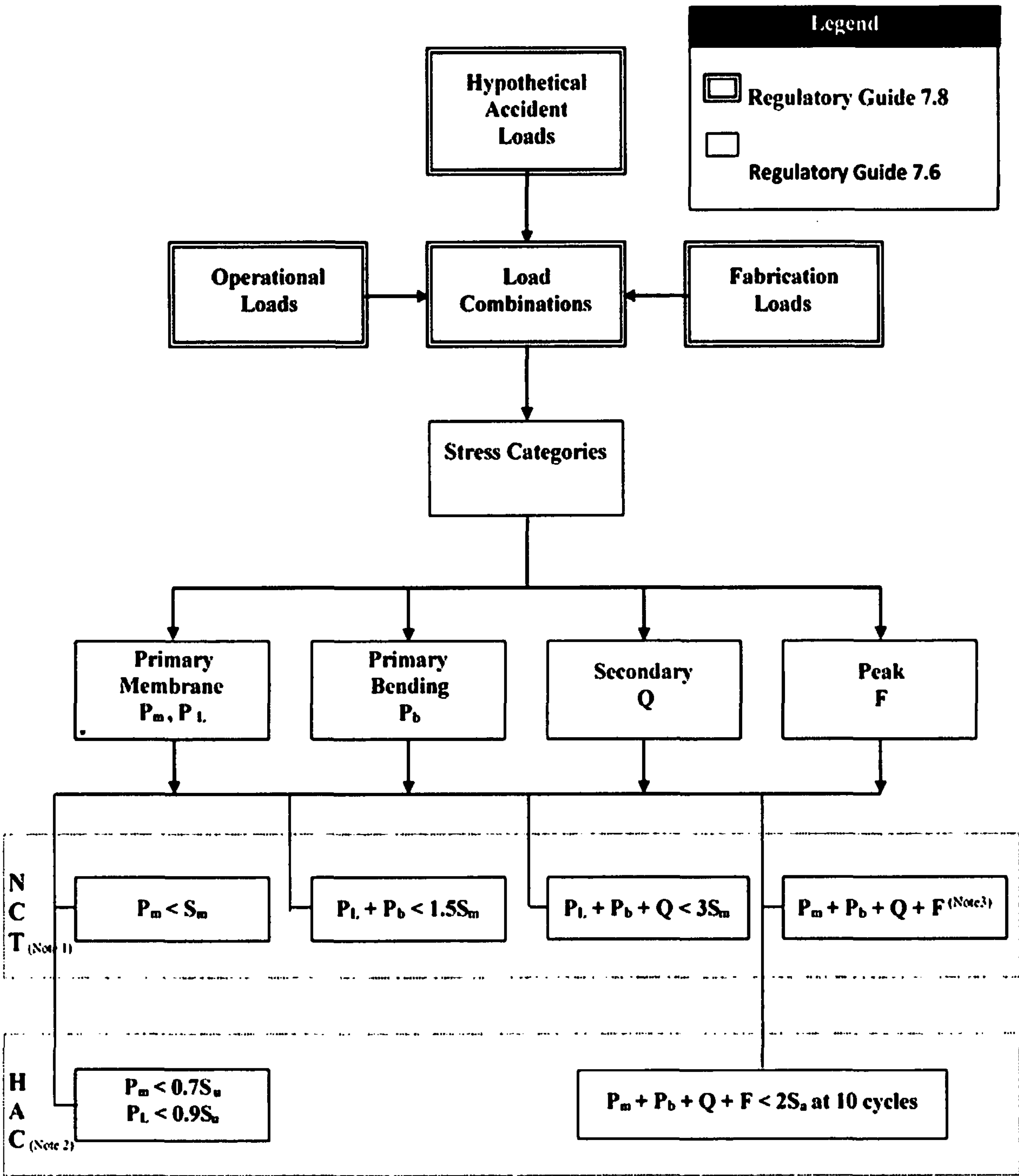
Positioning Devices and other Credited Components

The melter position within the container is maintained by the emplaced LDCC that fills the annular space between the melter and the container walls. The pressure loads on the LDCC during NCT and HAC are compared to the material's documented crush strength to assess LDCC damage.

Lifting and Tie-Down

Lifting devices are removed from the WVMP prior to shipment. The attachment points for these lugs are evaluated and demonstrated to be acceptable per 10 CFR 71.45 Tie-down components are evaluated to comply with 10 CFR 71.45. The acceptance criteria demonstrate no yielding would occur under the factored load conditions. Load factors are evaluated to meet 10 CFR 71 lifting requirements.

Figure 2-2 illustrates load combinations and stress intensity limits from RG 7.6 and RG 7.8 considered in the analyses.



Notes: (1) Level A Service Limits for Stress.

(2) Level D Service Limits for Stress, per B&PV Code, Section III, Appendix F, Article F-1341.2.

(3) The allowable stress intensity for the full range of fluctuations is 2 Sa per Figure NB-3222-1.

Figure 2-2. Load Combinations and Stress Intensity Limits from Regulatory Guides 7.6 and 7.8

2.1.3 Weights and Centers of Gravity

The weight basis for certification is shown below, based on summation of component weights tabulated in Appendix 2.12.2. Confirmation of the computed weights are presented in Appendix 2.12.2 by comparison to actual weights recorded during lifting and movement of components.

Container, With Shock Absorbers, Without Lift Lugs

Per drawing 4005-DW-001, sheet 2 of 8 (see Appendix 1.3.2), the container steel structure has a weight of 208,000 lbs. This includes the four lifting lugs (3,243 lbs total). The lugs are removed for the shipping configuration, resulting in a final weight of 208,000 lbs – 3,243 lbs = 204,757 lbs. This value is comparable with the more rigorously determined weight in Appendix 2.12.2 calculations of 204,864 lbs. This weight is located at the geometric center of the container.

Component Weight = 204,864 lbs

Melter

Per Appendix 2.12.2, the melter weight is 107,500 lbs.

LDCC

Per Appendix 2.12.2, a volume of 1,012 ft^3 was pumped into the structure. Per records, the average density was 69.9 lb/ft^3, corresponding to a weight of 1,012 ft^3 x 69.9 lb/ft^3 = 70,738 lbs

Component Weight = 70,738 lbs

Impact Limiter

Per Appendix 2.12.2, the added IL weight is 7,683 lbs.

Table 2-2 summarizes the component weights.

Table 2-2. WVMP Weight Summary

Component	Weight	Notes
Container	204,864 lbs	Geometrically centered
LDCC	70,738 lbs	4" below geometric center
Melter	107,500 lbs	8" below geometric center
IL	7,683 lbs	Located at one face
Total	**390,800 lbs**	Center of gravity (CG) shifts less than 3" from geometric center (down and toward the front) – See Figure 2-5

2.1.4 Identification of Codes and Standards for Package Design

The packaging design criteria are based on evaluation of the maximum radiological hazard (A_2 units) and curie (Ci) content for "normal form" radioactive material. The WVMP content form and amount of radioactivity (normal form), the WVMP is categorized as a Type B, Category II package. Applicable codes and standards to be used for the design, fabrication, assembly, and testing of the WVMP are specified in Table 1.1 of NUREG/CR-3854, *Summary of Fabrication Criteria Based on the ASME Code* (reference 2-7).

The fabrication drawings and quality assurance (QA) information included with Chapter 1 detail specific sections of the ASME code that are applicable to the WVMP design.

Based on the content form and amount of radioactivity (normal form, radioactive contents between 30 A_2 and 3,000 A_2 and not greater than 30,000 Ci), the WVMP is categorized as a Type B, Category II package (reference 2-5). Based on the recommendations of NUREG/CR-3854, the fabrication, examination, and inspection of the containment boundary components of a Type II package should be per the ASME B&PV Code Section III, Subsection ND.

2.2 Materials

2.2.1 Material Properties and Specifications

Material specifications are identified in Table 2-3.

Table 2-3. Material Specifications for WVMP Construction

Component	Material Specification	Reference
Container plate and door	ASME SA516 Grade 70	Drawing 4005-DW-001[(1)]
Closure bolts for door	ASTM A193-B7	Drawing 4005-DW-001[(1)]
Shock absorbers	ASTM A36	Drawing 4005-DW-001[(1)]
LDCC	ASTM C869 ASTM C495 ASTM C172 ASTM C138 ASTM C150 ASTM C33	Melter Waste Package Grouting Implementation/QA Plan (Rev. 2, Oct 23, 2013)[(2)]
Melter lid	ASTM A240, Grade 304L	Drawing 900D-2786[(3)]
Internal melter components	Inconel 690	Drawing 900D-2786[(3)]
Melter Lower Section Water Jacket Inner Walls	ASTM A240, Grade 304L, Inconel 690	Drawing 900D-2783[(3)]
Melter Lower Section Water Jacket Outer Walls	ASTM A500 Grade B	Drawing 900D-2783[(3)]
Melter Base Frame Members	ASTM A36	Drawing 900D-2784[(3)]
2"x9" plates of IL	ASTM A36	Drawing R-R3-A-00063[(4)]
6"x10" Tube Steel of IL	ASTM A500 Grade B or C	Drawing R-R3-A-00063[(4)]
2.5" Pins of IL	ASTM A36	Drawing R-R3-A-00063[(4)]
Crushable Foam of IL	Commercial polyurethane foam, 20 pcf	Drawing R-R3-A-00063[(4)]

NOTES: (1) See Appendix 1.3.2.
(2) Reference 7-7 in Chapter 7 (provided).
(3) West Valley vitrification melter drawings.
(4) See Appendix 1.3.3.

SA516-Grade 70 (Container)

SA516-70 is the specification for pressure vessel plates, carbon steel, intended for moderate and lower temperature service. The plates were purchased and certified to the 2001 version of the ASTM specification. Since the plates are over 1.5" thickness, the specification requires the plates to be normalized. Per the certified material test reports (CMTR's) (reference 2-18), the plates were all normalized at 1,650°F, as required. The mechanical properties are obtained from the specification and from ASME B&PV Code, II-D.

E_{516} = Young's Modulus	= 28.3×10^6 psi		[Ref. II-D Table TM-1]
	= 27.3×10^6 psi @ 250°F		[Ref. II-D Table TM-1]
	= 27.0×10^6 psi @ 300°F		[Ref. II-D Table TM-1]
Density	= 0.284 pci		[Ref. 2-16]
Yield Stress =	Sy = 38,000 psi @ 70°F		[Ref. II-D Table Y-1
	Sy = 35,700 psi @ 150°F		...page 544, Line 40]
	Sy = 34,800 psi @ 200°F		
	Sy = 31,000 psi @ 500°F	Sy = 27,200 psi @ 700°F	
	Sy = 29,100 psi @ 600°F	Sy = 24,700 psi @ 800°F	
Tensile Stress =	Su = 70,000 psi @ 70°F		[Ref. II-D Table U....
	Su = 70,000 psi @ 700°F		....page 464, line 29]
	Su = 69,100 psi @ 750°F		
	Su = 64,300 psi @ 800°F		
Elongation (2" Coupon) = 21%			[Ref 2-17, Table 2]
Expansion Coefficient	$\alpha = 8.5\times10^{-6}$ °F^{-1} @ 70°F		
	$\alpha = 8.9\times10^{-6}$ °F^{-1} @ 200°F		
	$\alpha = 9.2\times10^{-6}$ °F^{-1} @ 300°F		[Ref. II-DTable TE-1]

Material CMTRs for the ASME SA516-70 steel slabs show an average yield above 42 ksi, tensile above 76 ksi, and elongation at 25 percent.

Bolted Side Door Closure Bolts - ASME SA-193 Grade B7

Size	heavy hex, 1 ½-6UNC2A, by 8" long	
E_{bolt} = Young's Modulus	= $29.\times10^6$ psi	[Ref. II-D Table TM-1
	= 28.5×10^6 psi @ 200°F	...Group A data]
	= 23.9×10^6 psi @ 800°F	
Min. Yield Stress = Sy.b	= 105,000 psi @ 70°F	[Ref. II-D Table Y-1
	= 98,000 psi @ 200°F	... page 560, Line 21]
	= 88,500 psi @ 500°F	

Min. Tensile Stress = Su.b	= 125,000 psi	@ 70°F	[Ref. II-D Table U
	= 125,000 psi	@ 600°F	... page 470, Line 34]
	= 119,600 psi	@ 700°F	
Expansion Coefficient	$\alpha = 6.4\times10^{-6}$ °F^{-1}	@ 70°F	[Ref. II-D Table TE-1
	$\alpha = 6.8\times10^{-6}$ F^{-1}	@ 250°F	...Mat Grp 1]
	$\alpha = 7.8\times10^{-6}$ F^{-1}	@ 350°F	
Spec Minimum Elongation	= 16% elongation		[Ref. 2-8]
Minimum Reduction in Area	= 50%		[Ref. 2-8]

CMTR's (reference 2-18) show bolts are 140 ksi yield, 152 ksi tensile, 16% elongation.

Closure Bolts on 5 plugged openings - ASME SA-574

Size Socket Head Cap Screws, 5/16-18UNC3A, by 2.75" long and 3.75" long

E_{SH_bolt} = Young's Modulus	= $29.\times10^6$ psi		[Ref. II-D Table TM-1
	= 28.5×10^6 psi	@ 200°F	...Group A data]
	= 27.0×10^6 psi	@ 500°F	
	= 23.9×10^6 psi	@ 800°F	
Min. Yield Stress = Sy.b	= 140,500 psi	@ 70°F	[Ref. II-D Table Y-1]
	= 104,600 psi	@ 800°F	
Min. Tensile Stress = Su.b	= 180,000 psi	@ 70°F	[Ref. II-D Table U]
	= 155,000 psi	@ 800°F	
Expansion Coefficient	$\alpha = 6.4\times10^{-6}$ °F^{-1}	@ 70°F	[Ref. II-D Table TE-1
	$\alpha = 6.8\times10^{-6}$ F^{-1}	@ 250°F	...Mat Grp 1]
	$\alpha = 7.8\times10^{-6}$ F^{-1}	@ 350°F	
Spec Minimum Elongation	= 10% elongation		[See App 2.12.2]
Minimum Reduction in Area	= 30%		[See App 2.12.2]

Impact Limiter Tube Steel

See Appendix 2.12.2 for source material for material properties.

Specification	ASTM SA-500 Grade B or C
E_{tube} =	Young's Modulus = 29.4×10^6 psi
Density	ρ = 0.284 pci
Yield Stress =	Sy = 46,000 psi @ 70°F
Tensile Stress =	Su = 58,000 psi @ 70°F
Elongation (2" coupon)	= 21%
Expansion Coefficient	$\alpha = 8.5\times10^{-6}$ °F^{-1} @ 70°F

ASTM A36 Steel in Shock Absorbers, Retaining Pins, and 2"x9" Plates in IL

See Appendix 2.12.2 for source material for material properties.

Specification	ASTM A36	
E36 =	Young's Modulus	= 29.4×106 psi
Density	ρ = 0.284 pci	
Yield Stress =	Sy = 36,000 psi @ 70°F	
Tensile Stress =	Su = 58,000 psi @ 70°F	
Elongation (2" Coupon)	= 20%	
Expansion Coefficient	α = 8.5×10-6 °F-1 @ 70°F	

CMTR's (reference 2-18) show A36 plates at 42 ksi yield, 75 ksi tensile, 25% elongation.

Low Density Cellular Concrete

The void space between the melter and the container is filled with LDCC. The LDCC consists of Portland cement (per ASTM C150) mixed with foaming agents (in accordance with ASTM C869) to create the cellular structure. The concrete sand structure is per ASTM C33. This LDCC was developed by GeoScience Groups to a 28-day, target strength of 1,000 psi specification with target density of 70 lb/ft^3. The LDCC was poured in late 2013. Six samples were taken from each of the seven pours. The strength and density records from these tests are documented in Appendix 2.12.2. From these data, a lower-bound strength of the actual LDCC was determined and used in the analysis. The relation between this lower-bound used and the average strength recorded from the test cylinder exceeds the statistical requirements from ACI-349, thus the value used in the analysis is a valid lower bound value.

Lower bound 28 day strength = 1,203 psi [Analysis used 1,200 psi]

Average density for all LDCC poured = 69.9 lb/ft^3

LDCC, like any concrete will continue to strengthen with time, depending on available moisture. Per ACI-308, strength increases can be significant (25% increase) after 365 days. This effect is not credited in the analysis.

Energy Absorbing Foam-Fill of Impact Limiter

The 6" by 10" tube steel members of the IL are filled with rigid polyurethane foam. The basic strength and variability with static and dynamic crush distance is developed in Appendix 2.12.2. The data are summarized in Table 2-4 and shown graphically in Figure 2-3.

Table 2-4. Mechanical Properties of Foam

Temp = 10°F			Temp = 75°F			Temp = 125°F		
E_{elas_mod} = 41,800 psi			E_{elas_mod} = 34,800 psi			E_{elas_mod} = 27,000 psi		
Eng. Strain	True Plastic Strain	Stress (psi)	Eng. Strain	True Plastic Strain	Stress (psi)	Eng Strain	True Plastic Strain	Stress (psi)
5.8%	0	2462.	5.7%	0	1983.	5.6%	0.0	1504.
10%	0.046	2462.	10%	0.048	1983.	10%	0.050	1504.
20%	0.167	2338.	20%	0.168	1905.	20%	0.169	1474.
30%	0.299	2391.	30%	0.300	1964.	30%	0.299	1543.
40%	0.448	2624.	40%	0.449	2140.	40%	0.447	1721.
50%	0.620	3042.	50%	0.621	2528.	50%	0.619	2014.
60%	0.822	3948.	60%	0.821	3323.	60%	0.817	2685.
65%	0.954	4003.	65%	0.951	3443.	65%	0.947	2777.
70%	1.079	5204.	70%	1.070	4684.	70%	1.059	3923.
Coefficient of Linear Thermal Expansion (in/in/°F)				3.5-5.0 10^{-5} (-320°F to 200°F)				
Density (Free Rise) (lb/ft^3)				20				

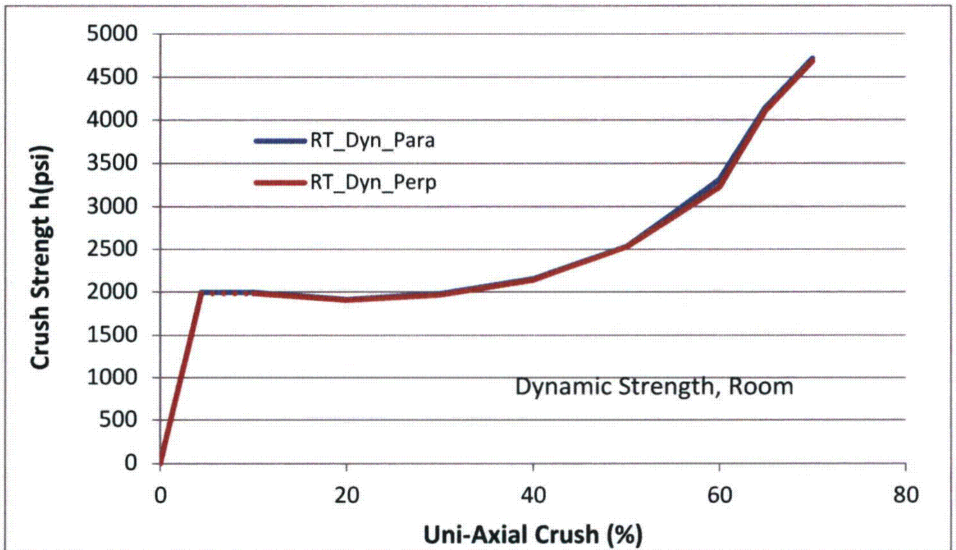


Figure 2-3. Dynamic Engineering Stress-Strain Curve for 20 lb/ft^3 Polyurethane Foam, Room Temperature

2.2.2 Chemical, Galvanic, or Other Reactions

Requirement: 10 CFR 71.43(d) – "A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents, including possible reaction resulting from in-leakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation."

Evaluation: The materials from which the WVMP is fabricated (carbon steel, LDCC, polyurethane foam) and the contents (stainless steel, Inconel, glass, refractory brick) will not have significant chemical, galvanic, or other reactions in air or water atmospheres. The foam insulation is chemically inert and carries no detectable chlorides. The closed-cell nature of the foam precludes water absorption.

2.2.3 Effects of Radiation on Materials

Requirement: 10 CFR 71.43(d) – "A package must be made of materials and construction that assure that there will be no significant chemical, galvanic, or other reaction among the packaging components, among package contents, or between the packaging components and the package contents, including possible reaction resulting from in-leakage of water, to the maximum credible extent. Account must be taken of the behavior of materials under irradiation."

Evaluation: For the steel structure and bolting, no degradation or activation of the carbon steel structural components is expected at the neutron and photon dose rates as calculated in Chapter 5.

Polyurethane foam will be used inside the 6" by 10" tube steel. Radiation dose experiments were performed at the University of Michigan on the General Plastics Manufacturing Company polyurethane foam and no effect was found on the compressive strength and intumescent properties from radiation doses of 2×10^7, 4.21×10^7 and 2×10^8 rads (reference 2-9).

2.3 Fabrication and Examination

The WVMP is constructed in accordance with the design drawings provided in Appendix 1.3.2 and Quality Assurance requirements of Chapter 1.

2.3.1 Fabrication

For a Type B, Category II package, NUREG/CR-3854 recommends using ASME B&PV Code, Section III, Subsection ND, as the fabrication criteria. The WVMP container was fabricated in accordance with American Welding Society (AWS) Structural Code D1.1 (reference 2-10). Comparisons between AWS D1.1 fabrication requirements and the additional requirements imposed during construction and ASME III-ND fabrication requirements are made in Chapter 8 to demonstrate equivalent safety for a one-time shipment. The fabrication for the IL construction is per ASME Code, Section III, Subsection NF, in accordance with NUREG/CR-3854, Table 4-1.

2.3.2 Examination

For a Type-B, Category II package, NUREG/CR-3854 recommends using ASME B&PV Code, Section III, Subsection ND, as the examination criteria. Examinations performed during fabrication of the GMP were accordance with AWS D1.1. Chapter 8 compares the combination of the AWS D1.1 examination requirements and the additional requirements imposed during construction (material certifications, heat treatments, and normalizations) to the ASME III-ND examination requirements to demonstrate equivalent safety for a one-time shipment. The examination for the IL construction is per ASME Code, Section III, Subsection NF, in accordance with NUREG/CR-3854, Table 4-1.

2.4 General Requirements for All Packages

10 CFR 71.43(a) through (c) and (e) through (h) establish the general standards for packages. This section identifies these standards and provides the basis to demonstrate compliance.

2.4.1 Minimum Package Size

Requirement: 10 CFR 71.43(a) – "The smallest overall dimension of a package shall not be less than 10 cm (4")."

Evaluation: The smallest overall dimension of the WVMP is 12' 6.5", which exceeds the 4" minimum. Therefore, the minimum package size requirement is satisfied.

2.4.2 Tamper-Indicating Feature

Requirement: 10 CFR 71.43(b) – "The outside of the package must incorporate a feature, such as a seal, that is not readily breakable and that, while intact, would be evident that the package has not been opened by unauthorized persons."

Evaluation: The outside of the WVMP is a welded structure consisting of 4" thick and 6" thick steel walls. The walls have five penetrations of 4.5" diameter, stepped to 6.5" diameter for the outer half of the plate thickness. After grouting, inspections and final closure, a matched stepped, circular plug is then secured with three recessed socket head cap screws, resulting in a flush continuous surface. Tamper indicating device tape is placed over each. The 2" by 9" plates of the IL are pinned and welded to the container integral corner shock absorbers and these plates block access to the side door bolts. Attempts to defeat the closure devices would require mechanical destruction of structural components. Therefore, the requirement of the tamper-indicating feature is satisfied.

2.4.3 Positive Closure

Requirement: 10 CFR 71.43(c) – "Each package must include a containment system securely closed by a positive fastening device that cannot be opened unintentionally or by a pressure that may arise within the package."

Evaluation: The container consists of five steel slabs fully welded together, with the sixth being a bolted side door for the container. The closure joint consists of a 4" wide gasketed (1/4" neoprene) face seal around the wall surface edges. The side walls also feature a step-design that allows the bolted side door to be inset into this step, so that a perimeter seal is formed between the 6" thick edge of the wall panel and the step feature on the side walls. This region is filled with RTV to create a seal. The 2" face of the IL's 2" by 9" plates are then welded over this wall panel joint to provide the positive closure. Per the evaluation in Appendix 2.12.2, the container is capable of sustaining worst case combinations of Maximum Normal Operating Pressure (MNOP) and reduced/increased external pressure as well as the HAC fire event. The demands on this seal joint are also evaluated during NCT and HAC drop impacts, to demonstrate closure performance (See Figure 2-3).

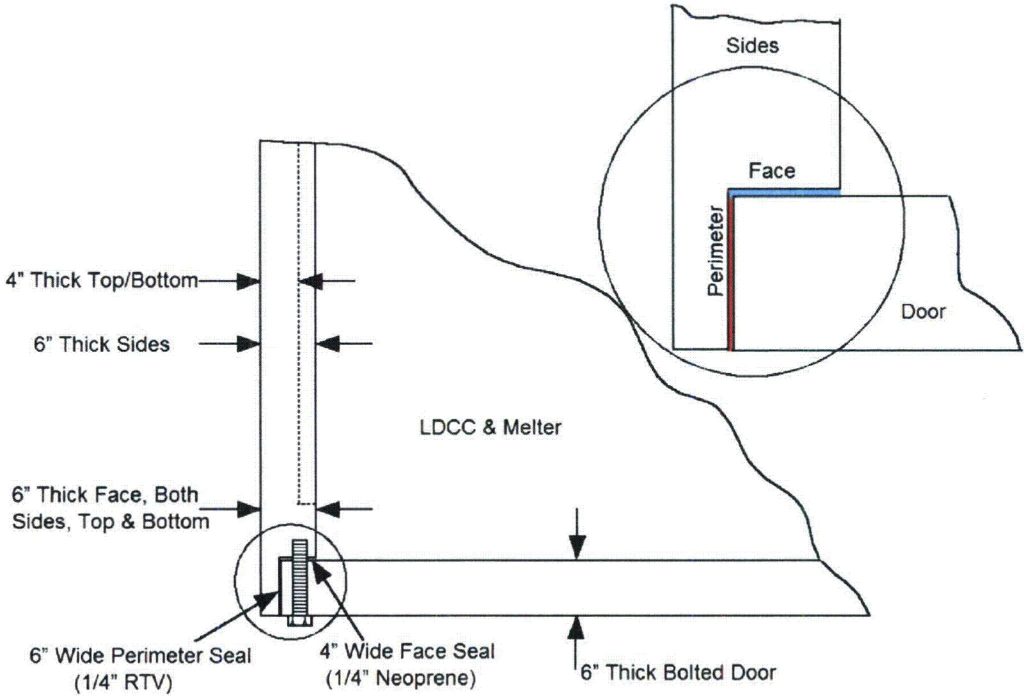


Figure 2-4. Schematic Showing Location and Naming Convention for Bolted Side Door Seal Closure

2.4.4 Package Valving

Requirement: 10 CFR 71.43(e) – "A package valve or other device, the failure of which would allow radioactive contents to escape, must be protected against unauthorized operation and, except for a pressure relief device, must be provided with an enclosure to retain any leakage."

Evaluation: The WVMP does not contain valves or other pressure relief devices. All containment penetrations made during fabrication have been closed. Therefore, the requirements of 10 CFR 71.43(e) have been satisfied.

2.4.5 Packaging Effectiveness

Requirement: 10 CFR 71.43(f) – "A package must be designed, constructed, and prepared for shipment so that under the tests specified in § 71.71 (*Normal Conditions of Transport*) there would be no loss or dispersal of radioactive contents, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging."

Evaluation: The WVMP is designed and shown through structural evaluation that under the NCT specified in 10 CFR 71.71 there is no unacceptable release of radioactive contents, no significant increase in external surface radiation levels, and hence, no significant reduction in the effectiveness of the packaging. Structural evaluation of NCT includes thermal effects, pressure effects, vibration and shock, water spray in-leakage, drop impacts, stacking compression, and penetration impact.

2.4.6 Transportation Use (Surface Temperature)

Requirement: 10 CFR 71.43(g) – "A package must be designed, constructed, and prepared for transport so that in still air at 38°C (100°F) and in the shade, no accessible surface of a package would have a temperature exceeding 50°C (122°F) in a nonexclusive use shipment, or 85°C (185°F) in an exclusive use shipment."

Evaluation: The WVMP is an exclusive use shipment, such that the 10 CFR 71.43(g) requirement is applicable, with a limit of 185°F. The Chapter 3 thermal analysis shows that the maximum temperature of the package under the 10 CFR 71.43(g) conditions is less than 110°F.

2.4.7 Continuous Package Venting

Requirement: 10 CFR 71.43(h) – "A package may not incorporate a feature intended to allow continuous venting during transport."

Evaluation: The WVMP does not incorporate any feature intended to allow continuous venting during transport.

2.5 Lifting and Tie-down Standards for All Packages

2.5.1 Lifting Devices

Requirement: 10 CFR 71.45(a) – "Any lifting attachment that is a structural part of a package must be designed with a minimum safety factor of three against yielding when used to lift the package in the intended manner, and it must be designed so that failure of any lifting device under excessive load would not impair the ability of the package to meet other requirements of this subpart. Any other structural part of the package that could be used to lift the package must be capable of being rendered inoperable for lifting the package during transport, or must be designed with strength equivalent to that required for lifting attachments."

Evaluation: The lifting device for the WVMP is not a structural element of the package and will be removed before transport. Therefore, the design of the lifting lugs was not evaluated in the application for package approval. The lug attachment location on the WVMP is evaluated in the tie-down section below. Each lug attachment location is shown capable of sustaining 1,494,000 lbs (nearly 4 times the WVMP weight), thus the attachment points are capable of sustaining more than 3 times the WVMP weight. There are no lift attachment points on the IL. The upper corner shock absorbers are not intended as lift attachment points, and have no designed attachment point. Although not intended to be used as lift points, the tie-down analysis section demonstrates a corner shock absorber capable of more than 1,500,000 lbs vertical load capacity, which exceeds the factor of three on weight. The railcar securement plates are not to be used for lifting and will be marked "Not for Lifting or Tie-down". Additionally, the front side impact limiter completely blocks access to the front side securement plates. Therefore, the criteria of 10 CFR 71.45 are met.

2.5.2 Tie-Down Devices

Requirement: 10 CFR 71.45(b)(1) – "If there is a system of tie-down devices that is a structural part of the package, the system must be capable of withstanding, without generating stress in any material of the package in excess of its yield strength, a static force applied to the center of gravity of the package having a vertical component of 2 times the weight of the package with its contents, a horizontal component along the direction in which the vehicle travels of 10 times the weight of the package with its contents, and a horizontal component in the transverse direction of five times the weight of the package with its contents."

10 CFR 71.45(b)(2) – "Any other structural part of the package that could be used to tie down the package must be capable of being rendered inoperable for tying down the package during transport, or must be designed with strength equivalent to that required for tie-down devices."

10 CFR 71.45(b)(3) – "Each tie-down device that is a structural part of a package must be designed so that failure of the device under excessive load would not impair the ability of the package to meet other requirements of this part."

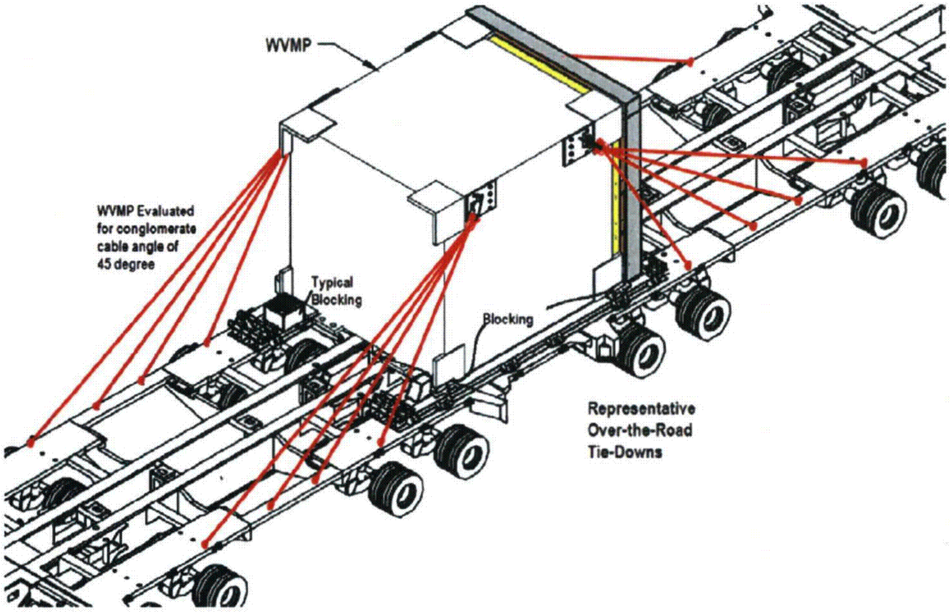
Evaluation:

The WVMP will be transported by a combination of an over the road heavy haul transport truck and a rail car. The WVMP does not have integrally designed tie-down devices, but it does have features that could serve as tie-down attachment points. The following analysis evaluates two modes of tie-down. The analysis condition for truck transport securement is by combination of shear blocks at the WVMP base and restraint cables attached near the top (See Figure 2-5). The analysis condition for railcar transport securement is that only lower positions of the WVMP are used for shear and hold-down.

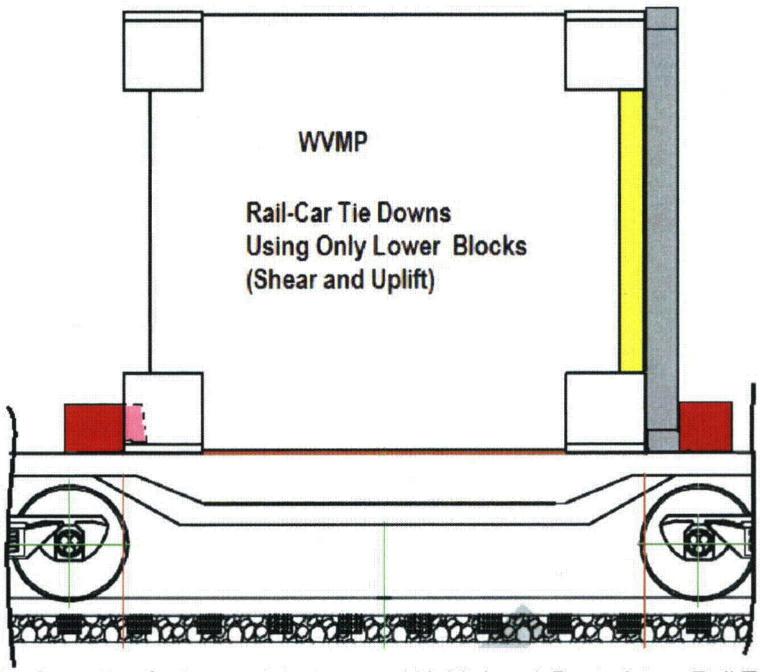
Restraint Loads – Heavy Haul Transport Truck

The heavy haul transporter is a specialized two-lane width carrier, sufficiently wide to accommodate the full foot print of the WVMP. Shear blocks are used at the base to resist lateral and longitudinal accelerations, and restraint cables are used to resist uplift, overturning and shear. There are four weld-on plates located at the top of the GMP side walls (See Figures 2-5 and 2-6) that could serve as tie-down points for cable attachment. The required forces at these locations are determined below. The restraint forces are determined by moment equilibrium about the front lower corner. Refer to Figure 2-6 for dimensions, terminology and tie-down structural details to work around and protect the impact limiter during shipment.

A summary of the tie-down assessments follows the figures.



Evaluation Configuration for Upper (cables) and Lower (blocking) Restraints – Road Transport



Evaluation Configuration for Lower (blocking and Hold-down) Restraints – Rail Transport

Figure 2-5. Configurations for Tie-Down Assessment

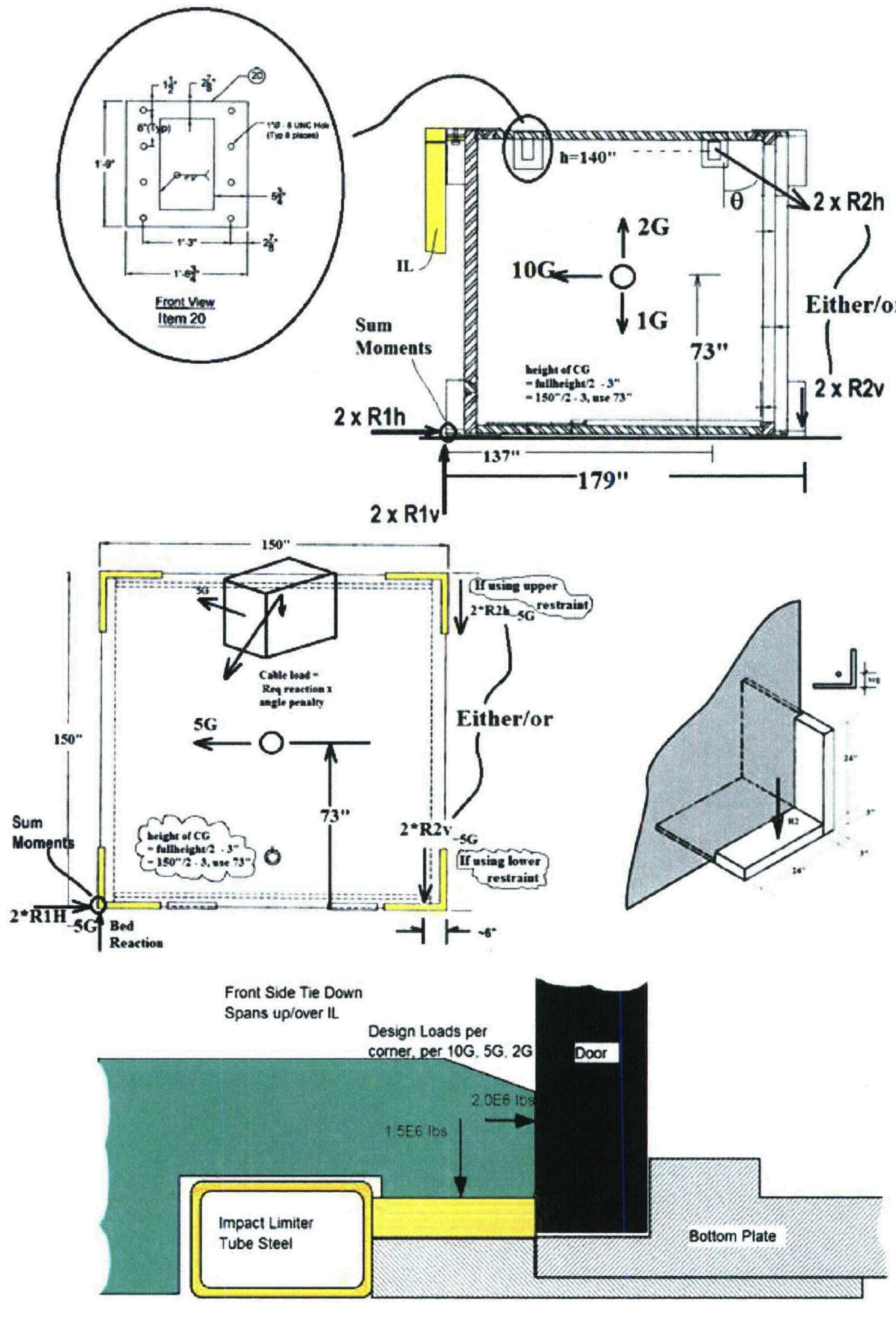


Figure 2-6. Sketches for Tie-Down Assessment

<u>Combined 10G Longitudinal and 2G Vertical and Dead Weight</u>

Define Terms:

Height to CG = Hcg = 73 inch, Height to Cable Connection =Htie = 140 inch,
Length_WVMP = 179 inch, Length, Pivot to Cable = L_cab = 137 inch
R1 = Reaction Forces on the Package Front Side (h=horizontal, v = vertical)
R2 = Reaction Forces on the Package Back Side (v = Vertical, h=cable direction load)

Sum moments about front corner of WVMP (See Figure 2-6)

Height to CG = Hcg = 73 inch, Height to Cable Connection =Htie = 140 inch,
Length_WVMP = 179 inch, Length, Pivot to Cable = L_cab = 137 inch
Motm = 10G x Hcg + 2G x Length_WVMP/2 = 10G x 73" + 2G x 179"/2 = 909 xG

Mres = 2x R2h x cos(θ) x L_cab + 2 x {R2h x sin(θ)} x Htie + 1G x Length_WVMP/2
Mres = 2x R2h x cos(θ) x 137" + 2 x {R2h x sin(θ)} x 140" + 1G * 179"/2
For cable angle $\theta \sim 45$ degree $\Rightarrow$ Mres = 2 x R2h x (sqrt(137^2+140^2)
Mres = 392 x R2h + 1G x 89.5"

Motm = Mres$\Rightarrow$ 392 x R2h + 1G x 89.5" =909 xG
R2h = 2.1G = 2.1 x 390,800 lbs
$\boxed{\textbf{R2h = 821,000 lbs}}$ (Cable pull, acting ~ 45 degree)
(Cartesian components are 580,500 lbs down, 580,500lbs longitudinal)

Sum Forces

Longitudinal: 2R1h + 2x R2h*sin(θ) = 10G
2R1h + 2x 580,500 lbs = 10*390,800 lbs
$\boxed{\textbf{R1h = 1,373,500 lbs}}$ <u>at two locations</u>

Vertical: 2 x R1v = -2G + 1G + 2x {R2h*cos(θ)}
2 x R1v = -1G + 2x {580,500 lb}
=- 390,800 lbs + 1,161,000 lbs
$\boxed{\textbf{R1v = 385,100 lbs}}$ <u>at two locations</u>

<u>Contribution from 5G Lateral (The subscript _5G) is added to the terms)</u>

The 5G lateral is treated separately, then added (superposition) to the 10G/2G case.

Sum moments about front corner of WVMP (See Figure 2-6)

WVMP Width = W = 150 in
Motm_5G = 5G x Hcg = 5G x 73 inch
Mres_5G = 2 x R2h_5G x cos(θ) x W = 1.414 x 150" x R2h_5G (for 45 degree sling angle)
Motm_5G = Mres_5G
5G x 73 inch = 1.414 x 150" x R2h_5G
R2h_5G = 5 x 390,800 lb x 73" /(1.414 * 150")
$\boxed{\textbf{R2h\_5G = 672,522 lb}}$

Sum Forces

Lateral: 2 x R1h_5G = 5G

2R1h_5G = 5*390,800 lbs

$\boxed{\textbf{R1h\_5G = 977,000 lbs}}$ at two locations at the base of the WVMP

Vertical: 2 x R1v_5G = 2x {R2h_5G x cos(θ)}

2 x R1v_5G = 2x {672,522 x 0.7071}

R1v_5G ={672,522 x 0.7071}

$\boxed{\textbf{R1v\_5G = 475,540 lb}}$

Total, 10G, 2G, 5G acting concurrently

Cable Load, Max = R2h_total = R2h_10G + R2h_5G = 821,000 lb +672,522 lb = 1,494,000 lbs
Lower Shear Block Loads_Longitudinal = R1h = 1,373,000 lbs, two corners
Lower Shear Block Loads_Lateral = R1h_5G = 977,000 lbs, two corners

Solution Check by Force Balance

Vertical ⇒ 2G accel – 1G grav = 2 x R2h x cos(θ) + 2 x R2h_5G x cos(θ) – 2 x R1v – 2 x R1v_5G

1G = 2 x 821,000 lbs x 0.7071 + 2 x 672,522 x 0.7071 – 2 x 385,100 lb – 2 x 475,540 lbs

390,800 lbs = 390,860 lbs Checks

Longitudinal ⇒ 10G = 2 x R2h x sin(θ) + 2 x R1h *(longitudinal cable forces from 5G case are offsetting)*

10x 390,800 lbs = 2 x 821,000 lbs * 0.7071 + 2 x 1,373,000 lbs

3,908,000 lb = 3,907,060 lb Checks

Lateral ⇒ 5G = 2 x R1h_5G

5x 390,800 lbs = 2 x 977,000 lbs

1,954,000 lb = 1,954,000 lb Checks

Restraint Loads – Rail Car

For railcar transport, width restrictions may prevent using cable connections along the side of the WVMP. The WVMP is analyzed based on using blocking and hold-downs only at the lower four corners. The extended plates of the eight corner shock absorbers are used for hold-down clamps, with clamps bridging over the impact limiter (Figure 2-6). The required forces at these locations are determined below. The restraint forces are determined by moment equilibrium about the front lower corner. Refer to Figure 2-6 for dimensions.

Combined 10G Longitudinal and 2G Vertical and Dead Weight

Sum Moments about Front Edge

Motm = 10G x Hcg + 2G x width /2 = 10G x 73" + 1G x 179"/2 = 909 xG

The clamp load is evaluated as if centered over the 9 inch extension (9"/2 = 4.5", use 5 inch).

Mres = 2 x R2v x (179"- 5") + 1G x width /2 =348 x R2v +1G x 89.5"

Motm = Mres⇒ 348xR2v + 1G x 89.5" =909xG⇒ 348xR2v =819.5xG

R2v = {819.5/348} x G = 2.355G = 2.355 x 390,800 lbs

$\boxed{\textbf{R2v = 920,300 lbs}}$

Sum Forces to determine other reaction loads

Longitudinal: 2xR1h = 10G

2x R1h = 10*390,800 lbs

$\boxed{\textbf{R1h = 1,954,000 lbs}}$

Vertical: 2 x R1v = -2G + 1G + 2x {R2v}
2 x R1v = -1G + 2x {920,300 lb}
=- 390,800 lbs + 1,840,600 lbs
R1v = 724,900 lbs at two locations

Contribution from 5G Lateral

The 5G lateral is treated separately, then added (superposition) to the 10G/2G case.

Sum moments about front corner of WVMP (See Figure 2-6)

WVMP Width = W = 150 in, Clamp force taken as centered 6 inch from edge

Motm_5G = 5G x Hcg = 5G x 73 inch

Mres_5G = 2 x R2v_5G x {W – 6"} = 2 x R2v_5G x {150" – 6"} = 288" x R2v_5G

Motm_5G = Mres_5G

5G x 73 inch = 288" x R2v_5G

R2v_5G = 5 x 390,800 lb x 73" /(288")

R2v_5G = 495,300 lb

Sum Forces for 5G Lateral

Lateral: 2 x R1h_5G = 5G
2 x R1h_5G = 5 x 390,800 lbs
R1h_5G = 977,000 lbs at two locations at the base of the WVMP

Vertical: 2 x R1v_5G = 2x {R2v_5G }
R1v_5G = 495,300 lb

Total, 10G, 2G, 5G acting concurrently

Hold-Down Load, Max = R2v_total = R2v_10G + R2v_5G = 920,300 lb +495,300 lb = 1,415,600 lbs
Lower Shear Block Loads_Longitudinal = R1h = 1,954,000 lbs, two corners
Lower Shear Block Loads_Lateral = R1h_5G = 977,000 lbs, two corners

Railcar Solution Check by Force Balance

Vertical ⇒ 2G accel – 1G grav = 2 x R2v + 2 x R2v_5G – 2 x R1v – 2 x R1v_5G
1G = 2 x 920,300 lbs + 2 x 495,300lb – 2 x 724,900 lb – 2 x 495,300 lbs
390,800 lbs = 390,800 lbs Checks

Longitudinal ⇒ 10G = 2 x R1h
10x 390,800 lbs = 2 x 1,954,000 lbs
3,908,000 lb = 3,908,000 lb Checks

Lateral ⇒ 5G = 2 x R1h_5G
5x 390,800 lbs = 2 x 977,000 lbs
1,954,000 lb = 1,954,000 lb Checks

Requirements (1) & (2) for Upper Restraint Location

The upper wall of the WVMP features four 1" thick plate, 21" tall and 20.75" wide, welded to the 6" thick container wall with 1/2" fillet weld, all around (Appendix 1.3.2). There is also a central cutout in the center of this plate (9.25" by 15.25"). This inner edge is welded to the container wall, using a 1" fillet weld. The plate has eight threaded holes. The intent of the threaded holes is to secure a lift lug plate or tie-down plate that has intimate contact with the square edged perimeter of the welded on plate, thus loading the plate in shear. Both the weld throat and base metal are checked. The shear yield is taken as 57 percent of tensile yield (bounds Mises, or Principal stress theory)

Check Weld Strength:

- E70 electrodes on carbon steel, Reference 2-16
- Weld Strength Yield: Per AWS D1.1:2010, Annex V, identical to AWS A5.1 (Reference 2-19)
    - Tensile Yield = 53 ksi (minimum for any type of E70XX)

      Shear Yield = 57% x 53 ksi = 30.2 ksi

Weld Throat Area: (Groove weld throat = size, fillet throat = 0.707 size)

Outer Welds: (2 x 20.75" + 2 x 21") x ½ groove = 41.7 in^2

Inner Welds: 2x (9.25"+15.25") x 1" fillet x 0.707 = 34 in^2

Total Load Capacity = 30,200 psi x (41.7 in^2 + 34 in^2) = 2.3E6 lbs

Check Base Metal Strength: (Groove weld base = size, fillet base = leg size)

- A516-70 container plates, Item #20 is A516-Grade 60
    - Yield = 32 ksi , Shear Yield = 57% of tensile = 18.2 ksi

Base Metal Area of Weld:

Outer Welds: (2 x 20.75" + 2 x 21") x ½" groove = 41.7 in^2

Inner Welds: 2x (9.25"+15.25") x 1" fillet = 49 in^2

Total Shear Load Capacity = 18,200 psi x (41.7 in^2 + 49 in^2) = 1.65E6 lbs

Demand: R2h_total = 1,494,000 lbs

vs 2.3E6 lbs weld throat capacity, 1.65E6 base metal capacity

The demand is less than the capacity; therefore, the CFR requirement is met for the sides plates at the upper end of the side walls (remnants from lift lug attachments). The upper shock absorbers are not intended to be used as tie-down devices and have no provisions for attachment. However, the analysis below demonstrates the lower shock absorbers can be used as tie-down devices, which also validates the upper shock absorber. The upper is structurally identical and subject to less demand (R2v is less than R2h). Therefore, the CFR requirement is met for these components.

Requirements (1) and (2) for Lower Restraint Location

The corner shock absorbers of the container extend outward from the main structure, and could be used as a tie-down location, using an external structure that presses onto the surface of this extension, or presses onto the 2" by 9" plate of the IL, which then presses down onto the shock absorber surface. The 2" by 9" plate helps distribute the load, thus is beneficial, such that a bounding calculation need only consider the integrity of the shock absorber. The shock absorbers are evaluated for bending and shear loads from the required reaction for to resists the 10 CFR 71.45 loads.

Cross-Sectional Area = 3" x (24" + 27") = 153 in^2

Cross-Section Centroid: $x_{cg} = \dfrac{3''\cdot 27''\cdot 1.5''+3''\cdot 24''\cdot(3''+24''/2)}{153in^2} = 7.85in$

Moment of Inertia:

$$I = 3"\cdot 27"\cdot(7.85"-1.5")^2 + \frac{1}{12}\cdot 3"\cdot 24"^3 + 3"\cdot 24"\cdot(3"+24/2-7.85)^2 = 10{,}403 in^4$$

Section Modulus: I / (27in-7.85in) = 543in^3

Weld Area = The 3" extension has 1" groove weld on inside surface, 1" continuous plate on the outside surface, so weld area is 2/3 of the plate area

Thus A_weld = 2/3 x 153 in^2 = A_weld = 102 in^2

Section Bending: Consider for acting the full 9" distance

Moment = R2v_total x 9" = 1,415,600 lbs x 9" = 12,740,400 in-lbs

Bending Stress = Moment/Section Mod = 12,740,400 in-lbs/543 in^3 = **23,463 psi**

Shear Stress:

$$\text{Shear Stress} = \tau_{shr} = \frac{R2v}{A\_weld} = \frac{1{,}415{,}600 lb}{102 in^2} = \underline{13{,}878 psi}$$

Combined, Effective Mises Stress (w/ simplifying basis that component stresses are orthogonal):

$$\sigma_{eff} = \frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + \tau_{shr}^2} = \frac{23{,}463}{2} + \sqrt{\left(\frac{23{,}463}{2}\right)^2 + 13{,}878^2} = 29{,}900 psi$$

The above stress for the factored load condition is only 83 percent of the A36 plate yield strength. Therefore, the CFR requirement is met.

<u>Lateral and Longitudinal Shear Loads</u>

The lateral (5G) and longitudinal (10G) loads are resisted mainly by shear blocks at the base of the WVMP. For the railcar securement condition, the shear blocks react 100% of the shear loads (discrediting friction). The maximum shear restraint load was R1h = 1,954,000 lbs, occurring in the 10G longitudinal direction. This was based on two shear blocks, one at each corner. For 36 ksi yield, the amount of compressive area necessary to react the 2 x 1.954E6 = 3.9E6 longitudinal load is:

Area = Load/Stress = 3.9E6 lbs/36,000 psi = 109 in^2 (total)

Each corner shock absorber has frontal area = (27"+24")x3" = 153 in^2,

306 in^2 total for two

Therefore, tie-down securement need only contact about 1/3 of the shock absorber front.

<u>Requirement (3)</u>

The upper plate is located at the upper edge, such that the loads would be transferred into the in-plane directions of the top plate or side wall. Therefore, simple area comparison confirms that the small 1" plate attached with ½" fillet welds and 1" fillet welds, when excessively loaded, would fail prior to the 6" and 4" thick steel walls of the WVMP. The HAC drop analysis demonstrates the shock absorbers can be excessively loaded (full plastic moment) without compromising the structure portion of the container walls. Therefore, the requirements of 10 CFR 71.45(b)(3) are met.

Rail Car Attachment Plates

The addition of the impact limiter on the WVMP front side renders the rail car attachment plates inaccessible as a tie-down attachment point. The corresponding plates on the back side will be marked "Not for Lifting or Tie-Down." These plates may be used as compression stops, as shown below.

Maximum Lateral Load = 10G = 3.9E6 lbs
Bearing Area = 21 inch length x 3 inch thick = 63 in^2
Number of plates = 2 per side
Stress = 3.9E6 lbs /(2 x 63in^2) = 31.0 ksi.

The above stress is less than the 32 ksi yield stress for the A516-60 plates (item 26 in drawing). The nine inch length of the plate renders a beam length short enough to alleviate elastic buckling concerns. The section radius of gyration = 25% x thickness, resulting in a buckling stress greater than the yield stress. Thus yield stress is limiting.

$$\sigma_{cr} = \frac{\pi^2 E}{(L/r)^2} = \frac{\pi^2 29.5E6psi}{(9''/0.75'')^2} >> Yield$$

2.6 Normal Conditions of Transport

This section demonstrates the WVMP demonstrates an equivalent level of safety with the performance requirements of 10 CFR 71.43(f) and 10 CFR 71.51(a)(1), (b) and (c) so that, when prepared for transport, under the test conditions specified in 10 CFR 71.71 *Normal Conditions of Transport (NCT)*, there is no loss or dispersal of radioactive contents (as demonstrated to a sensitivity of $10^{-6}A_2$ per hr), no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging.

A summary of the NCT analyses performed that demonstrate the WVMP meets equivalence levels of safety to 10 CFR 71 is provided in the following sections.

2.6.1 Heat

Requirement: 10 CFR 71.71(c)(1) – "Exposure to an ambient temperature of 100°F in still air, and insolation according to Table 2-5."

Table 2-5. Insolation Data

Form and location of surface		Total Insolation for a 12-hour period (g cal/cm^2)
Flat surfaces transported horizontally;		
	Base	None
	Other Surfaces	800
Flat surfaces not transported horizontally		200
Curved surfaces		400

Evaluation: The WVMP is analyzed for the 100°F environment with and without solar insolation (See Chapter 3). The internal heat load of 9.21 watts is also included in the analysis. The MNOP is established based on the resulting WVMP cavity temperatures.

2.6.1.1 Summary of Pressures and Temperatures

The WVMP MNOP and component temperatures under NCT are determined in Chapter 3 and summarized below.

NCT Maximum Normal Operating Pressure 12 psig [Ref. Ch 3, Table 3-3]

NCT Temperature with Solar

Container walls:	= 209°F max, occurs in extremes of corners	[Ref Ch 3, Figure 3-7]
	= 200°F through wall average	
	= 10°F, max through wall gradient	
LDCC:	= 183°F max, only at extreme top surface	[Ref Ch 3, Figure 3-7]
	= < 150°F average temperature	
Melter:	= 145°F	[Ref Ch 3, Table 3-5]

NCT Temperature without Solar, in 100°F Conditions

The thermal analysis shows the maximum temperature increase anywhere in the WVMP is 5°F above the ambient condition (100°F).

2.6.1.2 Differential Thermal Expansion

The only significant temperature changes occur under the solar insolation condition. In this condition, the container sees the greatest temperature rise. Since this is the outermost component of the WVMP, its bulk thermal expansion is not a stress increase. The only significant stress occurs due to the relatively high temperature increase in the container top plate, which heats to an effective average of 200°F, whereas the upper portions of the side walls are only 160°F. Stresses from this differential expansion are shown in the next subsection.

2.6.1.3 Stress Calculations

Pressure Stresses

Appendix 2.12.2 computes the stress in the WVMP container walls from the combined MNOP and worst case reduced/increased external pressure. The resulting pressure demand (12 psi + 11.2 psi = 23.2 psi) was shown to result in a 5,000 psi stress on the container top plate (4" thick).

Thermal Stresses

Considering the plate to act as a beam with ends fixed by the side walls, the maximum thermal stress developed as the thermal expansion ($\alpha\Delta TL$) is converted into strain ($\varepsilon = \alpha\Delta TL / L$) and then into stress, given by the equation below:

$$\sigma = E\alpha\Delta T = (29.0e6psi) * 8.5e-6 * (200 - 160^{\circ}F) = 9{,}900psi$$

Combined

Stresses from pressure loadings and thermal loads were computed in Appendix 2.12.2 resulting in the following values:

Pm = insignificant, the flat plate resists pressure load via bending
Pm + Pb = 5,000 psi [Ref App 2.12.2]
Sm = 9,900 psi [Section 2.6.1.3]
Pm + Pb + Sm = 14,900 psi

Closure Bolt Stress

Pressure load on side door = 12 psi × 144" × 144" = ~250,000 lbs
Number of bolts = N = 32
Load per bolt: = Total/N = 7,813 lb
Load Capacity for Bolt = Appendix 2.12.2, Accounting for thread shear, tensile failure, etc.
2/3 of the yield Load = 2/3 × 136,700 lbs = 91,100 lbs

2.6.1.4 Comparison with Allowable Stresses

Allowable stresses are based on the 200°F through wall average temperature. The allowable stresses are derived in Appendix 2.12.2 and summarized below for the ASME SA516-70 steel structure:

$$P_m \leq S_m = 23{,}200\,psi$$
$$P_{m+b} \leq 150\% P_{m=} = 34{,}800\,psi$$
$$P_L \leq 150\% P_{m=}$$
Secondary (includes thermal) < 3Sm = 69,600 psi

The comparison is shown in Table 2-6.

Table 2-6. Comparison of Stresses with Allowables, NCT Condition

	ASME Designation	Stress	Allowable	Comparison Stress/Allowable
Primary Membrane	P_m	~	23,200 psi	~
Primary Membrane + Bending	$P_L + P_b$	5,000 psi	34,800 psi	14%
Secondary	S_{m+b}	9,900 psi	~	~
Primary plus Secondary	$P_{L+b} + S_{m+b}$	14,900 psi	69,600 psi	21%
Bolts	~	Load = 7,813 lbs	91,100 lbs	8.5%

2.6.2 Cold

Requirement: 10 CFR 71.71(c)(2) *Cold* – "An ambient temperature of -40°C (-40°F) in still air and shade."

Evaluation: Per Appendix 2.12.2, the minimum temperature in which the package can be transported has been set to a minimum of 3°F lowest service temperature (LST).

LST = 3°F

The determination of the above is documented in section 5.3 of Appendix 2.12.2, and is based on the guidance in NUREG/CR-1815, *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick* (reference 2-11) and NUREG/CR-3826, *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Greater than Four Inches Thick* (reference 2-12), and the rules of ASME VIII-2 and API-579, *Fitness-for-Service* (reference 2-13). Although ASTM SA516-70 is intended for moderate and low temperature applications, the 3°F LST is set to protect from low temperature embrittlement.

Other components in the WVMP include the type 304L austenitic stainless steel and Inconel 690 within the melter. As stated in RG 7.11, stainless steel is effective at low temperatures, particularly regarding impact strength, making it a proper selection for -40°F applications. The structural properties of items like the LDCC do not vary significantly for the temperature range of the WVMP.

2.6.3 Reduced External Pressure

Requirement: 10 CFR 71.71(c)(3) *Reduced external pressure* – "An external pressure of 25 kPa (3.5 lbf/in^2) absolute."

Evaluation: The reduced external pressure condition is equivalent to an increase in internal pressure. The reduced external pressure load was evaluated in Appendix 2.12.2. The resulting pressure effect was already added to the MNOP analysis presented subsection 2.6.1.1.

2.6.4 Increased External Pressure

Requirement: 10 CFR 71.71(c)(4) *Increased external pressure* – "An external pressure of 140 kPa (20 lbf/in^2) absolute."

Evaluation: The increased external pressure condition was evaluated in Appendix 2.12.2. This pressure condition was shown to be bounded by the combined MNOP and reduced external pressure condition. The resulting pressure effect was already added to the MNOP analysis presented subsection 2.6.1.1.

An increased external pressure will have no adverse effect on the ability of the packaging to satisfy the requirements of NCT.

2.6.5 Vibration

Requirement: 10 CFR 71.71(c)(5) – "Vibration normally incident to transportation."

Evaluation: An analysis of random vibrations reported in Appendix 2.12.2 demonstrates that vibration and shock loadings are small and would not cause any fatigue concerns or bolt loosening during normal transport (Appendix 2.12.2).

Based on the Appendix 2.12.2 analysis, vibration normally incident to transportation will have no adverse effect on the ability of the packaging to satisfy the requirements of NCT.

2.6.6 Water Spray

Requirement: "The package design is evaluated for the effects of water spray of approximately 2in/hour for at least one hour as required by 10 CFR 71.71(c)(6)."

Evaluation: The package exterior is constructed of steel with no openings and water spray would have no effect.

2.6.7 Free Drop

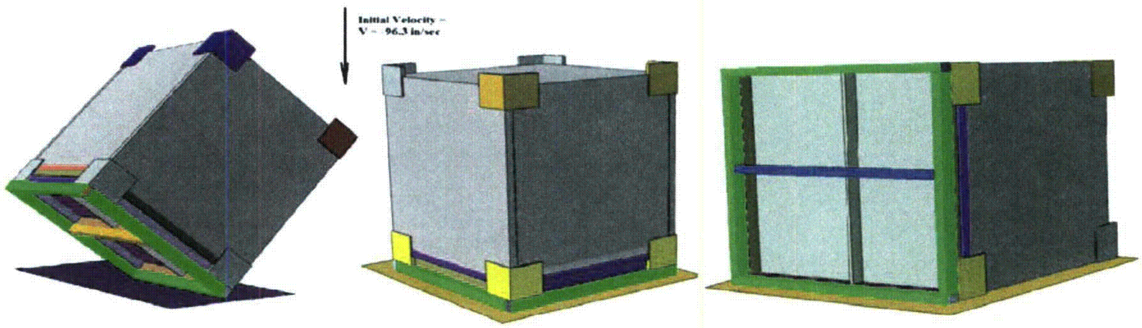
Requirement: 10 CFR 71.71(c)(7) – *Free drop*. "Between 1.5 and 2.5 hours after the conclusion of the water spray test, a free drop through the distance of 1' (for packages weighing more than 11,000 lbs) onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected."

Evaluation: The WVMP is evaluated for the 1' free drop by analytical simulations using the ABAQUS/Explicit dynamics computer code. Three drop orientations were simulated for NCT, as well as tip-over and slap-down. These are:

- CG over edge (expected to maximize IL deformation),
- Bolted side door down (to challenge the IL's protection of the bolted side door), and
- Bottom down (reflective of most probable NCT drop).

  (Left or right side down drop, which is structurally same as bottom down)

Figure 2-7 shows these drop orientations.



CG over Edge　　　Bolted Side Door Down　　　Bottom Down

Figure 2-7. Drop Orientations Evaluated in NCT

The analysis and results are documented in Appendix 2.12.2 with a summary of bounding drops presented below in Table 2-7.

Table 2-7. Results for NCT Drop Analysis

Position	G-Level	Limiter Deformation	LDCC Damage	Door Bolts	Door Seal Status
CG over edge	5.0 G	Minor denting on lowermost tube steel	< 0.005%	D/A = 50% (note 1)	Maintained
Bolted side door down	49 G	Insignificant	0.06%	D/A = 96%	Maintained
Bottom down	76 G	None	0.05%	D/A at 100% D/C = 73%	Maintained

Note: (1) D/A = Demand/Allowable, D/C = Demand to Capacity

The analysis shows that the bolted side door closure seal remains intact and undisturbed, the closure bolts do not fail, and the LDCC damage is inconsequential (0.06%). The IL is shown to eliminate any concerns associated with the bolted side door during NCT. With the IL, the most demanding drops on the LDCC are orientations targeting the non-limiter sides, such as bottom drops, or side wall drops. Even in these bounding cases, the LDCC damage is inconsequential. Figure 2-8 shows the finite element analysis (FEA) simulation results from the CG over front corner, which represented the most damage to the IL. As shown, the damage level is low, such that its performance in subsequent HAC would be unaffected.

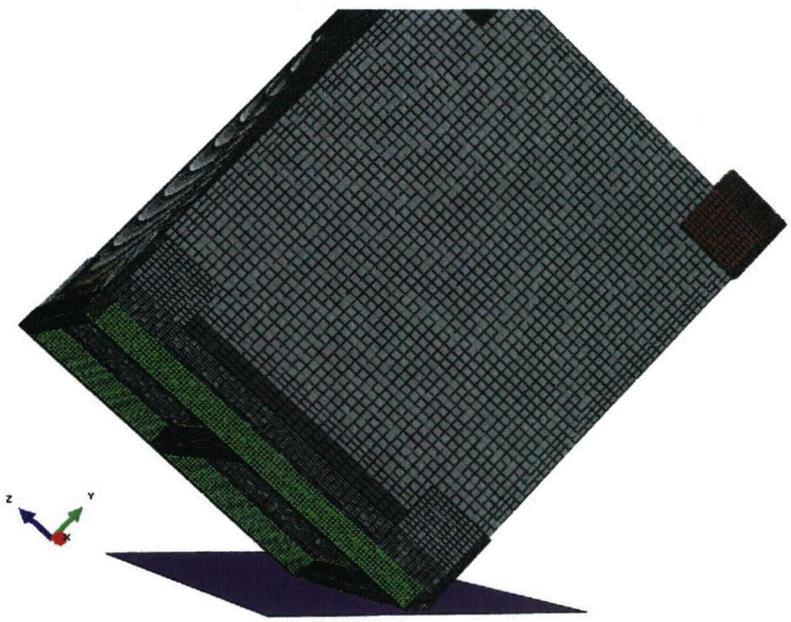


Figure 2-8. Deformed Shapes of WVMP from NCT 1 foot Drop, CG over Front Corner

2.6.8 Corner Drop

Requirement: 10 CFR 71.71(c)(8) – *Corner Drop*. "A free drop onto each corner of the package in succession, or in the case of a cylindrical package onto each quarter of each rim, from a height of 0.3 m (1') onto a flat, essentially unyielding, horizontal surface. This test applies only to fiberboard, wood, or fissile material rectangular packages not exceeding 50 kg (110 lbs) and fiberboard, wood, or fissile material cylindrical packages not exceeding 100 kg (220 lbs)."

Evaluation: The requirement is not applicable, since the WVMP is a rectangular package exceeding 50 kg and is not a fiberboard, wood, or fissile material cylindrical package.

2.6.9 Compression

Requirement: 10 CFR 71.71(c)(9) – *Compression*. "For packages weighing up to 5,000 kg (11,000 lbs), the package must be subjected, for a period of 24 hours, to a compressive load applied uniformly to the top and bottom of the package in the position in which the package would normally be transported. The compressive load must be the greater of the following:

(i) The equivalent of 5 times the weight of the package; or

(ii) The equivalent of 13 kPa (2 lbf/in^2) multiplied by the vertically projected area of the package."

Evaluation: The requirement is not applicable, since the WVMP weight of 390,800 lbs exceeds the 11,000 lb criterion.

2.6.10 Penetration

Requirement: 10 CFR 71.71(c)(10) – *Penetration*. "Impact of the hemispherical end of a vertical steel cylinder of 3.2 cm (1.25") diameter and 6 kg (13 lbs) mass, dropped from a height of 1 m (40") onto the exposed surface of the package that is expected to be most vulnerable to puncture. The long axis of the cylinder must be perpendicular to the package surface."

Evaluation: The WVMP would be unaffected by this threat and is bounded by the successful puncture analysis.

2.7 Hypothetical Accident Conditions

This section demonstrates that the WVMP satisfies the performance requirements of 10 CFR 71.51(a)(2) when subjected to the HAC as defined in 10 CFR 71.73. Equivalent level of safety is demonstrated by analysis, as allowed by 10CFR 71.41(a) and Regulatory Guide 7.6. The HAC include:

(1) Free drop - a free drop of 30 feet onto a flat, essentially unyielding surface,

(2) Crush – not applicable,

(3) Puncture - a free drop through a distance of 40", striking a bar 6" in diameter,

(4) Thermal - exposure to an environment of 1475°F for 30 minutes,

(5) Immersion (fissile material) – not applicable, and

(6) Immersion (all) - immersion in water of an undamaged package to a minimum depth of 50 feet for at least 8 hours.

2.7.1 Free Drop

Requirement: 10 CFR 71.73 (c)(7) – *Free Drop*. "A free drop of the specimen through a distance of 9 m (30') onto a flat, essentially unyielding, horizontal surface, striking the surface in a position for which maximum damage is expected."

Evaluation: An equivalent level of safety is demonstrated through dynamic FEA as described in the following sections. A total of seven package orientations were evaluated and documented in the Appendix 2.12.2 calculations. The seven orientations were each chosen to maximize demands on different components (e.g., WVMP structure, vs. LDCC, vs. IL). The worst case drop orientation was the CG over side edge (Figure 2-9).

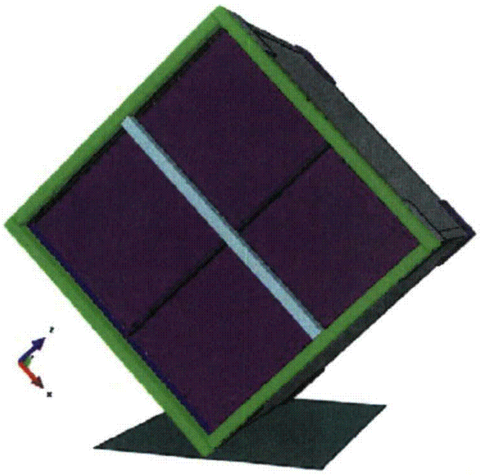


Figure 2.9. HAC Condition, 30 foot Drop, CG over Side Edge

The HAC drops are severe enough to fail the closure bolts in nearly all cases. The exceptions are for orientations that have the bolted side door tilted either upward, downward, or normal to the impact surface (side drops). The results produced the following general trends:

- The WVMP survives the HAC drops without appreciable deformation or material strains. The most localized damage to the container walls occurred in the CG over corner, where the corner experienced high compression. The most general deformation occurred in the CG over side edge, where the impact causes pressure loads on the two adjacent walls, thus bending in the corner joint. The maximum strains of 10% were within the material and weld-joint capacity.
- The closure bolts fail in most drops, exceptions being impacts onto flat sides.
- An inverse relation was shown between LDCC crush and door seal deformation. The high G impact drops that damaged the largest percentage of LDCC came from side-down impacts and back-side down impacts. These drop scenarios were associated with lower demands on the bolted side door seal joint. Orientations that challenged the bolted side door seal were the front corner drops (on edge or corner). These drops were associated with minimal LDCC damage, as the IL was effective in reducing the impact G-level.

For the 30 foot drops that resulted in bolted side door seal displacements, the maximum LDCC crush was 30%. The side drops produced 35% LDCC crush, but no displacement of the face seal. The displacements of the face seal and perimeter seal joints were tracked throughout the seven HAC drops, before, during and after, to demonstrate the integrity of the joint in each case (See Appendix 2.12.2). The results of the HAC drop simulations are summarized in the following sections.

2.7.1.1 End Drop

The end drop simulated was with the bolted side door oriented down. With the IL in place, the bolted side door seal sees very little to no tensile demands. The inertial pressures of the contents are transferred directly to the 2" by 9" plate, which is cushioned by the foam filled tube steel.

Impact G-Level = 97.5 G

Deformation of WVMP: insignificant

Maximum Strains in WVMP container walls <10%

Condition of bolts: most fail, but due to shear from wall bending, not bolt tension

LDCC damage = 5.5%

Bolted side door seal displacements: face seal = 0.18"
perimeter seal = 0.10"

2.7.1.2 Side Drop

The side drops represented the highest G-load, highest LDCC crush, but the smallest bolted side door seal displacement. The 6" walls of the container are able to resist the high G loads, and there was no significant displacement of the bolted side door face seal joint. The lower most plate of the container does bend in a transient manner at impact (the one inch thick shock absorbers elevate the center region of the WVMP above the impacted surface). This bending does result in a small displacement of the perimeter seal. However, the face seal is not impacted.

Impact G-level = 546 G

Deformation of WVMP: insignificant

Maximum strains in WVMP walls < 10%

Condition of bolts: only a few fail

LDCC damage = 35%

Bolted side door seal displacements: Face Seal = ~0"
Perimeter Seal = 0.33" (only on the bottom side – see Appendix 2.12.2)

2.7.1.3 Corner Drop

The corner drop of interest was the drop onto one of the corners at the bolted side door joint. The eight shock absorbers were specifically designed to limit the impact damage in this drop condition. The effectiveness is shown in the Appendix 2.12.2 results, where the impact G-level was held to a relatively low 53 G. This drop also resulted in a low fraction of LDCC damage, at 11%. Complete results are shown in Appendix 2.12.2, and a summary is shown below:

Impact G-Level = 53 G

Deformation of WVMP: Some failure of the lowermost shock absorber, slight compression of the container corner, limited to the 2" thick face seal extension surrounding the bolted side door.

Maximum strains in WVMP Walls: <30%

Condition of bolts: Nearly all bolts fail

LDCC damage = 11%

Bolted side door seal displacements: face seal = 1.5"
perimeter seal = 3.2"

2.7.1.4 Oblique Drop

Several oblique drops were investigated, as shown below. These orientations all involved positioning the CG over one of the edges. The goal was to maximize demand on the bolted side door closure and the LDCC.

- CG over side edge,
- Inverted with top side down, CG over top front edge,
- CG over back edge, and
- CG over front bottom edge

The most damaging impact orientation is with the CG over a side edge. This impact caused the largest displacements at the seal joints coupled with higher levels of LDCC crush.

Impact G-Level = 47G to 137G

Deformation of WVMP: Essentially zero for drops over front or back edges, where the shock absorbers and front IL are effective. In the CG over side edge impact, the two sides that meet the impacted edge will have a transient deflection.

Maximum strains in WVMP walls: 32% localized, exceeds local strain limit, but only in outer edge of corner joint, in 2 inch plate extensions, does not alter release opening path, since this area is constrained by the corner bumper. Strains are, <10% general bending, which is within allowable.

Condition of bolts: Nearly all bolts fail.

LDCC damage = 7% to 10% for front back edges, 21% for top down any edge, 30% for side edge

Bolted side door seal displacements: face seal = 1.2"
perimeter seal = 5.8"

Condition of Welds: The oblique drops represented bounding weld joint demands. The appendix 2.12.2 calculations shows some failure of the groove weld along the inside weld seam, for a span less than 5 feet, starting at the bolted door side of the weld joint. The groove welds along the outside edge does not indicate failure, thus the door gaps stated above represent the significant leak path, and no gross failure of the WVMP steel walls occurs during the HAC impacts.

2.7.1.5 Summary of Results

The results of the various analyses of free drop test may be summarized as follow:

- End drop: Insignificant deformation of WVMP, most bolts fail due to wall bending, 5.5% LDCC damage, minor face and perimeter seal displacement;
- Side drop: Insignificant deformation of WVMP, a few bolts fail, 35% LDCC damage, no face seal displacement, and minor perimeter seal displacement;
- Corner drop: Minor damage to lowermost shock absorber and slight compression of container corner, nearly all bolts fail, 11% LDCC damage, minor face and perimeter seal displacement; and
- Oblique drop: In limiting orientation (CG over side edge), maximum strain in WVMP walls of 31% (localized failure) and <11% general bending, nearly all bolts fail, up to 30% LDCC damage, and minor face and perimeter seal displacement.

The analyses show the WVMP meets the requirements.

2.7.2 Crush

Requirement: 10 CFR 71.73(c)(2) – *Crush*. "Subjection of the specimen to a dynamic crush test by positioning the specimen on a flat, essentially unyielding horizontal surface so as to suffer maximum damage by the drop of a 1,100-lb mass from 30' onto the specimen. The mass must consist of a solid mild steel plate 40" square and must fall in a horizontal attitude. The crush test is required only when the specimen has a mass not greater than 1,100 lb, an overall density not greater than 62.4 lb/ft^3 based on external dimension, and radioactive contents greater than 1000 A_2 not as special form radioactive material. For packages containing fissile material, the radioactive contents greater than 1000 A_2 criterion does not apply."

Evaluation: The 10 CFR 71.73(c)(2) crush test is not applicable to the WVMP, which exceeds the 1,100 lb limit, has an overall density greater than 62.4 lb/ft^3, and radioactive content less than 1,000 A_2.

2.7.3 Puncture

Requirement: 10 CFR 71.73(c)(3) – *Puncture*. "A free drop of the specimen through a distance of 40" in a position for which maximum damage is expected, onto the upper end of a solid, vertical, cylindrical, mild steel bar mounted on an essentially unyielding, horizontal surface. The bar must be 6" in diameter, with the top horizontal and its edge rounded to a radius of not more than 0.25" and of a length as to cause maximum damage to the package, but not less than 8" long. The long axis of the bar must be vertical."

Evaluation: The WVMP is evaluated for puncture by combination of explicit FEA and supporting engineering calculations in order to demonstrate that sequential HAC puncture test will not adversely affect the performance of the package before being subjected to thermal testing.

Three bounding puncture locations are assessed:

1. Puncture bar targeting near the bottom front edge of the container, to maximize damage at the bolted side door joint.
2. Puncture bar targeting the IL, to attempt to shear off the IL. After the HAC 30 foot drops, the IL is the only creditable structure maintaining position of the bolted side door.
3. Puncture bar targeting the center region of the container bottom.

Figure 2-10 shows these puncture locations.

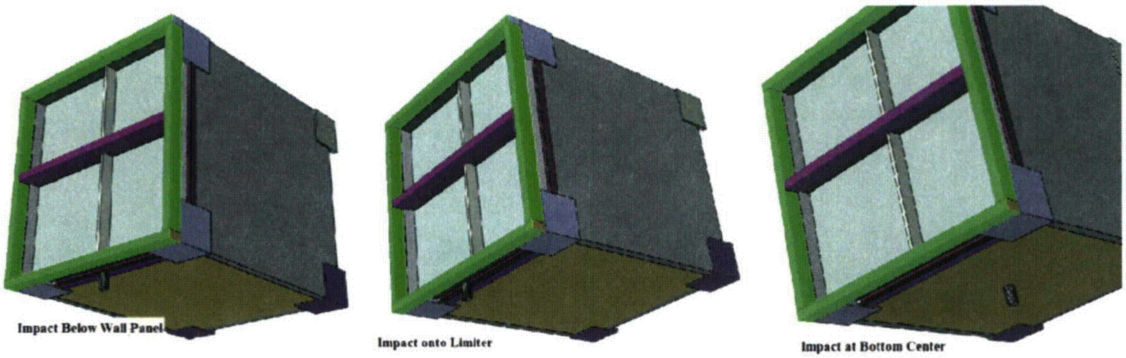


Figure 2-10. Puncture Analysis Orientations

General Assessment

In the puncture tests, a mild steel bar of 6" diameter is specified. The bar length must not be less than 8". Relative to the 390,800 lbs WVMP with 4" and 6" thick walls, it can be shown that the mild steel bar does not have sufficient strength or size to challenge the WVMP.

Mild steel bars range in yields strengths from 20 ksi (for example ASTM A1008) to 50 ksi (for example ASTM A500 Grade C), with the more common ASTM A36 having an intermediate value. The ultimate strength for mild steel has less variance, with ASTM specification minimums being 58 ksi to 80 ksi for structural steels (A36, A500, A1008, for example). For an upper bound, ASTM A36 imposes an upper strength limit of 80 ksi. Therefore, the maximum stiffness and force that can be imposed during the puncture is that of the shortest length bar (8" for the 10 CFR 71.73 requirement) with the highest material strength:

$$K = \frac{EA}{L} = \frac{29E6psi \cdot (\pi/4)*(6in)^2}{8inch} = 103{,}000{,}000in - lb$$

$$F_{\max} = \sigma_{flow} * A = 80{,}000psi*(\pi/4)*(6in)^2 = 2.3E6lbs$$

With the maximum impact force being limited to around 2.3 E+6 lbs, the maximum G-level of the WVMP during the puncture tests is limited to:

$$G_{\max} = {F_{\max}}/{Wgt} = {2.3E6lbs}/{390{,}800lbs} = 5.9G$$

By comparison, the HAC 30 foot drop simulations showed that the WVMP could sustain G-levels ranging from 50 G to 550 G, without significant damage to the WVMP container. The NCT 1' drops showed impact G levels in the 5 G range resulting in essentially no structural damage and no LDCC crush.

WVMP Plate Steel Puncture (Shear) vs WVMP Plate Bending vs. Puncture Bar Crush

If the WVMP wall thickness is sufficient to preclude penetration, then the structural response is limited to either bending (and compression) of the WVMP walls or plastic collapse of the puncture bar.

The Nelm's Equation (reference 2-14) predicts the required plate thickness (t_{req}) to prevent penetration from the puncture bar. The equation is based on the weight (Wgt) of the component dropped and the ultimate strength (S_u) of the steel.

$$t_{req} = \left({Wgt}/{S_u}\right)^{0.7} = \left({390{,}800}/{70{,}000}\right)^{0.7} = 3.33inch$$

vs. 4" available thinnest plate of WVMP.

The above equation does not incorporate the relative strength of the bar, and is overly conservative for high weight packages and mild steel puncture bars. Even with that conservatism, the analysis still shows the 4" plate thickness is sufficient to preclude penetration or puncture by the bar. From a qualitative standpoint, the above comparison does not suggest that the penetration would be (3.33"/4") but that the 4" thickness is sufficient to preclude penetration. The subsequent FEA indicates zero penetration.

Puncture Strike to WVMP Bottom below Bolted Side Door

In this orientation, the impact is resisted by the in-plane strength of the container. Any door gaps existing from the prior 30' drops would have the tendency to be closed by the impact with the puncture bar. The three possible puncture responses are discussed below:

- WVMP shear: as shown, the 4" plate thickness is sufficient to preclude penetration,
- WVMP bending: with the bar targeting near the container, the high in-plane stiffness would preclude any bending response.
- Bar crush: Due to the sufficient shear and bending resistance, this scenario would resolve itself into crush of the puncture bar, and the WVMP would experience a less than 6 G impact. Based on comparison to the HAC drops, no additional damage would occur at this low impact level. This impact level is similar to the NCT events, which showed no damage. Therefore, this puncture impact would not result in damage that would alter its thermal performance. Since the WVMP response would be of near-zero deformation and extremely low G value, no additional LDCC damage would occur. Therefore, this puncture is not considered further.

Puncture Strike onto the Impact Limiter

The IL is external to the GMP and was not credited in the HAC fire thermal analysis. Penetration or perforation of a local region of the IL, which sequentially occurs after the drop and crush, is not of a structural concern. There are six 2" by 9" by approximately 12' long structural plate sections comprising the structural part of the IL. After the HAC drops, the puncture test could eliminate, at most, one of the six members. The remaining five members would still be nestled within the container shock absorbers and provide the necessary displacement control on the bolted side door. Therefore, this puncture is not considered further.

Puncture Strike at Center of any Wall Panel

The two prior puncture target locations demonstrate targeting the container hard points or the IL will not challenge the structural steel integrity, impose additional damage to the LDCC, nor jeopardize its configuration for the pending thermal tests. The last remaining scenario is to target the center of a container wall, to impart a bending response to the plate steel. As demonstrated in the HAC drops, the LDCC is most vulnerable to loads that cause diaphragm bending of a wall panel, since the non-ductile LDCC cannot respond without damage.

Puncture Simulation Results

The analysis shows that the initial response to the puncture simulation is bending of the target wall surface. As the wall bends, it stiffens, not only due to its own response but due to compression of the adjacent LDCC. At time = 0.024 seconds into the impact, the WVMP deformation ceases to accumulate as the upper credibility strength of the 6" mild steel bar is surpassed. This is confirmed by comparing the deformed shape of the WVMP at time = 0.024 seconds (Figure 2-13) and at time = 0.06 second (Figure 2-14), both plots showing 4.2" of plate deformation. The energy history plot (Figure 2-11) shows less than 10G (matching the estimate on previous page), and also shows that the plastic dissipation of the LDCC has essentially reached a plateau at the 0.024 sec.

The maximum strains in the WVMP wall are shown in Figure 2-15, 10% in surface strain (vs. 56% allowed local, 11% allowed bending) and less than 2% membrane. The LDCC crush is insignificant (Figure 2-16), with less than 1% damaged, and in a region away from the bolted side door. Based on the structural characteristics of the WVMP container walls, the center strike is the most challenging to the LDCC, as punctures threats targeted toward the plate periphery would be reacted with a much stiffer plate, with little to no deformation.

Based on the FEA simulation and the supplemental discussion and analysis, it is shown that the WVMP meets the 10 CFR 71 requirements for HAC puncture resistance.

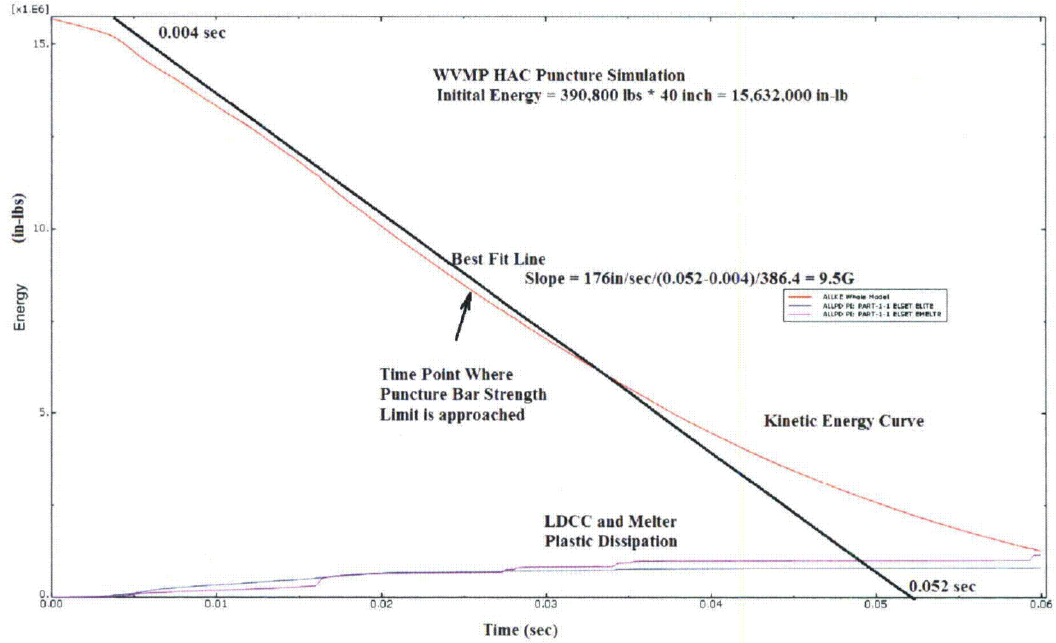


Figure 2-11. Kinetic Energy History Plot during HAC Puncture Simulation

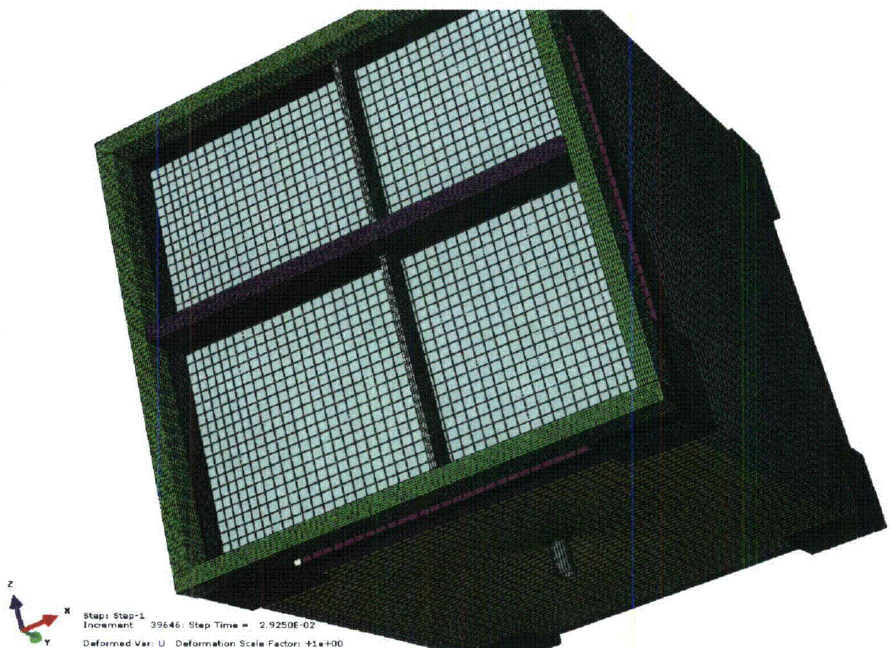


Figure 2-12. Deformed Shape of WVMP after Puncture Simulation

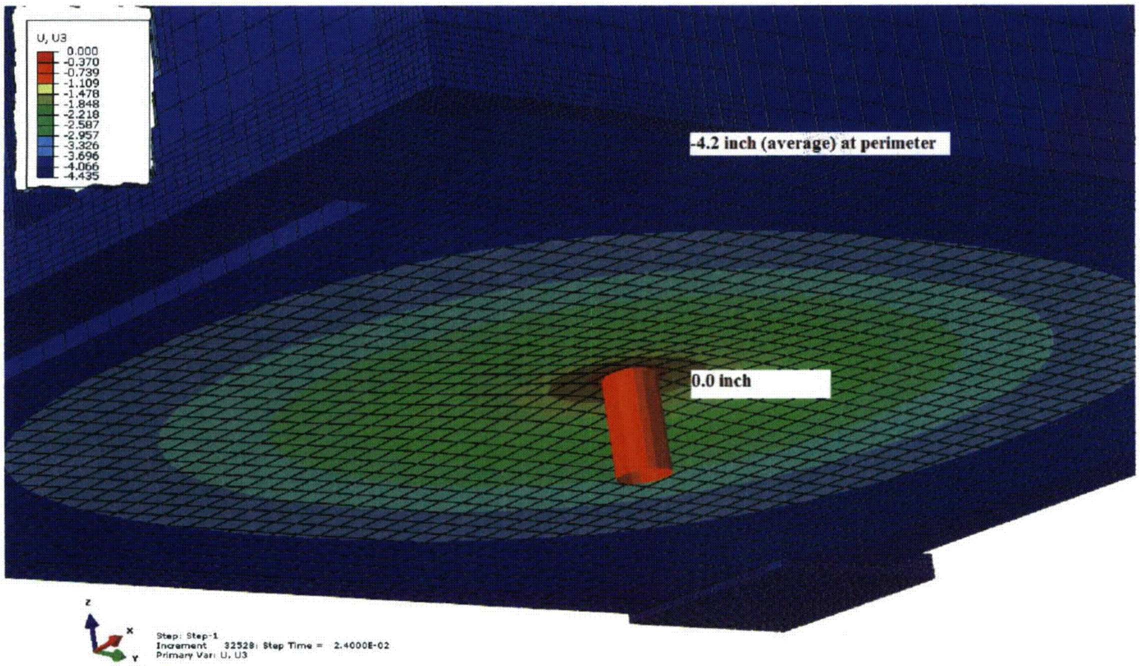


Figure 2-13. Deflection Contour at Time = 0.024 Seconds, Showing 4.2" Differential between Plate Center and Plate Edges Time instance when WVMP Deformations have diminished

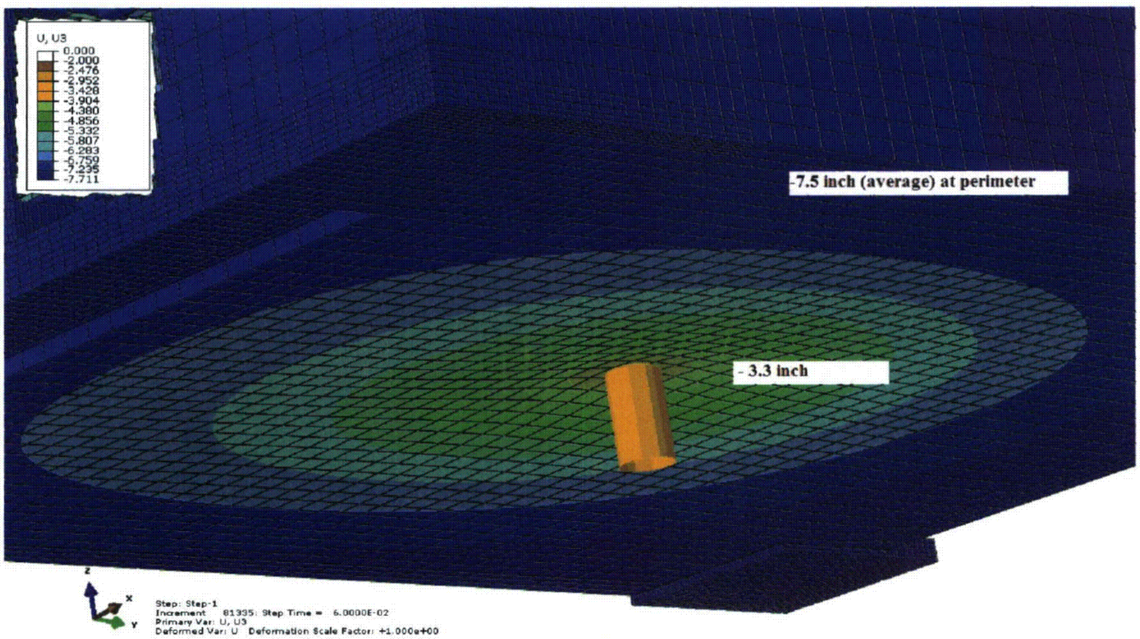


Figure 2.14. Deflection Contour at Time = 0.060 sec (End of Puncture Simulation), Showing 4.2" Differential between Plate Center and Plate Edges

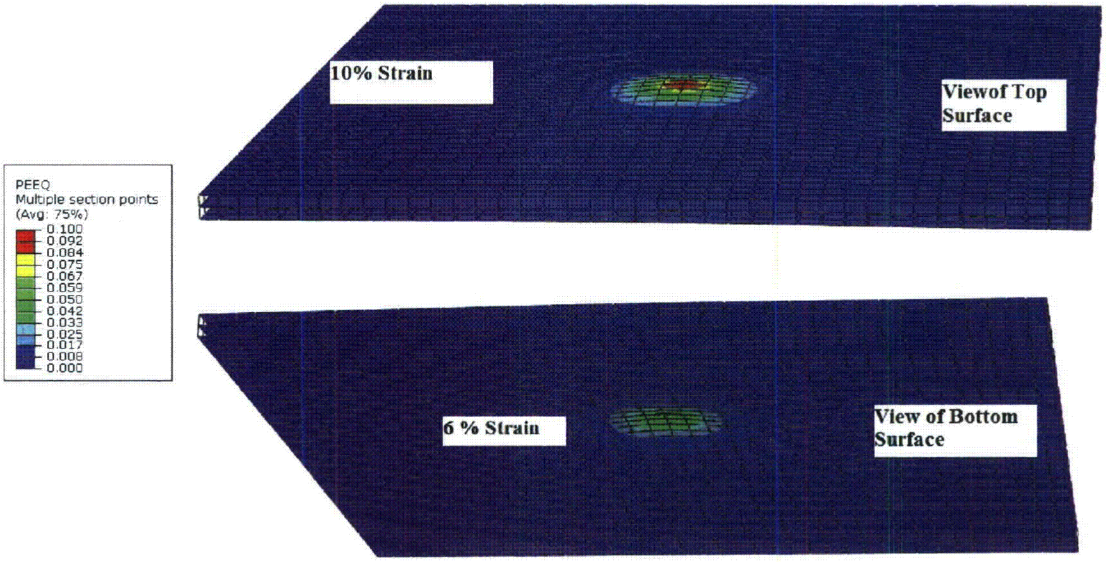


Figure 2-15. Contour Plot of Total Accumulated Plastic Strains after WVMP Puncture Test Simulation, Showing 6% to 10% Surface Strains. Membrane Strains are less than 2% (Per FEA Strain Query, not Shown)

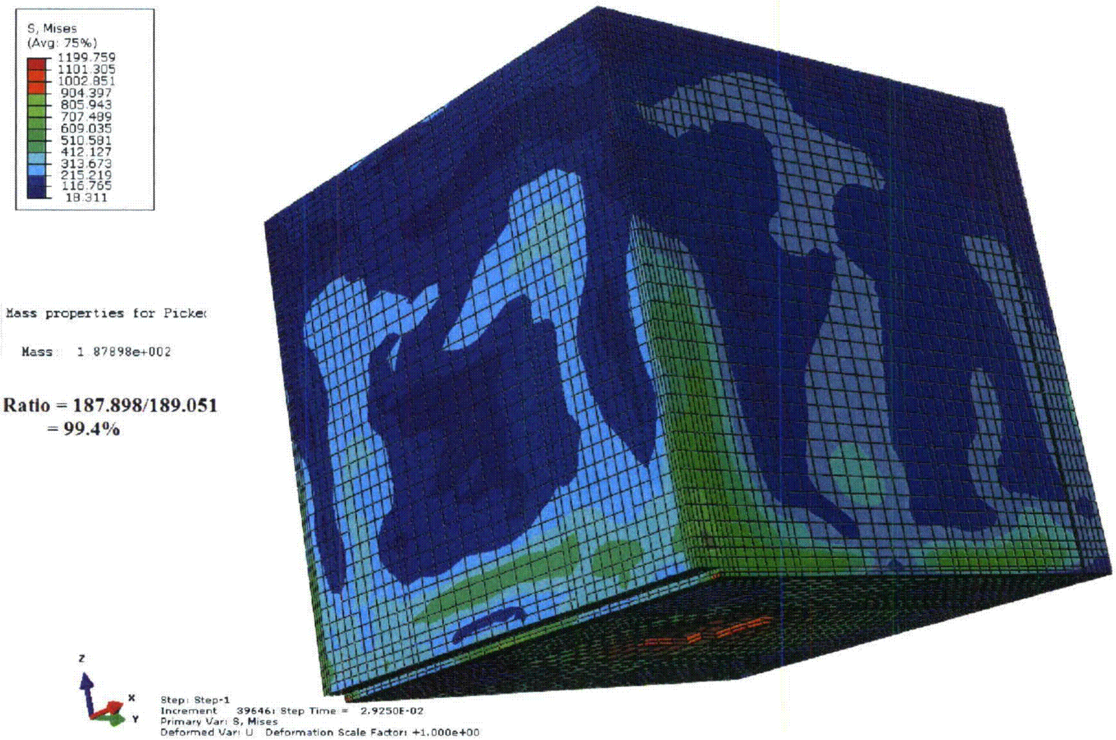


Figure 2-16. Stress Contour Plot of LDCC, with potential damages to LDCC removed from element selection, showing less than 1% damaged

2.7.4 Thermal

Requirement: 10 CFR 71.73(c)(4) – *Thermal.* "Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 1475°F for a period of 30 minutes. The fuel source must extend horizontally at least 40", but may not extend more than 10', beyond any external surface of the specimen, and the specimen must be positioned 40" above the surface of the fuel source. For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to possess if exposed to the fire specified or 0.8, whichever is greater; and the convective coefficient must be that value which may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally."

Evaluation: A numerical thermal evaluation of the WVMP under the fully engulfing fire has been performed, as documented in Section 3.4 of the SAR. Structural evaluation of the WVMP under the resulting temperatures and pressures was performed in Appendix 2.12.2.

2.7.4.1 Summary of Pressures and Temperatures

The large thermal mass of the WVMP container (204,000 lbs of steel) minimizes thermal penetration of the HAC fire temperatures. The thermal analysis was based on no credit for the IL. If the WVMP was not pressure tight after the HAC drops, then no internal pressure would develop and the only structural load demands would be from differential thermal expansion. Conservatively, a HAC pressure was computed based on intact seals and maximum evaporation of the moisture in the LDCC, based on temperature demand. Per Section 3.4 of the SAR:

HAC fire condition internal pressure: 73 psig

HAC fire condition temperature:

WVMP walls:	= 1221°F max, occurs in extremes of corners	[Ref Table 3-6]
	= 750°F through wall average	[Ref. App 2.12.2]
	= 155°F, max through wall gradient	[Ref. App 2.12.2]
LDCC:	= 693°F max, only at extreme outside surface	[Ref. 2-15, Fig 11]
	= 204°F average temperature	[Ref Table 3-6]
Melter:	= 145°F, essentially unchanged from pre-fire	[Ref Table 3-6]

2.7.4.2 Differential Thermal Expansion

Differential thermal expansion is evaluated in Appendix 2.12.2 for the HAC fire condition. The analysis evaluated stresses from thermal gradients within a single component (e.g., bending due to through wall temperature gradients) and stresses arising from differential thermal expansion of adjoining components.

The maximum thermal stress from through-wall temperature gradients was shown to be 21 ksi. When added to the maximum primary stress during HAC fire conditions (26.1 ksi), the combined stress remains less than their respective allowables.

The analysis of bulk thermal expansion shows that the WVMP steel and bolting have the same thermal expansion coefficients, thus they expand and contract uniformly with temperature. The thermal expansion of the container exceeds that of the LDCC during the fire (based on steel's higher thermal expansion coefficient and the steel's much higher temperature during the fire), such that the LDCC will not apply a load on the container. The thermal analysis shows that the melter experiences an insignificant temperature rise during the HAC fire, so the melter will not apply a load against the hotter LDCC.

2.7.4.3 Stress Calculations

Stresses from pressure loadings and thermal loads were computed in Appendix 2.12.2, resulting in the following values:

Pm = insignificant, the flat plate resists pressure load via bending

Pm+Pb = 26.1 ksi [Ref App 2.12.2]

Sm = 21 ksi [Ref App 2.12.2]

Pm + Pb + Sm = 47.1 ksi

2.7.4.4 Comparison with Allowable Stresses

Allowable stresses are based on the 750°F through-wall average temperature. For additional conservatism and to address any uncertainly in the thermal analysis, the structural assessment will be based on material allowables at 800°F. The allowable stresses are derived in Appendix 2.12.2 and summarized below.

For the ASTM SA516-70 steel structure, these limits are (from -20°F to 800°F):

$$P_m \leq 0.7S_u = 0.7 * 64{,}300 psi = 45{,}000 psi$$

$$P_L \leq 150\% P_m$$

P + S, ASME does not require evaluation of secondary stress levels for Level D service limits. For conservatism, the level A service limit of 3Sm is imposed.

The comparison is shown below in Table 2-8.

Table 2-8. Comparison of Stresses with Allowables, HAC Fire Condition

Location	ASME Designation	Stress	Allowable	Comparison Stress/Allowable
Primary Membrane	P_m	~	45 ksi	~
Primary Membrane + Bending	$P_L + P_b$	26.1 ksi	45 ksi	58%
Secondary	S_{m+b}	21 ksi	~	~
Primary plus Secondary	$P_{L+b} + S_{m+b}$	47.1 ksi	3Sm = 54.3 ksi	87%

2.7.5 Immersion – Fissile Material

Requirement: 10 CFR 71.73(c)(5) – *Immersion--fissile material.* "For fissile material subject to § 71.55, in those cases where water in-leakage has not been assumed for criticality analysis, immersion under a head of water of at least 3' in the attitude for which maximum leakage is expected."

Evaluation: Contents do not include fissile material subject to 10 CFR 71.55.

2.7.6 Water Immersion – All Packages

Requirement: 10 CFR 71.73(c)(6) – *Immersion--all packages.* "A separate, undamaged specimen must be subjected to water pressure equivalent to immersion under a head of water of at least 50'. For test purposes, an external water pressure of 21.7 lbf/in^2 gauge is used."

Evaluation: The 21.7 psig external pressure is bounded by the HAC internal pressure of 73 psig. Since the flat plates have the same stress response to internal pressure as they do external pressure, and the allowable stresses at the water immersion temperature is bounding verses the allowable stresses at the HAC fire pressure condition, the WVMP is shown to meet this requirement.

2.7.7 Deep Water Immersion Test (for Type B Packages Containing More Than 10^6 A_2)

Requirement: 10 CFR 71.61 – *Special requirements for Type B packages containing more than 10^5 A_2.* "A Type B package containing more than 10^5 A_2 must be designed so that its undamaged containment system can withstand an external water pressure of 290 psi for a period of not less than 1 hour without collapse, buckling, or inleakage of water."

Evaluation: Not applicable. The WVMP contains less than 10^5 A_2.

2.7.8 Summary of Damage

The WVMP was evaluated by analysis for the NCT drops, water immersion, HAC drops, HAC puncture, and HAC fire. The analysis shows essentially no damage to the WVMP, including the IL, during and after the NCT. The LDCC shows no more than 0.06% damage, and the door bolts and the IL shear pins are shown to remain structurally sound and maintaining seal closure. A few of the door bolts did exceed NCT allowable, but were shown to be within the bolts actual capacity. NCT drops results calculated in Appendix 2.12.2 are summarized below in Table 2-9.

Table 2-9. Summary of Damage, NCT 1 ft Drop Condition

Orientation	G-Level	Limiter Deformation	LDCC Damage	Closure Bolts	Door Seal Status
CG over Edge	5.0 G	Minor denting on lowermost tubesteel	< 0.005%	D/A = 50%	Maintained
CG over Limiter	49 G	Insignificant	0.06%	D/A = 96%	Maintained
CG over Hard Side	76G	None	0.05%	D/A at 100% D/C = 73 %	maintained

The HAC drop analysis did predict deformations to the IL and the corner shock absorbers. The most significant damage experienced by the WVMP was failure of the bolts at the bolted side door. It was shown that the structural portion of the IL acts to maintain the position of the bolted side door, with only small movements of the face and perimeter seal regions. The container itself remained essentially un-deformed and plastic strains were within ASME service level D limits.

The HAC impacts results in significant G-levels, and/or transient diaphragm bending of the walls that results in the mitigation of LDCC crush. The total LDCC crushed ranged from 5% for drop orientations associated with the highest bolted side door seal displacements, to 35% for drop orientations associated with no bolted side door seal displacements. The bounding LDCC damage associated with any door seal movement was for a drop onto the side edge, which showed 30% LDCC crush and seal motion of:

Face seal displacement = 1.2" (vs. available 6" before breach path exposed)

Perimeter seal displacement = 5.8" transient
= 4" to 4.5" final
(3.75" face overlap before breach path exposed)

Table 2-10 summarizes the results for the HAC cases. Only the worst case results are shown for LDCC crush, seal displacement, and GMP plate strains. The subsequent pin drop is shown to not add significant additional damage. The weld analysis in appendix 2.12.2 shows some welds may fail in the oblique angle drops, but these failures are not through wall, and the integral corner bumpers maintain constraint on the steel panels.

Therefore, based on analysis the WVMP satisfies the performance intents of 10 CFR 71.51(a)(2) under HAC given in 10 CFR 71.73.

Table 2-10. Summary of Damage, HAC 30 ft Drop Condition

Condition	Maximum GMP Shell Strain	Maximum LDCC Crush & max G-Load	Maximum Door Gaps
Drop Configuration Associated with Maximum	CG over Side Edge	Hardside Down	CG over Bottom Corner
GMP Strains 21.4% allowed max	Less than 10%, vs 21% allowed	8% in Corner absorbers, 4.5% in GMP plates	Less than 9% in main plates
LDCC Crush	30%	35%	11%
Pin Shear (250,000 lb limit)	200,000 lbs	130,000 lbs	230,000 lbs
Door Gap	F= 1.2 inch P = 5.8 inch at midspan, recovers to 4.5 inch	F ~ 0.0 inch P = 0.33 inch	Two extremes: F=3.2", P=0.9" P = 3.2", F = 1.5"
Impact G-Load	137 G	546 G	53G

2.8 Accident Conditions for Air Transport of Plutonium

Not applicable.

2.9 Accident Conditions for Fissile Material Packages for Air Transport

Not applicable.

2.10 Special Form

Not applicable.

2.11 Fuel Rods

Not applicable.

2.12 Appendix

This appendix contains the following information:

2.12.1 List of references

2.12.2 Structural Evaluation of WVMP to Specific Requirements of 10 CFR 71.71 (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Request for Withholding*)

APPENDIX 2.12.1 – REFERENCES

2-1 10 CFR Part 71, *Packaging and Transportation of Radioactive Material*, Code of Federal Regulations, Washington, D.C., December 2006.

2-2 49 CFR Part 173, *Shippers - General Requirements for Shipments and Packaging,* Code of Federal Regulations, Washington, D.C., January 2007.

2-3 *Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels*, Regulatory Guide 7.6, Revision 1, U.S. Nuclear Regulatory Commission, March 1978.

2-4 *Load Combinations for the Structural Analysis of Shipping Casks for Radioactive Material*, Regulatory Guide 7.8, Revision 1, U.S. Nuclear Regulatory Commission, Washington, D.C., March 1989.

2-5 *Fracture Toughness Criteria of Base Material for Ferritic Steel Shipping Cask Containment Vessels with a Maximum Wall Thickness of 4 Inches (0.1 m)*, Regulatory Guide 7.11, Revision 0, U.S. Nuclear Regulatory Commission, Washington, D.C., June 1991.

2-6 *ASME Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, N.Y., 2013

2-7 *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854, U.S. Nuclear Regulatory Commission, Washington, D.C., March 1985.

2-8 ASME SA-193, *Specification for Alloy-Steel and Stainless Steel Bolting Materials for High Temperature or High Pressure Service and Other Special Purpose Applications*, ASTM International, 2001

2-9 General Plastics LAST-A-FOAM FR-3700 for Crash & Fire Protection of Nuclear Material Shipping Containers, http://pbadupws.nrc.gov/docs/ML0504/ML050410066.pdf

2-10 *Structural Welding Code – Steel*, D1.1, American Welding Society, 2000

2-11 *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick*, NUREG/CR-1815, U.S. Nuclear Regulatory Commission, Washington, D.C., June 1981.

2-12 *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Greater than Four Inches Thick*, NUREG/CR-3826, U.S. Nuclear Regulatory Commission, Washington, D.C., April 1984.

2-13 *Fitness-For-Service*, API 579-1/ ASME FFS, American Petroleum Institute, Washington, D.C., 2007.

2-14 *Cask Designers Guide*, ORNL-NSIC-68, Shappert, L.B., et al., Oak Ridge National Laboratory, February 1970.

2-15 *Thermal Analysis for West Valley Melter Package*, M-CLC-A-00498, Revision 0, Savannah River National Laboratory, Aiken, South Carolina, September 2014. (see Chapter 3)

2-16 AISC Steel Construction Manual, AISC-325-11, 14th Edition.

2-17 ASTM A516/A516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate and Lower-Temperature Service*, ASTM International, 2001 Edition.

2-18 Receiving Inspection & Material validation – Steel Plate, Document 40945-000, West Valley Purchase Order 53634. (provided)

2-19 AWS D1.1, 2010, *Structural Welding Code – Steel*, 17th Edition, Prepared by AWS Committee on Structural Welding.

3.0 THERMAL EVALUATION

This chapter provides a thermal evaluation for the shipment of the West Valley Melter Package (WVMP) as part of the safety analysis for this shipment. The thermal evaluation performed for the WVMP demonstrates compliance with the performance requirements for Normal Conditions of Transport (NCT) as specified in 10 CFR 71.71 (reference 3-1), and for Hypothetical Accident Conditions (HAC) as specified in 10 CFR 71.73 (reference 3-2). The WVMP is comprised of (1) the Grouted Melter Package (GMP), consisting of the melter and Low Density Cellular Concrete (LDCC) inside the steel container; and (2) the Impact Limiter (IL). Figure 3-1 shows the components of the WVMP.

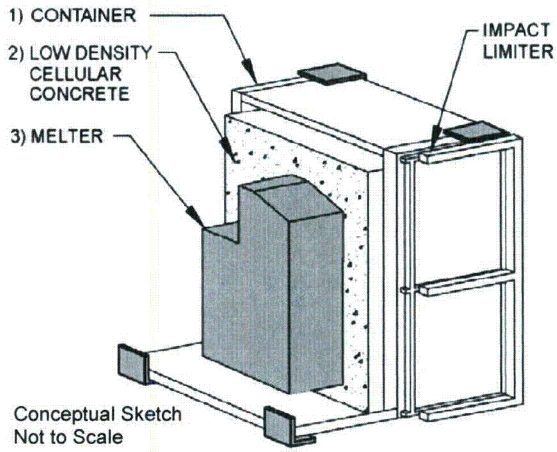


Figure 3-1. WVMP Components

3.1 Description of Thermal Design

Thermal analyses are provided for NCT and HAC (Appendix 3.5.4). The conditions for NCT and HAC are stipulated in 10 CFR 71. NCT covers conditions for outdoor storage of the waste package, including heat transfer to ambient air and sun exposure (insolation). The HAC assume exposure to a 1475°F fire. The thermal analysis does not account for the presence of the Impact Limiter (IL) added to the exterior of the WVMP. For the thermal analysis, the omission of the IL is conservatively bounding since it does not include the insulation it provides. The WVMP without the IL component is referred to as the Grouted Melter Package (GMP) component.

The analysis of temperatures for NCT follows the requirements of 10 CFR 71.71. The required temperatures are:

(1) The maximum temperatures for exposure to 100°F air at steady state.

(2) The maximum temperatures for exposure to 100°F still air with insolation of 800 cal/cm^2 on the top surface and 200 cal/cm^2 on the side surfaces for a period of 12 hours. The package bottom is assumed to be an insulated (adiabatic) surface.

(3) The minimum (surface) temperature for exposure to a cold environment of -20°F, with no insolation.

(4) The minimum (surface) temperature for exposure to a maximum cold environment of -40°F, with no insolation.

Key Terms and Acronyms in this Chapter	
GMP	Grouted Melter Package (consisting of the melter and LDCC inside the container)
HAC	Hypothetical Accident Conditions
IL	Impact Limiter
LDCC	Low Density Cellular Concrete
NCT	Normal Conditions of Transport
WVMP	West Valley Melter Package (consisting of the GMP with the IL installed)

The WVMP accessible surface temperature in still air at 100°F, with no insolation, must not exceed the exclusive use shipment limit of 185°F, as specified in 10 CFR 71.43(g) (reference 3-3). In addition, there must be no loss of the radioactive contents, no significant increase in external surface radiation level, and no significant decrease in package effectiveness, as stated in 10 CFR 71.43(f) (reference 3-3) and 71.51(a)(1) (reference 3-4). To address this requirement, the maximum pressure that can develop inside the WVMP during NCT is calculated for use in the structural analysis.

The analysis of temperatures for HAC follows the requirements of 10 CFR 71.73. These requirements specify the package is exposed to an engulfing 1475°F (800°C) fire for 30 minutes, followed by a cool down to ambient conditions. The fire emissivity is specified as 0.9 and the surface emissivity for the surface of the package is set at 0.8. The requirements also specify the use of a convective heat transfer coefficient appropriate for the fire.

The HAC analysis must demonstrate the activity release during the HAC will not exceed the limits established by 10 CFR 71.51(a)(2) (reference 3-4). To demonstrate no release of activity will occur, the maximum pressure that can develop inside the WVMP during the HAC is calculated for use in a structural analysis.

3.1.1 Design Features

The WVMP consists of a container with a 12'4.75" long by 11'4" wide by 11'4" high volume (reference 3-5). The melter is grouted in place inside this container by Low Density Cellular Concrete (LDCC). The LDCC fills the container to within 10" of the inside top surface (reference 3-6). The top and bottom container thickness is 4"; the sides of the container are 6" thick (reference 3-5). The container also includes steel rails, gaskets, and sacrificial shock absorbers at each of the eight corners (reference 3-5); these components are not modeled in the heat transfer analysis. Exclusion of these components yields conservatively bounding values for the calculated temperatures, since they provide added insulation for the interior of the WVMP when it is heated by either insolation or by the fire.

The mass of the melter is 107,500 lbm (48,761 kg), (reference 3-6). The LDCC mass is 70,738 lbm (32,086 kg) (reference 3-6). The mass of the melter glass is 467.2 kg (1,030 lbm) (reference 3-7).

The volumes occupied by each type of material can be calculated by dividing the estimated mass of material by its density. The WVMP interior volume, i.e., the interior volume minus the volume of the glass remaining in the melter, is estimated indirectly from the equation.

$$V_{ref} = V_i - V_{air,1} - \frac{m_{LDCC}}{\rho_{LDCC}} - \frac{m_{glass}}{\rho_{glass}} \qquad (3.1.1\text{-}1)$$

where

V_{ref} = WVMP interior volume minus volume of glass, m^3

V_i = total interior volume of WVMP, m^3

$V_{air,1}$ = volume air pocket above LDCC inside WVMP, m^3

m_{LDCC} = mass of LDCC, kg

ρ_{LDCC} = LDCC density, kg/m^3

m_{glass} = mass of glass in melter, kg

ρ_{glass} = glass density, kg/m^3

The melter structure is comprised of Inconel®[1], Type 304 stainless steel, and Type 304L stainless steel (reference 3-5). As an approximation, the properties of the melter steel are set equal to the properties of Type 304L stainless steel. The refractory material is a combination of Monofrax™[2] K-3 and Zirmul™ (reference 3-7). Accordingly, the volume of the structural metal inside the melter is given by

$$V_{ss} = \frac{m_m - \rho_{Mono} V_{Mono} - \rho_{Zirm} V_{Zirm}}{\rho_{ss}} \tag{3.1.1-2}$$

where

V_{ss} = volume of metal inside melter, m^3

m_m = total melter mass, kg

ρ_{Mono} = density of Monofrax™, kg/m^3

V_{mono} = volume of Monofrax™ refractory inside melter, m^3

ρ_{Zirm} = density of Zirmul™, kg/m^3

V_{Zirm} = volume of Zirmul™ refractory inside melter, m^3

ρ_{ss} = density of Type 304L stainless steel, kg/m^3

Any portion of the melter volume that is not metal or refractory is assumed to be an air pocket. The melter air pocket volume is calculated by subtracting the metal and refractory volumes from the total refractory volume given by equation (3.1.1-1):

$$V_{air,2} = V_{ref} - V_{ss} - V_{Mono} - V_{Zirm} \tag{3.1.1-3}$$

where

$V_{air,2}$ = volume of air pocket inside melter, m^3

3.1.2 Content's Decay Heat

The heat generation rate in the glass is calculated from a RADCALC analysis of the activity in the glass (references 3-7, 3-8, 3-9, and 3-10) and tabulations of the energy emissions for each radionuclide from the International Committee on Radiological Protection (ICRP) tables (reference 3-11). The full list of radionuclides from the RADCALC®[3] output is included in the tabulation. The

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[1] Inconel is a registered trademark of Special Metals Corporation of New Hartford, New York.

[2] Monofrax™ is a trademark of RHI Monofrax Ltd. of Falconer, New York. Zirmul™ is a contraction of the mineral names zirconia (ZrO^2) and mullite ($3Al_2O_3 \cdot 2SiO_2$). Zirmul™ is a registered trademark of North American Refractories Company of Pittsburgh, Pennsylvania.

[3] RADCALC is a registered tradename of LifeLine Software, Inc., of Austin, Texas.

radiolytic heat generation calculations are summarized in Appendix 3.5.2. The maximum decay heat is 9.21 W.

3.1.3 Summary Tables of Temperatures

The following tables summarize maximum and minimum temperatures for NCT and, for HAC, the time interval between the beginning of the fire exposure and the peak temperatures.

Table 3-1. Temperatures for NCT

NCT, No Insolation, 100°F Ambient Air	
Component	**Maximum Temperature**
Overall	105.4°F
Glass	105.4°F
Melter	101.5°F
LDCC	101.0°F
Air Pocket	100.3°F
Container	100.2°F
NCT, No Insolation, -20°F Ambient Air	
Component	**Minimum Temperature**
Overall	-19.9°F
Glass	-18.7°F
Melter	-19.2°F
LDCC	-19.9°F
Air Pocket	-19.9°F
Container	-19.9°F
NCT, No Insolation, -40°F Ambient Air	
Component	**Minimum Temperature**
Overall	-39.9°F
Glass	-38.7°F
Melter	-39.2°F
LDCC	-39.9°F
Air Pocket	-39.9°F
Container	-39.9°F
With Insolation, 100°F Ambient Air	
Component	**Maximum Temperature**
Overall	209.4°F
Glass	146.3°F
Melter	144.6°F
LDCC	183.5°F
Air Pocket	208.9°F
Container	209.4°F

Table 3-2. Limiting Conditions for HAC

HAC, With Insolation, 100°F Ambient Air, 1475°F Fire Exposure for 30 minutes		
Component	**Maximum Temperature(°F)**	**Time for Maximum Temperature (minutes)**
Overall	1221.1°F	30
Glass	146.3°F	750+(1)
Melter	145.2°F	750+(1)
LDCC	693.0°F	68
Air Pocket	727.9°F	68
Container	1221.1°	30

NOTE: (1) The glass and melter temperatures had not peaked 750 minutes after the start of the fire (720 minutes after the end of the fire exposure), but are judged to have been within 1°F of their peak values.

3.1.4 Summary Table of Maximum Pressures

The following table lists maximum pressures for NCT and HAC. These maximum pressures are calculated for the air pocket at the top.

Table 3-3. Maximum Pressures for NCT and HAC

Condition	Maximum Pressure
NCT	12.0 psig
HAC	73.0 psig

3.2 Material Properties and Component Specifications

Evaluation of thermal conductivities, densities, and heat capacities is required for the thermal analysis. The LDCC contains waters of hydration that may dehydrate to form water vapor when the WVMP is exposed to the sun under NCT or, more particularly, to fire under HAC. The dehydration reaction is endothermic, so the dehydration process will act as a heat sink in the thermal analysis. The water vapor from dehydration will pressurize the container. Therefore, the fractional dehydration as a function of temperature and the heats of hydration and vaporization are needed inputs. Finally, the radionuclide contents of the melter glass and the decay heats for each of the isotopes in the glass are needed to compute the rate of radiolytic heating of the glass.

3.2.1 Material Properties

The density of the glass is 2600 kg/m^3 (reference 3-7).

The average LDCC density is conservatively assumed to be equal to the density of the concrete batch with the lowest measured compressive strength, which was 71.2 lbm/ft^3 (1140 kg/m^3) (reference 3-6).

The total refractory volume is 92.7 ft^3, of which 61.88 ft^3 is Monofrax™ K-3 and 30.82 ft^3 is Zirmul™ (reference 3-7). The thermal analysis uses the crystalline densities of these materials, 3900 kg/m^3 for Monofrax™ K-3 and 3140 kg/m^3 for Zirmul™, and the corresponding thermal conductivities at

100°C, 4.19 W/m/K for Monofrax™ K-3 and 0.20 W/m/K for Zirmul™ (reference 3-12). The heat capacities are calculated from the compositions of Monofrax™ K-3 and Zirmul™ (reference 3-12) and the estimated heat capacities of the crystalline phases of the oxide constituents (references 3-13 and 3-14). The compositions and density calculations are summarized in Table 3-4; the resulting heat capacities are 774 J/kg/K for Monofrax™ K-3 and 709 J/kg/K for Zirmul™. The Monofrax™ and Zirmul™ heat capacities are computed using the weighted averages of only those constituents listed in Table 3-4, despite the fact that their weight fractions do not sum to one.

Table 3-4. Compositions and Heat Capacities for Monofrax™ K-3 and Zirmul™

Oxide	Mol. Wt. (g/mole)	Heat Capacity (J/mol/K)	Monofrax™ K-3		Zirmul™	
			wt %	J/g/K	wt %	J/g/K)
Al_2O_3	101.96	79	44	0.341	70	0.542
CaO	56.08	42	0.18	0.001	0	0
Cr_2O_3	151.99	118.7	19	0.148	0	0
Fe_2O_3	159.69	103.9	5.85	0.038	0	0
Na_2O	62	69.1	0.2	0.002	0	0
MnO_2	86.94	54.1	0.06	0.000	0	0
MgO	40.3	37.2	3.71	0.034	0	0
SiO_2	60.08	44.4	0.6	0.004	10.2	0.075
TiO_2	79.88	55	0.16	0.001	0	0
ZrO_2	123.22	56.2	0	0.001	19.5	0.089
Total				**0.774**		**0.709**

As stated previously, the melter metal is assigned the properties of Type 304L stainless steel. The container walls are fabricated from Type SA516 carbon steel (reference 3-5). The density of Type 516 carbon steel is 483.8 lbm/ft^3 (7,749.7 kg/m^3), and the density of Type 304L stainless steel is 499.4 lbm/ft^3 (7,999.6 kg/m^3) (reference 3-15). The heat capacities and thermal conductivities are correlated as functions of temperature as shown in Figures 3-2 and 3-3 (reference 3-15).

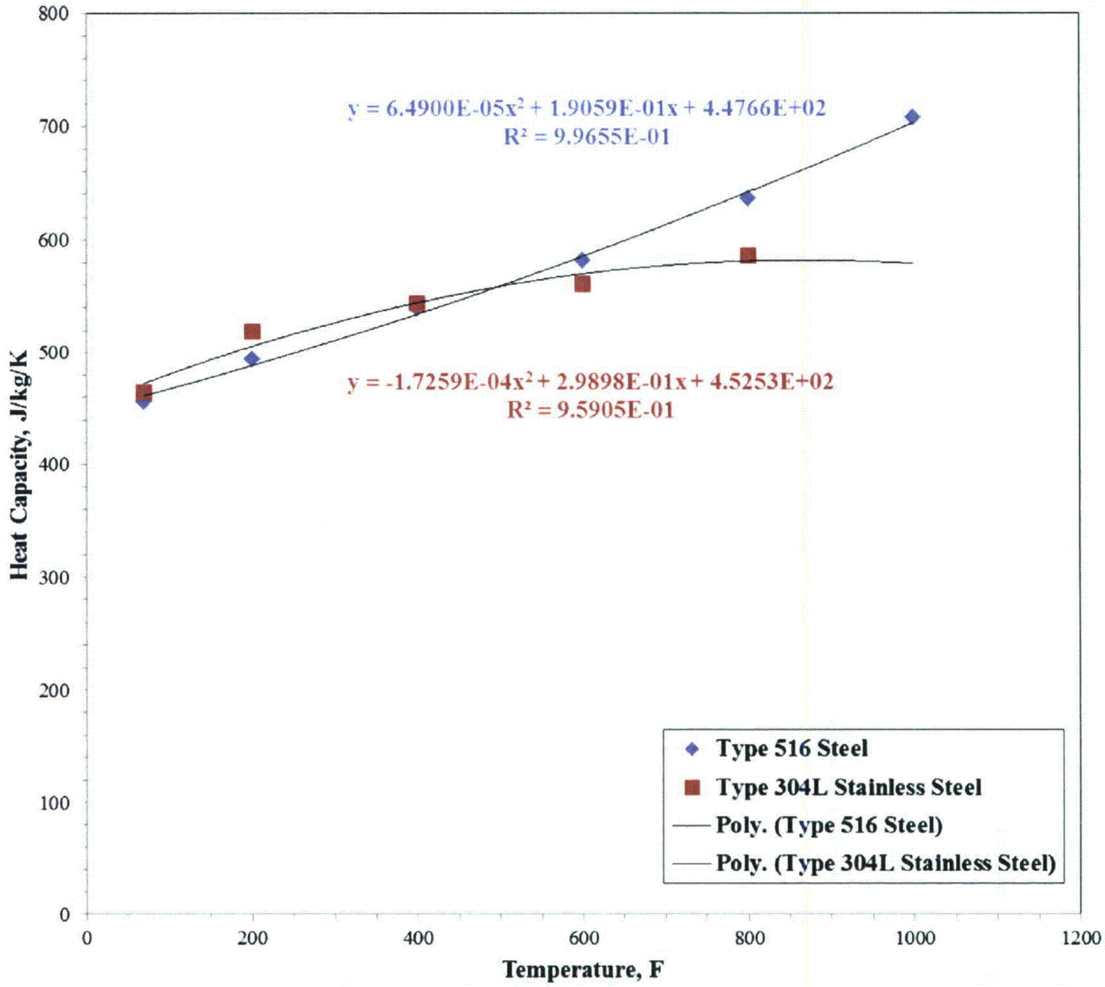


Figure 3-2. Correlation of Heat Capacities for Types SA516 and 304L Steels (reference 3-16)

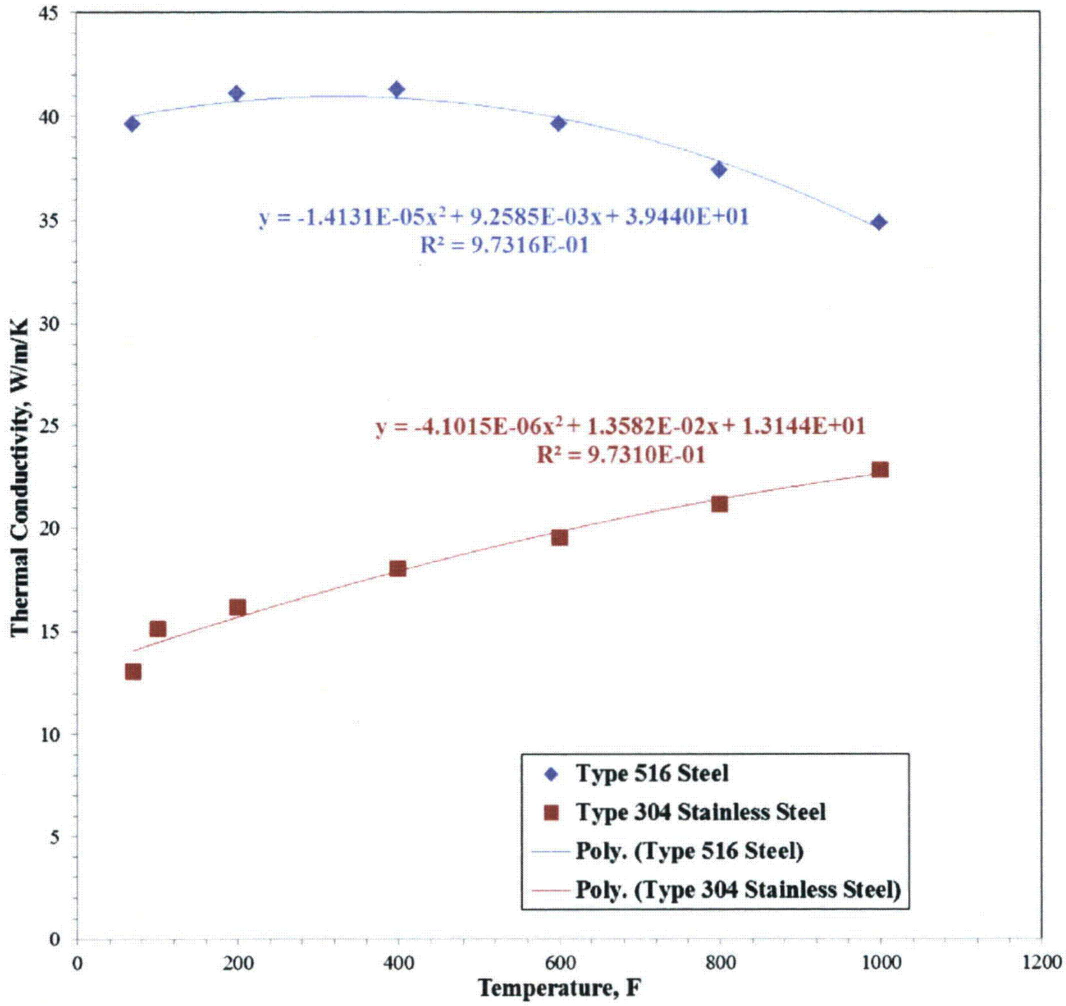


Figure 3-3. Correlation of Thermal Conductivities for Types SA516 and 304L Steels (reference 3-16).

The glass heat capacity is fit to typical values for borosilicate glass (reference 3-16), using the empirical correlation

$$c_{p,gl} = \min\left(\frac{0.19242 + 0.001081 T_{gl}}{1 + 0.00251 T_{gl}}, 0.2\right) \quad (3.2.1\text{-}1)$$

where

$c_{p,gl}$ = thermal conductivity of the melter glass, cal/g/K

T_{gl} = glass temperature, °C

The heat capacity of the LDCC is set equal to a typical value for a cement mix with a water content close to that estimated for LDCC. LDCC contains on average 510 lbm/yd^3 cement, with added water amounting to 20% of the cement by weight, and enough sand to increase the density to the specified value. The result for the given density of 71.2 lbm/ft^3 is 18.89 lbm/ft^3 cement, 48.53 lbm/ft^3 sand (SiO_2), and 3.78 lbm/ft^3 water (references 3-17 and 3-18). The water content is 5.3 wt %. The closest value for which a cement heat capacity is reported is a mix with 3 wt % water, for which the heat capacity was measured to be 765 J/kg/K (reference 3-19).

The thermal conductivities for the glass are set at its minimum value for borosilicate glass of 0.42 W/m/K (reference 3-16). The LDCC thermal conductivity is set at its minimum value for its density, which is approximately 0.26 W/m/K (reference 3-20).

3.2.2 Component Specifications

There are no internal components that will be outside the range of allowable service temperatures or pressures for either NCT or HAC conditions. The glass, metal, refractory, and LDCC will withstand any temperatures extremes that would occur under NCT or HAC. The melter is thermally insulated from the HAC fire, so its temperature will be significantly lower than the container temperature during the fire. The only significant change to component properties during the fire exposure would be dehydration of the LDCC, i.e., loss of the cement waters of hydration.

During the HAC fire exposure, the container plates may exceed their service temperature, which is 700°F for nuclear service and 1,000°F for ordinary service (reference 3-21). The structural analysis in Chapter 2 addresses the structural integrity of the WVMP during HAC. The structural analysis is based on a bounding average container plate temperature of 800°F.

The following table summarizes limiting temperatures for the WVMP components. Separate limiting temperatures are listed for (1) NCT and the HAC for dropping the WVMP, and for (2) the HAC fire. The maximum temperature limit is set equal to either the limiting temperature specified by 10 CFR 71.71 or 10 CFR 71.73; if the maximum temperature for the component exceeds this limiting temperature or the component is not credited in the thermal or structural analysis, or to the maximum temperature for the structural integrity of the component. All minimum temperatures are set equal to the minimum limiting temperature for NCT.

Table 3-5. Limiting Temperatures for WVMP Components

Component	Min. Limiting Temp., NCT and HAC Drop(1)	Max. Limiting Temp., NCT and HAC Drop(2)	Min. Limiting Temp., HAC Fire(1)	Max. Limiting Temp., HAC Fire
Type 516 Steel Plates (Average Temp.)	-40°F	200°F	-40°F	800°F(3)
Type 516 Steel Plates (Extreme Temp.)	-40°F	200°F	-40°F	1475°F(4)
LDCC	-40°F	200°F	-40°F	1200°F(5)
Melter Metal	-40°F	200°F	-40°F	1475°F(6)
Melter Refractory	-40°F	200°F	-40°F	1475°F(6)
Melter Glass	-40°F	200°F	-40°F	1475°F(6)
Impact Limiter	-40°F	200°F	-40°F	1475°F(7)
RTV Gasket	-40°F	200°F	-40°F	1475°F(7)
Neoprene Gasket	-40°F	200°F	-40°F	1475°F(7)

NOTES:

(1) All components will withstand the minimum NCT temperature of -40°F. For NCT and HAC, the temperature will not drop below -40°F.

(2) The structural analysis (see Chapter 2) credits a maximum temperature of 200°F for NCT and the HAC drop.

(3) The structural analysis (see Chapter 2) credits an average steel plate temperature of no higher than 800°F.

(4) The Type 516 steel container plates will not melt or significantly deform at the fire temperature of 1475°F.

(5) The LDCC maximum temperature is conservatively set at the approximate minimum temperature at which LDCC slabs fail under their own weight (see reference 3-22).

(6) The melter components are designed to operate at temperatures that exceed the fire temperature of 1475°F

(7) The temperatures of the impact limiter and the RTV and neoprene gaskets will approach the fire temperature of 1475°F. These components are not included in the thermal model and are not credited in the HAC fire analysis.

The thermal analysis does not address the failure of individual components under pressure, since there is no requirement for individual components to provide pressure confinement. Instead, the analysis estimates a maximum overall pressure under the assumption that the container frame provides pressure confinement. The limiting pressure associated with the maximum pressure generated by heating under HAC is calculated from the margin between the applied load due to this pressure and the allowable load when the frame plates are at 800°F. The combined primary and secondary allowable stress on the side wall at this temperature is 54.3 ksi, compared to an applied stress of 47.1 ksi at the maximum container pressure computed for the HAC thermal analysis, which is 73.0 psig. On this basis, the maximum container pressure is computed to be 54.3 ksi / 47.1 ksi x 73.0 psig, or 84.1 psig.

The Arrhenius correlation of the fractional dehydration is based on data for crystalline calcium silicates, which are by far the major constituents of typical cement. It is assumed that the LDCC is fully cured so that there is no free water in the cement pores and so that, consequently, all dehydration involves the breaking of crystalline bonds, followed by evaporation of liquid water. For tricalcium silicate hydrate ($3CaO:SiO_2:2H_2O$), the fractional dehydration is correlated as an Arrhenius function of the form (reference 3-23).

$$\alpha = A_r \exp\left(-\frac{E_a}{R_g T}\right) \qquad (3.2.2\text{-}1)$$

where

α = cumulative fraction of calcium silicate oxides that have undergone dehydration

A_r = pre-exponential Arrhenius constant for cement dehydration, dimensionless

E_a = activation energy for cement dehydration, J/mole

R_g = gas constant, J/mole/K

The Arrhenius equation was fit to the dehydration data as shown by Figure 3-4.

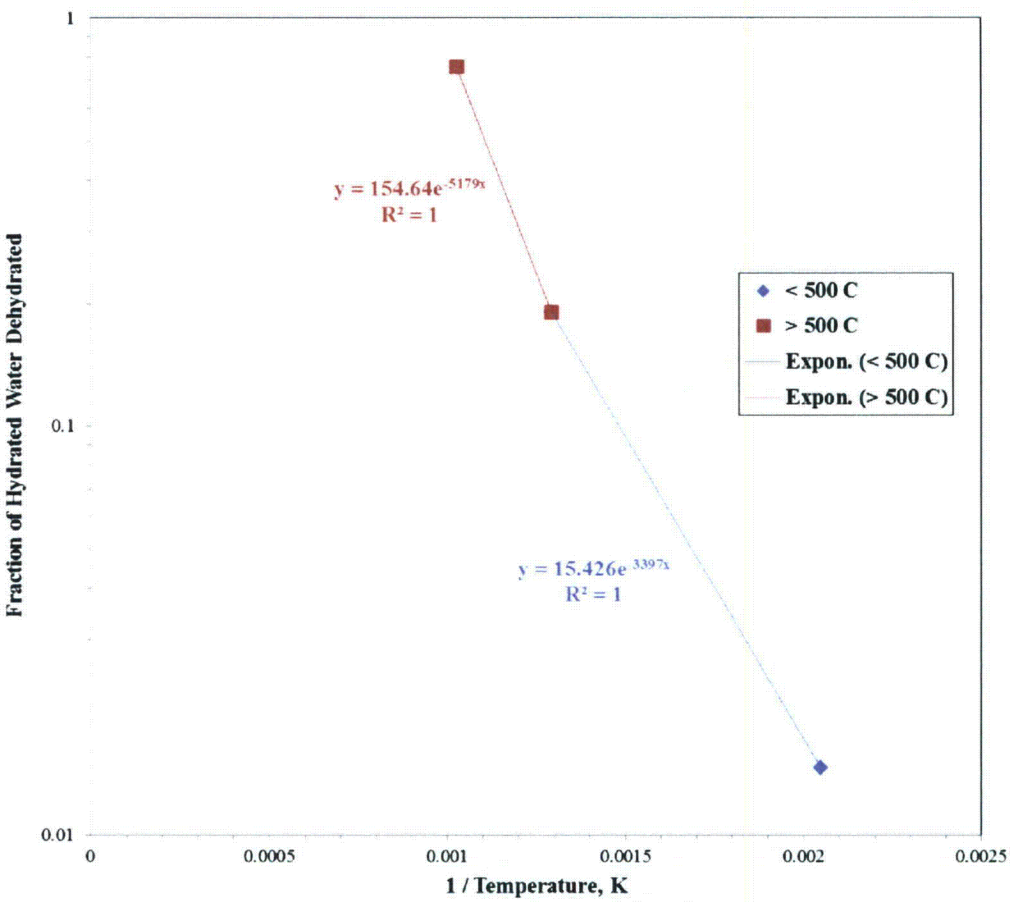


Figure 3-4. Correlation of Measurements for Dehydration of $3CaO:SiO_2:2H_2O$

As indicated by the figure, the Arrhenius constants, for temperatures below 500°C, are

$$A_r = 15.426, \frac{E_a}{R_g} = 3397 \text{ K} \tag{3.2.2-2}$$

The heat of hydration for tricalcium silicate is 65.59 kJ/mole H_2O (reference 3-24), and the heat of hydration for calcium oxide is 63.92 kJ/mole H_2O (reference 3-25). The tricalcium silicate heat of hydration is used in the thermal analysis, since it is more representative of the LDCC composition.

The heat of vaporization for water is added to the heat of reaction for dehydration. The heat of vaporization is correlated as a function of temperature by (reference 3-26).

$$\lambda = \lambda_b \left(\frac{1 - T_r}{1 - T_{r,b}} \right)^{0.38} \tag{3.2.2-3}$$

where

λ = heat of vaporization, J/mole

λ_b = heat of vaporization at the normal boiling point (373.15 K), J/mole

T_r = relative temperature

$T_{r,b}$ = relative temperature at the normal boiling point

The relative temperature is normalized with respect to the critical temperature for water, which is 373.99°C or 647.14°K (reference 3-27). The heat of vaporization of water at the normal boiling point is 40,657 J/mole (reference 3-27).

3.3 Thermal Evaluation under Normal Conditions of Transport

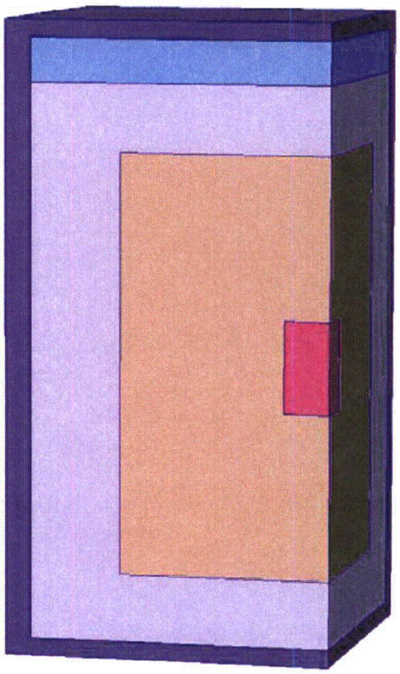
The thermal analysis is performed using Version 4.3a of the finite element modeling code COMSOL®[4] Multiphysics. COMSOL® Multiphysics is approved for use in heat transfer modeling at the Savannah River National Laboratory and has been used to calculate NCT and HAC temperatures for other waste transfer packages (references 3-28 and 3-29). The COMSOL® model uses the actual outer dimensions for the container and approximates the contents of the WVMP as a nested series of cubes, with the innermost cube comprised of the radioactive glass in the melter heel, the spout, and any glass dispersed into the refractory of the melter. In the model, this inner core is surrounded by a layer comprised of the melter refractory and structural steel, a layer of the LDCC used to stabilize the melter in the package, and the steel container walls. There also is a 10" thick air space between the top surface of the LDCC and the top container wall. This air pocket is present because the WVMP was not completely filled with LDCC.

To simplify the heat transfer analysis, it is assumed that the glass, steel, refractory, and LDCC layers form concentric, symmetrical cubes within the container walls and upper air pocket. The symmetry provides a conservative, lower bound to the actual overall rate of heat transfer in that it averages out any variations in the thicknesses of the insulation provided by the LDCC and the refractory. Any asymmetrical variations would increase the local, and the average, rate of heat transfer. A lower bound to the heat transfer rate is desired because it maximizes the surface

[4]COMSOL® is a registered trade name of COMSOL, Inc., of Burlingame, Massachusetts.

temperature for insolation and fire exposure and maximizes increases in the glass temperature due to radiolytic heating for the case of no insolation. (The maximum glass temperature is used to estimate the bounding surface temperature without insolation, to account for asymmetries in the thickness of the LDCC around the melter.)

The COMSOL® model utilizes bilateral symmetry along the length and width of the WVMP to reduce the volume analyzed to a one-quarter corner of the WVMP that extends from the top surface to the bottom surface. Figure 3-5 depicts the simplified COMSOL® model, with the various materials shown. Figure 3-6 shows the discretization mesh for the finite element calculations. The total number of calculation nodes is 125,148. Trial calculations were performed to ensure that the discretization was sufficiently fine to calculate the WVMP temperature profile with a high degree of precision. Appendix 3.5.3 provides a list of parameters and variables used for the COMSOL® model.



Key:

Dark Blue	**Container**
Medium Blue	**Air Space**
Light Violet	**LDCC**
Tan	**Melter Structural Steel and Refractory**
Pink	**Glass**

Figure 3-5. Schematic of COMSOL® Multiphysics model of West Valley Melter Package

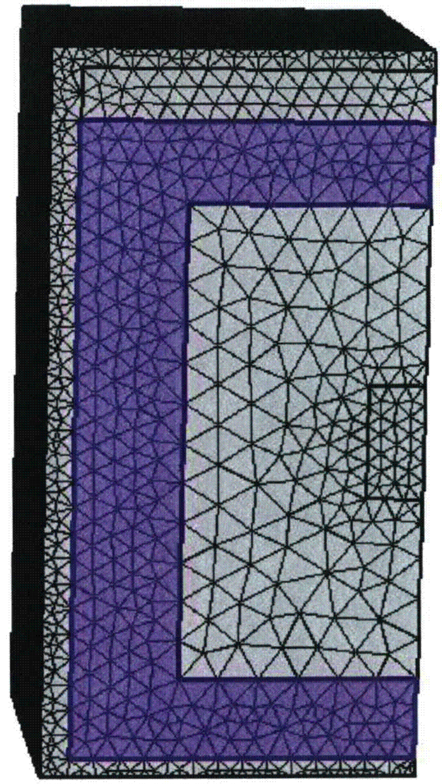


Figure 3-6. Meshing for COMSOL® Multiphysics Model of West Valley Melter Package

3.3.1 Thermal Analysis

The COMSOL® heat transfer equation for the glass takes the form

$$\rho c_p \frac{\partial T}{\partial t} - \nabla \bullet k \nabla T = \frac{Q}{V_{glass}} \tag{3.3-1}$$

where

ρ = density of the material, kg/m^3
c_p = heat capacity of the material, J/kg/K
∇ = dispersion operator, 1/m
t = time, s
k = thermal conductivity of material, W/m/K
T = temperature, K
Q = internal heat generation rate for radiolytic heating of the glass, W
V_{glass} = glass volume, m^3

The radiolytic heat generation rate is expressed as the sum of the products of the specific activity of the isotopes that are present in the glass and the decay energy for each isotope:

$$Q = \sum_j a_j e_j \qquad (3.3\text{-}2)$$

where

a_j = activity of the j^{th} isotope, Ci

e_j = decay energy of the j^{th} isotope, W/Ci

The total radiolytic heat generation rate is the sum of the individual heat generation rates for the glass in the melter heel, the glass in the melter spout, and the glass embedded in the melter refractory. In the model it is assumed that radiolytic heating occurs at a uniform rate throughout the glass. In itself, this is not necessarily a conservative assumption. However, because the melter glass has a relative high thermal conductivity compared to the LDCC, when it is modeled as a monolith, the melter glass should be at a relatively uniform temperature regardless of the distribution of the radiolytic heating. The assumption that the glass is concentrated in one central volume should yield a conservatively high estimate for the maximum temperature in the glass.

The heat transfer equation for the melter steel and refractory and the LDCC is

$$\rho c_p \frac{\partial T}{\partial t} - \nabla \bullet k \nabla T = 0 \qquad (3.3\text{-}3)$$

The equivalent thermal conductivity of the melter steel and refractory is computed by taking the volume average of the individual thermal conductivities of the steel and refractory:

$$k_{eq} = \frac{V_{ref} k_{ref} + V_{ss} k_{ss}}{V_{ref} + V_{ss} + V_{air,2}} \qquad (3.3\text{-}4)$$

where

k_{eq} = equivalent thermal conductivity for mixture of melter refractory and steel, W/m/K

k_{ss} = thermal conductivity of melter steel, W/m/K

V_{fb} = volume of refractory, m^3

This linear averaging method is consistent with an arrangement where structural steel beams radiate outward from the melter glass to the inner edge of the LDCC and provide a continuous path for heat transfer through the steel. The averaging accounts for the fraction of the total cross-sectional heat transfer area occupied by the refractory. Linear averaging provides a more realistic model for heat transfer in the melter than reciprocal averaging, which would follow from an assumption that the refractory and structural steel were randomly mixed. Melter glass temperatures calculated using a reciprocal averaging method for the combined thermal conductivity of the refractory and steel would yield calculated glass temperatures that would be unrealistically high. The same linear volume averaging is used to compute the equivalent density and heat capacity for the melter steel and refractory.

Heat losses and heat transfer associated with dehydration of cement hydrates in the LDCC are included in the COMSOL® model by incorporating the heat of dehydration into the effective heat capacity for the LDCC. The contribution of the combined heats of dehydration and evaporation equals the product of the heats of dehydration and evaporation, the mass fraction of hydrate in the LDCC, and the derivative of the fractional dehydration with respect to temperature.

Differentiation of the Arrhenius expression for the fraction dehydration (equation (3.2.2-1)) and substitution in the expression for the effective LDCC heat capacity yields the following equation.

$$c_p = c_{p,s} + \frac{(\Delta H_r + \lambda) m_{H_2O} A_r E_a}{m_{LDCC} M_{H_2O} R_g T^2} \exp\left(-\frac{E_a}{R_g T}\right) \tag{3.3-5}$$

where

$c_{p,s}$ = ordinary heat capacity for cement solids exclusive of reaction or phase change, J/kg/K

ΔH_r = heat of reaction for breaking hydrate bond, J/mole H_2O

M_{H_2O} = molecular mass of water, 0.018 kg/mole

m_{H_2O} = mass of water in LDCC hydrate, kg

m_{LDCC} = total mass of LDCC, kg

The orientation of the WVMP during HAC is not specified by 10 CFR 71.73. Different container orientations give different results for rates of heat transfer inside and outside the container. Inside the container, the orientation affects the rate of heat transfer through the air gap adjacent to the LDCC. If the container is upright, the hotter surface is above the air gap, and the heat transfer through the air gap is not enhanced by natural convection. If the container is upside down, the hotter surface is below the air gap, and the rate of heat transfer through the air gap increases due to natural convection. Enhancement of heat transfer in the air gap accelerates heating of the LDCC during fire exposure but also increases the rate of cooling after the fire, when heat is redistributed from the container frame to the LDCC. Because temperatures inside the LDCC peak during this cool-down period, it is not apparent whether enhancement of heat transfer by natural convection in the air gap results in higher or lower peak temperatures, amounts of water vapor generated by cement dehydration, and pressurization by this water vapor. Due to this uncertainty, HAC analyses are performed both with and without including natural convection in the air gap.

Outside the container, the orientation affects the rate of heat transfer from the top and bottom surfaces. During the fire exposure, the rate of natural convection heat transfer to the bottom of the container exceeds the corresponding rate of heat transfer to the top of the container. After the fire, the rate of natural convection from the top is greater than from the bottom. From these observations, it may be assumed that the net rate of heat transfer to the air gap is maximized when the container is upside down. In other words, for external natural convection, the upside down orientation is conservatively bounding with respect to heating of the air gap.

Natural convection is incorporated into the heat transfer equation for the air gap inside the WVMP using an effective thermal conductivity defined by

$$k_{eff} = k Nu_g \tag{3.3-6}$$

where

k_{eff} = effective gas thermal conductivity in the gap between the LDCC and the frame, accounting for natural convection, W/m/K

k = average gas thermal conductivity in the gap between the LDCC and the frame, W/m/K

Nu_g = Nusselt number for natural convection in the gap between the LDCC and the frame

The Nusselt number is evaluated using the Globe and Dropkin correlation for natural convection in a horizontal, enclosed gap (references 3-30 and 3-31), which takes the form

$$Nu_g = \frac{hL}{k} = 0.069 Ra_{L,g}^{1/3} Pr_g^{0.074} \tag{3.3-7}$$

where

L = gap height, m

$Ra_{L,g}$ = Rayleigh number based on gap height

Pr_g = Prandtl number

The Rayleigh number in this correlation is defined as

$$Ra_{L,g} = \frac{\rho \Delta\rho c_{p,g} g L^3}{\mu k} \tag{3.3-8}$$

where

ρ = average gas density, kg/m^3

$\Delta\rho$ = difference between gas density at top and bottom of gap, kg/m^3

$c_{p,g}$ = gas heat capacity, J/kg/K

g = gravitational acceleration, m/s^2

L = gap height, m

μ = average gas viscosity, kg/m/s

The Prandtl number is given by

$$Pr_g = \frac{c_{p,g}\mu}{k} \tag{3.3-9}$$

Natural convection heat transfer is included only for HAC, where it is assumed the gap is heated from below. Heat transfer in the air gap for NCT is modeled using molecular conduction only.

During NCT, the heat transfer equation for the steel frame is

$$\rho c_p \frac{\partial T}{\partial t} - \nabla \bullet k \nabla T = q''_i A_i - h_i A_i \left(T_{s,i} - T_a\right) \tag{3.3-10}$$

where

q''_i = surface heat flux due to insolation over the i^{th} surface (applies only to surface nodes), W/m^2

A_i = surface area for the i^{th} surface, m^2

h_i = surface heat transfer coefficient for the i^{th} surface (applies only to surface nodes), $W/m^2/K$

$T_{s,i}$ = temperature of the i^{th} surface, K

T_a = ambient temperature (or fire temperature for the HAC), K

For the fire exposure portion of the HAC transient, the heat transfer equation for the frame is

$$\rho c_p \frac{\partial T}{\partial t} - \nabla \bullet k \nabla T = \varepsilon_i \sigma A_i \left(T_{fire}{}^4 - T_{s,i}{}^4 \right) + h_i A_i \left(T_{fire} - T_{s,i} \right) \quad (3.3\text{-}11)$$

where

ε_i = emissivity for i^{th} surface, dimensionless

σ = Stefan-Boltzmann constant, $W/m^2/K^4$

T_{fire} = fire temperature, K

During the cool down portion of the HAC transient, the heat transfer equation for the frame becomes

$$\rho c_p \frac{\partial T}{\partial t} - \nabla \bullet k \nabla T = q''_i A_i - \varepsilon_i \sigma A_i \left(T_{s,i}{}^4 - T_a{}^4 \right) - h_i A_i \left(T_{s,i} - T_a \right) \quad (3.3\text{-}12)$$

As stipulated by 10 CFR 71.71, it is assumed that the air surrounding the WVMP during NCT is still. Consequently, the heat transfer coefficients are based on natural convection from exterior surfaces. Different correlations are applied for natural convection to the top surface of the WVMP, to the vertical side surfaces, and to the bottom surface. All three correlations are for turbulent natural convection; due to the large size of the WVMP, the natural convection flow is in the turbulent range for any significant temperature differences. The COMSOL® correlation for the side walls is given by Churchill and Chu (references 3-30 and 3-31).

$$h_v = \left(\frac{k_{air}}{L_v} \right) \left(0.825 + \frac{0.387 Ra^{1/6}}{\left(1 + \left(\frac{0.492}{Pr} \right)^{9/16} \right)^{8/27}} \right)^2 \quad (3.3\text{-}13)$$

where

h_v = heat transfer coefficient for natural convection to the sides of the WVMP, $W/m^2/K$

k_{air} = thermal conductivity of air, W/m/K

L_v = GMP height, m

Ra = Rayleigh number

Pr = Prandtl number

For natural convection from the top of the WVMP, COMSOL® uses a natural convection correlation recommended by Lloyd and Moran (references 3-29 and 3-31):

$$h_u = \left(\frac{k_{air}}{L_u}\right) 0.15 Ra^{1/3} \tag{3.3-14}$$

where

h_u = heat transfer coefficient for natural convection to the top of the WVMP, W/m²/K

L_u = GMP width at the top of the WVMP, m

Finally, for convection from the bottom surface of the WVMP, COMSOL® utilizes the following generalized correlation (reference 3-32).

$$h_d = \left(\frac{k_{air}}{L_d}\right) 0.27 Ra^{1/4} \tag{3.3-15}$$

where

h_d = heat transfer coefficient for natural convection to the bottom of the WVMP, W/m²/K

L_d = WVMP width at the bottom of the WVMP, m

The heat transfer coefficient given by equation (3.3-11) is used only for the HAC analysis.

The Rayleigh number in the preceding correlations is defined by

$$Ra = \frac{\rho_{air} \Delta\rho_{air} c_{p,air} g L^3}{\mu_{air} k_{air}} \tag{3.3-16}$$

where

ρ_{air} = air density, kg/m³

$\Delta\rho_{air}$ = difference between the density of air at ambient temperature and the average density at the WVMP surface, kg/m³

$c_{p,air}$ = air heat capacity, J/kg/K

g = gravitational acceleration, m/s²

L = GMP component height or equivalent width, m

μ_{air} = air viscosity, kg/m/s

The Prandtl number is given by

$$\Pr = \frac{c_{p,air}\mu_{air}}{k_{air}} \tag{3.3-17}$$

All gas properties except the density difference are evaluated at a temperature midway between the ambient temperature and the average temperature at the WVMP surface.

Surface heat losses during HAC are modeled using the same natural convection correlations. These correlations give a conservative estimate of heat losses for HAC because they assume that there is no forced convection associated with the presence of the flames. For HAC, heat transfer is conservatively modeled by assuming there is no heat transfer to the bottom surface during the cool-down period after the fire exposure.

3.3.2 Heat and Cold

Bounding temperatures for NCT with insolation are evaluated using a transient calculation in which 12 hour periods of insolation at the specified rates are followed by 12 hour of no insolation. This approach is consistent with the intent of 10 CFR 71.71, which implies that the limiting condition is continual outdoor exposure of the WVMP, with insolation during daylight hours and no insolation at night. The heat losses to the ambient air are assumed to continue day and night. The ambient air temperature is set equal to 100°F for nighttime exposure as well as daytime exposure. The COMSOL® calculations were extended to 30 days to assure an approach to a limiting diurnal temperature cycle. The limiting NCT conditions are evaluated at the end of the 12-hour period of insolation on the thirtieth day.

Table 3-6 summarizes the results of the NCT thermal analysis. The maximum temperature for exposure to 100°F air is 105.4°F, for the melter glass. Although the COMSOL® model predicts a surface temperature very close to the ambient air temperature, the glass temperature must be assigned as the bounding maximum surface temperature, because of the close approach of one arm of the melter to the bolted side door on one side of the WVMP. The maximum glass temperature of 105.4°F does not closely approach the limiting surface temperature of 185°F. The minimum temperatures for exposure to -20°F and -40°F ambient air are -19.9°F and -39.9°F, respectively. The maximum temperature with insolation is 209.4°F, for the container.

In keeping with the intent of 10 CFR 71.71, the maximum temperature is evaluated only at the end of 30 days, when the postulated diurnal temperature variations approach their cyclic limit. Although the maximum temperature after one day of insolation exceeds the maximum temperature for this limit, the one-day results are not used, because the calculation approach is not representative of the actual temperature cycles for heating of the WVMP by insolation. The maximum pressure is computed only for the case of insolation and exposure to 100°F air.

Figures 3-7 and 3-8 illustrate the development of the NCT temperature profile at the end of the 12-hour heating cycle, after 10 days and 30 days. It may be seen that the transient temperature distribution approaches a limiting profile reasonably closely after one cycle and quite closely after 10 days. The maximum temperature is 209.4°F and the minimum temperature is 133.1°F. Temperatures in the melter and the LDCC are close to the minimum temperature due to the relatively low thermal conductivity of the LDCC. The temperature increases toward the maximum only in the air pocket and the top wall of the WVMP.

The WVMP is a unique content package analyzed for a single use shipment. Therefore, the requirement for analysis of the effects of degradation in heat transfer due to expansion and contraction and other aging phenomena is not applicable, and these effects were not investigated. The effect of air gaps on material thermal conductivity is incorporated, either explicitly, as for the air pockets above the LDCC layer and inside the melter, or implicitly, in the bulk thermal conductivity of the LDCC.

Table 3-6. Limiting Conditions for NCT

NCT, No Insolation, 100°F Ambient Air		
Component	**Maximum Temperature**	
Overall	105.4°F	
Glass	105.4°F(1)	
Melter	101.5°F	
LDCC	101.0°F	
Air Pocket	100.3°F	
Container	100.2°F	
NCT, No Insolation, -20°F Ambient Air		
Component	**Minimum Temperature**	
Overall	-19.9°F	
Glass	-18.7°F(1)	
Melter	-19.2°F	
LDCC	-19.9°F	
Air Pocket	-19.9°F	
Container	-19.9°F	
NCT, No Insolation, -40°F Ambient Air		
Component	**Minimum Temperature**	
Overall	-39.9°F	
Glass	-38.7°F(1)	
Melter	-39.2°F	
LDCC	-39.9°F	
Air Pocket	-39.9°F	
Container	-39.9°F	
With Insolation, 100 °F Ambient Air		
Component	**Maximum Temperature**	**Maximum Pressure (psig)**
Overall	209.4°F	12.0
Glass	146.3°F	-
Melter	144.6°F	-
LDCC	183.5°F	-
Air Pocket	208.9°F	-
Container	209.4°F	-

NOTE: (1) The glass temperature exceeds the melter temperature due to radiolytic heating.

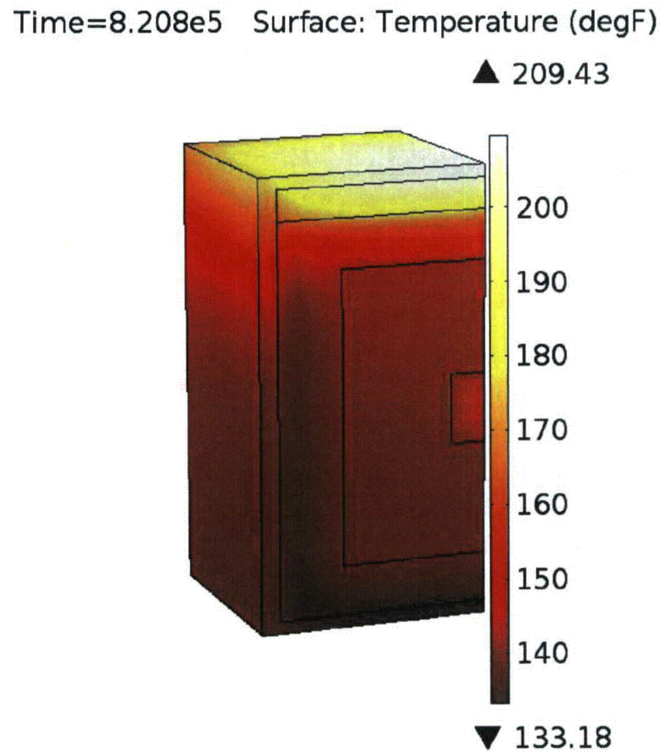


Figure 3-7. Temperature Profile for NCT with Insolation after 10 Days

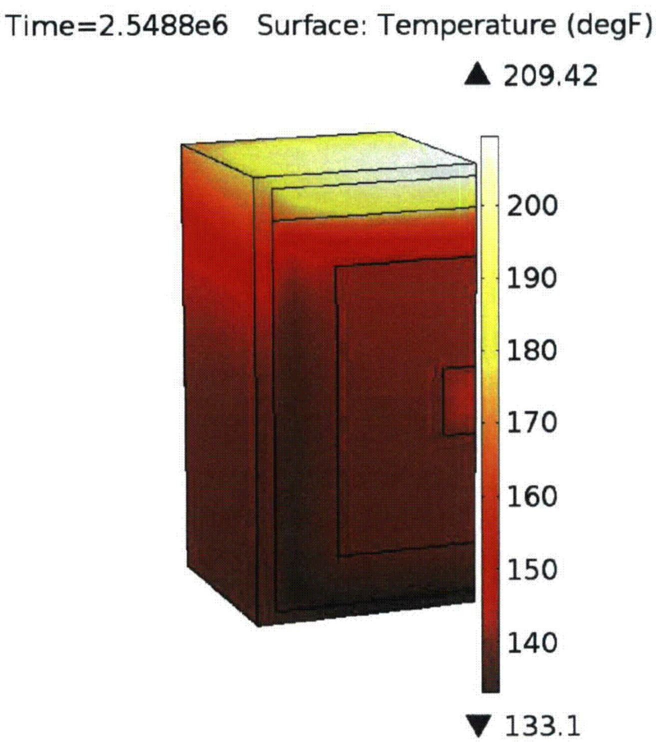


Figure 3-8. Temperature Profile for NCT with Insolation after 30 Days

3.3.3 Maximum Normal Operating Pressure

The maximum pressure is calculated by assuming all of the hydrated water content is released as vapor due to heating of the LDCC and accumulates in the upper air pocket. It is assumed any pressure that might develop internally in the concrete pores is contained within the LDCC layer. The gas volume inside the LDCC pores is conservatively neglected in the pressure calculation. The air pocket pressure computation is based on the ideal gas law and is performed separately from the COMSOL® heat transfer calculations. The equation for the maximum pressure is

$$P = P_0\left(1+\frac{n_{H_2O}}{n_{air}}\right)\frac{T}{T_0} \tag{3.3.2-1}$$

where

P = maximum pressure for NCT or HAC, atm or psia

P_0 = initial pressure, assumed to be equal to atmospheric pressure, atm or psia

n_{H_2O} = number of moles of water vapor generated by dehydration of the LDCC

n_{air} = number of moles of air initially in the air gap

T = average temperature in the air gap, K

T_0 = initial temperature in the air gap, assumed to be equal to 20 °C or 293.15 K

The number of moles of air at the start of the NCT transient is calculated using the ideal gas law relation

$$n_{air} = \frac{P_0 V_{air}}{R_g T_0} \tag{3.3.2-2}$$

where

V_{air} = volume of the air gap, m^3

R_g = gas law constant, 8.2057E-5 m^3 atm/mol/K

The number of moles of water evaporated is computed by taking the difference between the number of moles of hydrated water initially in the LDCC and the minimum number of moles that remain hydrated at any time during the HAC fire or cool-down period:

$$n_{H_2O} = \left(\rho_{H_2O,LDCC,0} - \bar{\rho}_{H_2O,LDCC}\right)V_{LDCC} \tag{3.3.2-3}$$

where

$\rho_{H_2O,LDCC,0}$ = initial concentration of hydrated water in the LDCC, kg/m^3

$\bar{\rho}_{H_2O,LDCC}$ = minimum average bulk concentration of hydrated water in the LDCC, kg/m^3

V_{LDCC} = total LDCC volume, m^3

The maximum WVMP pressure of 12.0 psig is calculated from an assumption that the active pressurization of the container is from the air pocket at the top of the WVMP. The calculated pressure is based on heating of this air from an assumed initial temperature of 68°F to an average temperature of 184.30°F. The pressurization also accounts for the vaporization of 62 moles of hydrated water to add to the 126 moles of air initially present in the air pocket.

3.4 Thermal Evaluation under Hypothetical Accident Conditions

The HAC is modeled using a transient calculation in which the WVMP is fully engulfed by the 1475°F fire. The analysis method is the same as that used for NCT, described in Section 3.2.

3.4.1 Initial Conditions

The initial temperature distribution is set equal to the limiting NCT temperature distribution, at the end of 12 hour insolation, at rates of 800 cal/cm^2 on the top surface and 200 cal/cm^2 on the side surfaces.

As stated in Section 3.3.1, the orientation of the WVMP during HAC is not specified by 10 CFR 71.73. To maximize the temperature of the air pocket inside the WVMP and hence the pressurization due to heating, it is assumed that the WVMP is upside down, so that natural convection heat losses from the wall adjacent to the air pocket are minimized during the cool-down period, when the interior temperatures reached their maximum values. (The natural convection heat transfer coefficient for heated surfaces facing down is less than the corresponding heat transfer coefficients for heated surfaces facing up or for vertical surfaces.)

Inclusion or omission of natural convection in the air pocket inside the WVMP gave mixed results for changes in the maximum calculated temperatures and pressure. The maximum pressure due to heating and generation of water vapor from cement dehydration is higher with natural convection omitted. Because the margin between the calculated maximum pressure and the limiting pressure is smaller than the margins between calculated and maximum pressures, the conservative approach is to cite the results calculated without including natural convection in the WVMP air pocket. Therefore, the reported results are those calculated without natural convection. Two sets of results are reported: one set that is based on molecular heat conduction in the WVMP air pocket (omitting natural convection) and another set that includes natural convection in the WVMP air pocket.

The structural analysis in Chapter 2 demonstrates minimal effects on the WVMP due to HAC accidents. Based on these analyses the thermal analysis does not incorporate any effects to the WVMP dimensions or material properties due to HAC drops and crushes. The HAC temperatures and pressures calculated by the thermal analysis are bounding for HAC accidents.

3.4.2 Fire Test Conditions

The fire is applied for 30 minutes, after which time it is assumed that the WVMP loses heat to 100°F ambient air and receives insolation at the same rate as during NCT. The transient calculation is continued 720 minutes into the cool-down period to ensure that maximum local temperatures are reached and that the maximum amount of dehydration has occurred. (It is assumed that the dehydration reaction is reversible in the sense that the cement will rehydrate as it cools.)

3.4.3 Maximum Temperatures and Pressure

Table 3-7 reports the results of the HAC thermal analysis without natural convection in the WVMP air pocket. The maximum temperature of 1221.2°F is located at the corners of the WVMP. The average temperature of the LDCC increases to 204.0°F, and the average temperature of the air pocket rises to 599.4°F. The temperatures of the melter and the melter glass are virtually unaffected by the 30 minute fire. The maximum pressure for HAC of 73.0 psig is calculated based on the maximum average air pocket temperature and a maximum amount of evaporation of 249 moles of water.

Table 3-8 reports the results of the HAC thermal analysis with natural convection in the WVMP air pocket. The maximum temperature of 1221.1°F is located at the corners of the WVMP. The average temperature of the LDCC increases to 196.7°F, and the average temperature of the air pocket rises to 577.7°F. Again, the temperatures of the melter and the melter glass are virtually unaffected by the 30 minute fire. The maximum pressure for HAC of 65.5 psig is calculated based on the maximum average air pocket temperature and a maximum amount of evaporation of 224 moles of water.

The maximum Maximum pressure conditions occur after the end of the fire exposure, during the cool-down period. The exact times at which the pressures peaks is are not listed because the maximum pressure is based on a combination of the maximum air pocket temperature and the maximum amount of hydrated water that evaporates; these maximums are reached at different times.

Table 3-7. Limiting Conditions for HAC Without Natural Convection in the WVMP Air Pocket

With Insolation, 100°F Ambient Air, 1475°F Fire Exposure for 30 minutes				
Component	**Maximum Temperature**	**Average Temperature**	**Maximum Pressure (psig)**	**Time for Maximum Temp. (minutes)**
Overall	1221.2 1 °F	-	73.0	30
Glass	146.3°F	-	-	750+(1)
Melter	145.2°F	-	-	750+(2)
LDCC	693.0°F	204.0°F	-	68
Air Pocket	727.9°F	599.4°F	-	68
Container	1221.2 1 °F	-	-	30

NOTES: (1) The maximum glass temperature for HAC is the same as for NCT.

(2) The glass and melter temperatures had not peaked 750 minutes after the start of the fire (720 minutes after the end of the fire exposure), but are judged to have been within 1°F of their peak values.

Table 3-8. Limiting Conditions for HAC with Natural Convection in the WVMP Air Pocket

With Insolation, 100°F Ambient Air, 1475°F Fire Exposure for 30 minutes				
Component	**Maximum Temperature**	**Average Temperature**	**Maximum Pressure (psig)**	**Time for Maximum Temp. (minutes)**
Overall	1221.2 °F	-	65.5	30
Glass	146.6°F	-	-	750+(1)
Melter	144.9°F	-	-	750+(2)
LDCC	693.7°F	196.7°F	-	43
Air Pocket	721.9°F	577.7°F	-	43
Container	1221.2 °F	-	-	30

NOTES: (1) The maximum glass temperature for HAC is the same as for NCT.

(2) The glass and melter temperatures had not peaked 750 minutes after the start of the fire (720 minutes after the end of the fire exposure), but are judged to have been within 1°F of their peak values.

Figures 3-9 and 3-10 shows the variation of the average LDCC and WVMP air pocket temperatures during the HAC fire transient, with and without natural convection in the air pocket. The average LDCC temperature reaches its maximum value of 204.0°F 592 minutes after the start of the fire (and 562 minutes after the end of the fire exposure), and the average air pocket temperature peaks at 599.4°F 68 minutes after the start of the fire. With natural convection, the average LDCC temperature peaks at 196.71°F 415 minutes after the start of the fire, and the maximum air pocket temperature peaks at 577.65°F 43 minutes after the start of the fire.

Figures 3-10 11 and 3-12 depicts the variations of the average bulk hydrated water content of the LDCC during the fire transient, with and without natural convection in the air pocket. The minimum hydrated water content, with the evaporation of a maximum 249 moles of water, occurs 256 minutes after the start of the fire, without natural convection. With natural convection in the air gap, the maximum evaporation is 224 moles 160 minutes after the start of the fire.

Figure 3-11 13 shows the HAC temperature profile at the end of the 30 minutes fire exposure, when the WVMP wall temperature is at its maximum, without natural convection in the air gap. It may be noted that the 1221.2°F maximum temperature is confined to the eight corners of the WVMP. The average container plate temperatures remain below 800°F. The average temperature of the hottest plate, adjacent to the WVMP air pocket, is 782.2°F on the outer surface and 626.9°F on the inside surface. The average plate temperature is approximately equal to the average of these two temperatures, which is 711.1°F. These temperatures do not change significantly when natural convection in the air gap is included. Except for that portion of the LDCC closest to the container and the air pocket at the end of the WVMP, the temperatures inside the WVMP do not vary significantly from their initial values for NCT with insolation.

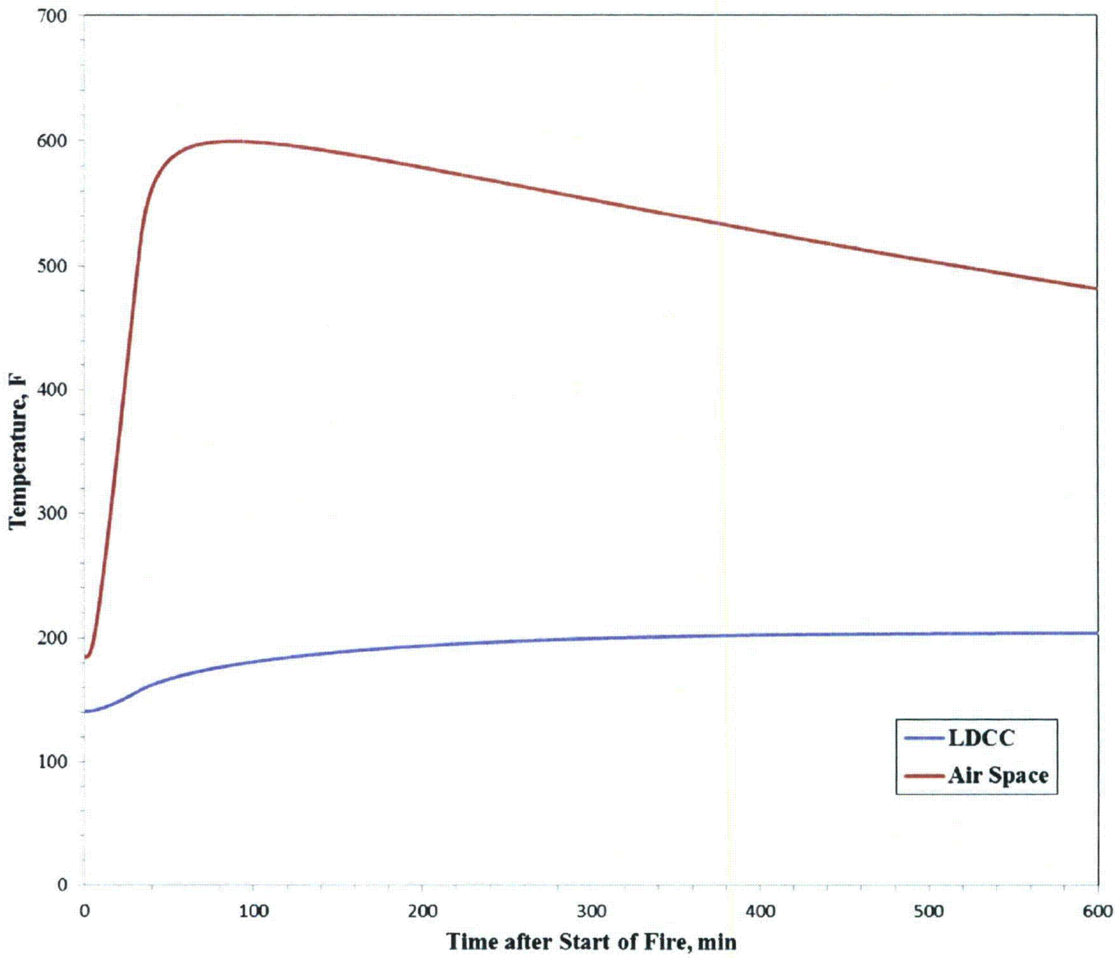


Figure 3-9. Variation of Average LDCC and WVMP Air Pocket Temperatures during the HAC Fire Scenario, Without Natural Convection in the WVMP Air Pocket

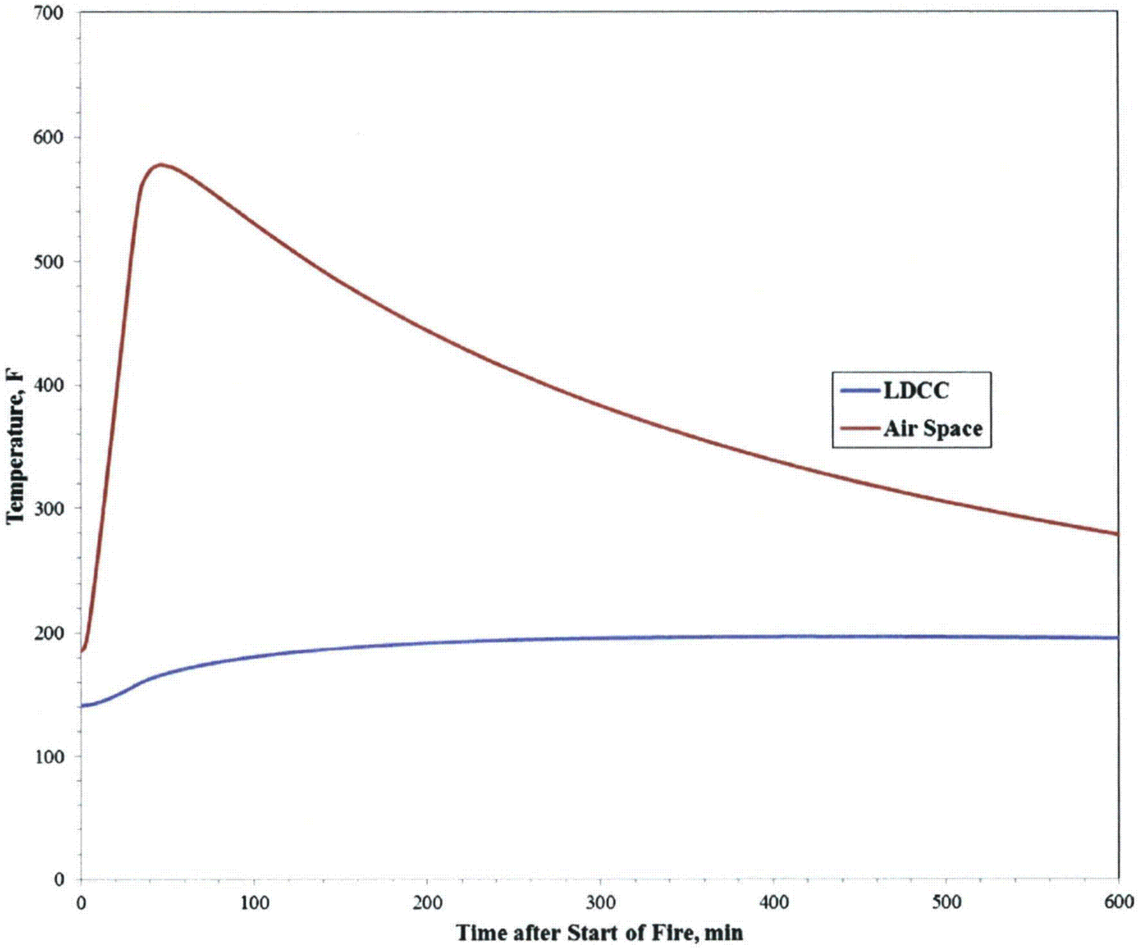


Figure 3-10. Variation of Average LDCC and WVMP Air Pocket Temperatures during the HAC Fire Scenario, With Natural Convection in the WVMP Air Pocket

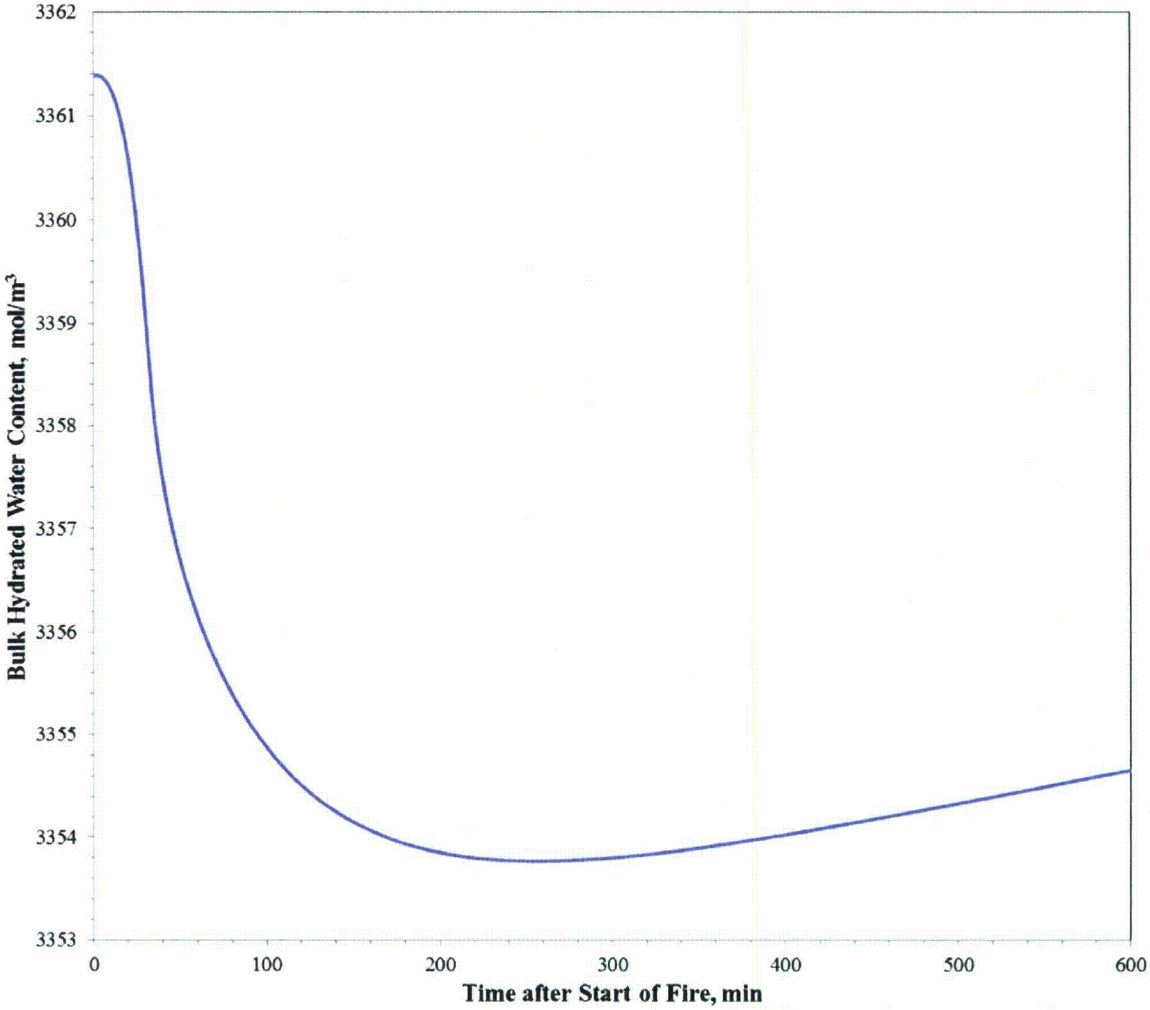


Figure 3-11. Variation of Average Bulk Hydrated Water Content in LDCC During HAC Fire Scenario, Without Natural Convection in the Air Pocket

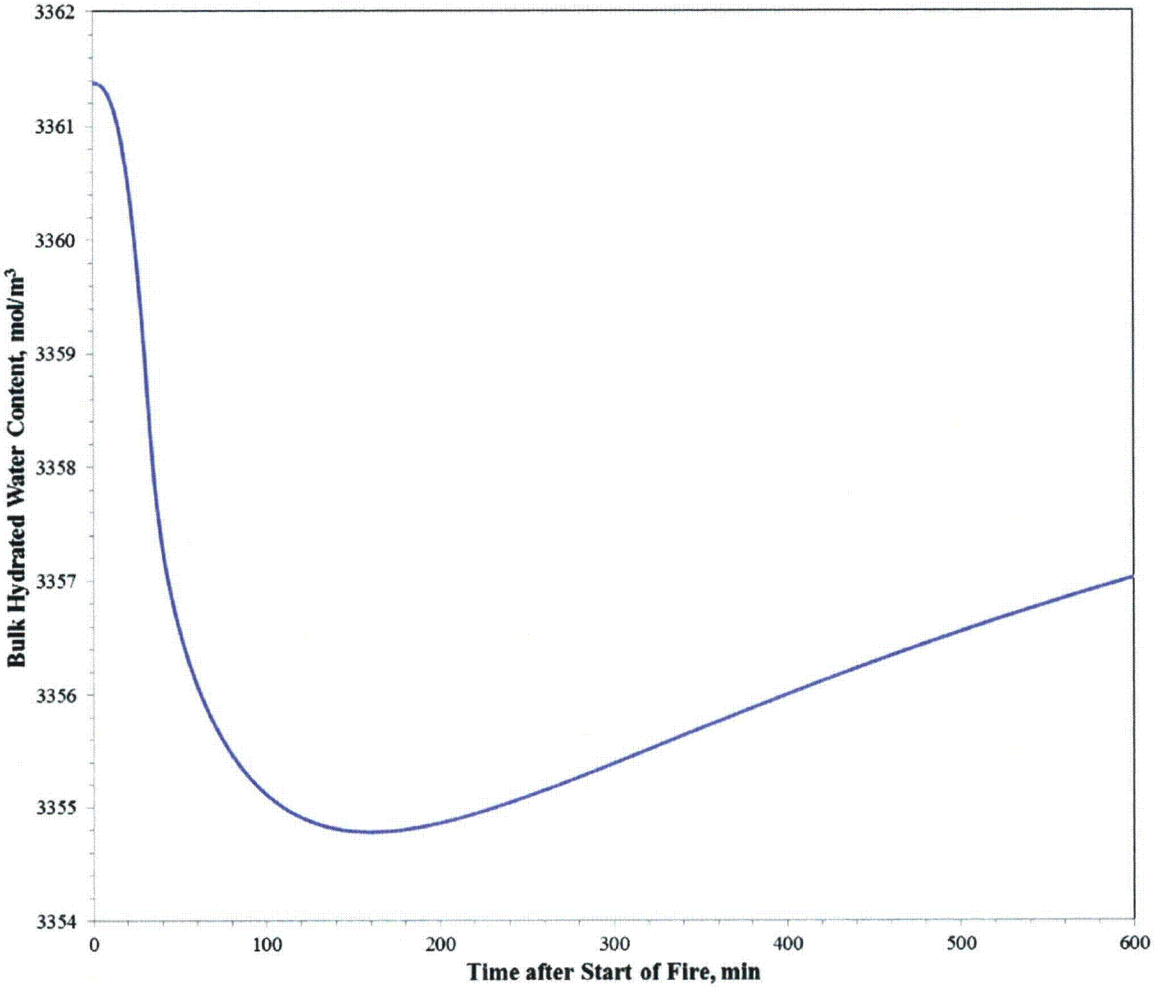


Figure 3-12. Variation of Average Bulk Hydrated Water Content in LDCC During HAC Fire Scenario, With Natural Convection in the WVMP Air Pocket

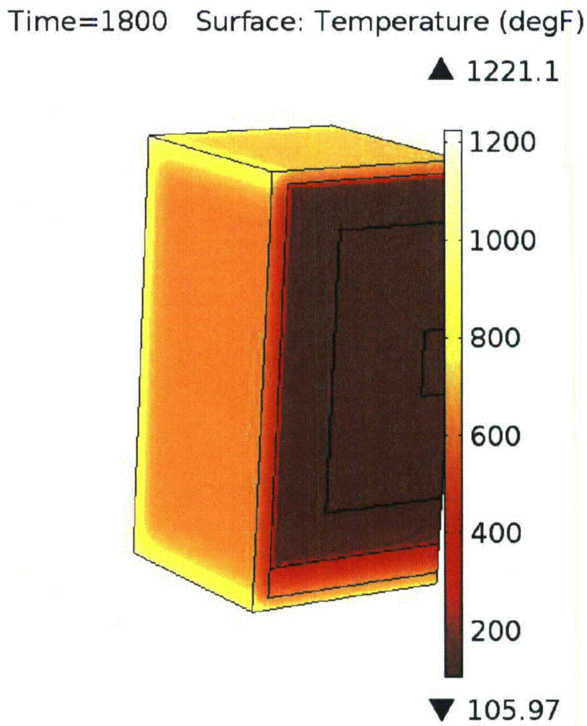


Figure 3-13. Surface Temperature Profile for HAC after 30 Minutes Fire Exposure, Without Natural Convection in the WVMP Air Pocket

3.4.4 Maximum Thermal Stresses

The WVMP does not include any components for which there would be adverse consequences due to a thermal stress failure. Thermal stresses in the container walls are addressed in Chapter 2 of this SAR. Therefore, a thermal stress analysis is not included as part of the HAC thermal evaluation.

3.4.5 Accident Conditions for Fissile Material Packages for Air Transport

Not applicable.

3.5 Appendix

This appendix contains the following information:

3.5.1 References

3.5.2 Summary of the Radionuclide Content and Radiolytic Heating for the Grouted Melter Package

3.5.3 Parameter and Variable List for COMSOL® Multiphysics Model

3.5.4 *Thermal Analysis for West Valley Melter Package*, Calculation Number M-CLC-A-00498, Savannah River National Laboratory, Revision 1, November 2014. (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Requests for Withholding*)

APPENDIX 3.5.1 – REFERENCES

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3-2 10 CFR Part 71.73, *Packaging and Transportation of Radioactive Material: Hypothetical accident conditions*, Code of Federal Regulations, July 2013.

3-3 10 CFR Part 71.43, *General Standards for All Packages*, Code of Federal Regulations, July 2014.

3-4 10 CFR Part 71.51, *Additional Requirements for Type B Packages*, Code of Federal Regulations, July 2014.

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3-10 *Melter Spout_062614.rad*, C. Brandjes, Ameriphysics, LLC, Knoxville, Tennessee, June 26, 2014. (provided)

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APPENDIX 3.5.2 – SUMMARY OF RADIONUCLIDE CONTENT AND RADIOLYTIC HEATING FOR WVMP

Table A-1. Radionuclide Content and Radiolytic Heating for Glass in Melter

Isotope	Ci	Mev/d	W/Ci	W
C-14	3.47E-03	0.0495	2.93E-04	1.02E-06
K-40	1.50E-02	0.6785	4.02E-03	6.03E-05
Mn-54	1.44E-06	0.8402	4.98E-03	7.16E-09
Co-60	3.16E-03	2.6007	1.54E-02	4.87E-05
Ni-63	1.52E-01	0.0174	1.03E-04	1.57E-05
Sr-90	3.12E+01	0.1957	1.16E-03	3.62E-02
Y-90	3.12E+01	0.9331	5.53E-03	1.73E-01
Zr-95	1.30E-20	0.8506	5.04E-03	6.55E-23
Nb-95	2.86E-20	0.8091	4.80E-03	1.37E-22
Nb-95m	1.49E-22	0.2497	1.48E-03	2.20E-25
Tc-99	2.01E-03	0.1013	6.01E-04	1.21E-06
Cs-137	5.42E+02	0.1884	1.12E-03	6.05E-01
Ba-137m	5.12E+02	0.6617	3.92E-03	2.01E+00
Eu-154	8.12E-02	1.5223	9.02E-03	7.33E-04
Hg-206	9.79E-16	0.5426	3.22E-03	3.15E-18
Tl-206	6.88E-14	0.5399	3.20E-03	2.20E-16
Tl-207	2.56E-09	0.4975	2.95E-03	7.55E-12
Tl-208	2.72E-03	3.9716	2.35E-02	6.40E-05
Tl-209	8.09E-08	2.8302	1.68E-02	1.36E-09
Tl-210	6.54E-11	4.0331	2.39E-02	1.56E-12
Pb-209	3.75E-06	0.1974	1.17E-03	4.38E-09
Pb-210	5.16E-08	0.0457	2.71E-04	1.40E-11
Pb-211	2.57E-09	0.5187	3.07E-03	7.89E-12
Pb-212	7.56E-03	0.3217	1.91E-03	1.44E-05
Pb-214	3.11E-07	0.5481	3.25E-03	1.01E-09
Bi-209	8.10E-25	----	----	----
Bi-210	5.14E-08	0.3889	2.31E-03	1.18E-10
Bi-211	2.57E-09	6.733	3.99E-02	1.02E-10
Bi-212	7.56E-03	2.8247	1.67E-02	1.27E-04
Bi-213	3.75E-06	0.6963	4.13E-03	1.55E-08
Bi-214	3.11E-07	2.1436	1.27E-02	3.96E-09
Bi-215	2.10E-15	0.9228	5.47E-03	1.15E-17
Po-210	4.71E-08	5.4075	3.21E-02	1.51E-09
Po-211	7.01E-12	7.5944	4.50E-02	3.15E-13
Po-212	4.84E-03	8.9541	5.31E-02	2.57E-04
Po-213	3.67E-06	8.537	5.06E-02	1.86E-07
Po-214	3.11E-07	7.8335	4.64E-02	1.45E-08
Po-215	2.57E-09	7.5263	4.46E-02	1.14E-10
Po-216	7.56E-03	6.9064	4.09E-02	3.10E-04
Po-218	3.11E-07	6.1135	3.62E-02	1.13E-08
At-215	1.03E-14	8.178	4.85E-02	4.97E-16
At-217	3.75E-06	7.2011	4.27E-02	1.60E-07
At-218	5.92E-11	6.8053	4.03E-02	2.39E-12
At-219	2.17E-15	6.1343	3.64E-02	7.87E-17
Rn-217	4.50E-10	7.8856	4.67E-02	2.10E-11
Rn-218	5.92E-14	7.2626	4.31E-02	2.55E-15
Rn-219	2.57E-09	6.9456	4.12E-02	1.06E-10
Rn-220	7.56E-03	6.4047	3.80E-02	2.87E-04
Rn-222	3.11E-07	5.5903	3.31E-02	1.03E-08

Table A-1. Radionuclide Content and Radiolytic Heating for Glass in Melter (continued)

Isotope	Ci	Mev/d	W/Ci	W
Fr-221	3.75E-06	6.4582	3.83E-02	1.43E-07
Fr-223	3.61E-11	0.4415	2.62E-03	9.44E-14
Ra-223	2.57E-09	5.9895	3.55E-02	9.11E-11
Ra-224	7.56E-03	5.7893	3.43E-02	2.60E-04
Ra-225	3.76E-06	0.1194	7.08E-04	2.66E-09
Ra-226	3.12E-07	4.8716	2.89E-02	9.00E-09
Ra-228	5.14E-05	0.0163	9.66E-05	4.97E-09
Ac-225	3.75E-06	5.9338	3.52E-02	1.32E-07
Ac-227	2.61E-09	0.0853	5.06E-04	1.32E-12
Ac-228	5.14E-05	1.3166	7.80E-03	4.01E-07
Th-227	2.55E-09	6.1955	3.67E-02	9.36E-11
Th-228	7.56E-03	5.5202	3.27E-02	2.47E-04
Th-229	3.78E-06	5.1772	3.07E-02	1.16E-07
Th-230	6.05E-05	4.7702	2.83E-02	1.71E-06
Th-231	6.15E-05	0.1891	1.12E-03	6.89E-08
Th-232	6.74E-05	4.0829	2.42E-02	1.63E-06
Th-234	3.74E-04	0.0728	4.32E-04	1.61E-07
Pa-231	1.55E-08	5.158	3.06E-02	4.75E-10
Pa-233	1.05E-03	0.438	2.60E-03	2.73E-06
Pa-234	5.61E-07	1.8755	1.11E-02	6.24E-09
Pa-234m	3.74E-04	0.8334	4.94E-03	1.85E-06
U-232	7.31E-03	5.4135	3.21E-02	2.35E-04
U-233	3.35E-03	4.9085	2.91E-02	9.75E-05
U-234	1.60E-03	4.8587	2.88E-02	4.62E-05
U-235	6.15E-05	4.6891	2.78E-02	1.71E-06
U-235m	2.61E-02	0	0.00E+00	0.00E+00
U-236	1.84E-04	4.5723	2.71E-02	4.99E-06
U-237	7.37E-06	0.3433	2.04E-03	1.50E-08
U-238	3.74E-04	4.2691	2.53E-02	9.46E-06
Np-237	1.05E-03	4.9529	2.94E-02	3.09E-05
Np-239	5.97E-03	0.4469	2.65E-03	1.58E-05
Pu-238	1.04E-01	5.593	3.32E-02	3.44E-03
Pu-239	2.61E-02	5.2442	3.11E-02	8.11E-04
Pu-240	2.01E-02	5.2559	3.12E-02	6.25E-04
Pu-241	2.99E-01	0.0054	3.20E-05	9.57E-06
Am-241	4.95E-01	5.6379	3.34E-02	1.66E-02
Am-243	5.97E-03	5.4402	3.22E-02	1.93E-04
Cm-242	3.08E-10	6.2156	3.68E-02	1.14E-11
Cm-243	2.16E-03	6.1624	3.65E-02	7.90E-05
Cm-244	4.70E-02	5.9014	3.50E-02	1.64E-03
Totals:	**1.12E+03**			**2.85E+00**

Table A-2. Radionuclide Content and Radiolytic Heating for Glass in Spout

Isotope	Ci	Mev/d	W/Ci	W
C-14	2.22E-03	0.0495	2.93E-04	6.51E-07
K-40	8.60E-03	0.6785	4.02E-03	3.46E-05
Mn-54	5.00E-07	0.8402	4.98E-03	2.49E-09
Co-60	5.47E-03	2.6007	1.54E-02	8.43E-05
Ni-63	9.80E-02	0.0174	1.03E-04	1.01E-05
Sr-90	6.33E+01	0.1957	1.16E-03	7.35E-02
Y-90	6.33E+01	0.9331	5.53E-03	3.50E-01
Zr-95	3.17E-22	0.8506	5.04E-03	1.60E-24
Nb-95	6.99E-22	0.8091	4.80E-03	3.35E-24
Nb-95m	3.63E-24	0.2497	1.48E-03	5.37E-27
Tc-99	1.57E-02	0.1013	6.01E-04	9.43E-06
Cs-137	8.57E+02	0.1884	1.12E-03	9.57E-01
Ba-137m	8.09E+02	0.6617	3.92E-03	3.17E+00
Eu-154	1.04E-01	1.5223	9.02E-03	9.41E-04
Hg-206	7.14E-16	0.5426	3.22E-03	2.30E-18
Tl-206	5.01E-14	0.5399	3.20E-03	1.60E-16
Tl-207	1.86E-09	0.4975	2.95E-03	5.49E-12
Tl-208	1.73E-03	3.9716	2.35E-02	4.08E-05
Tl-209	5.58E-08	2.8302	1.68E-02	9.36E-10
Tl-210	4.50E-11	4.0331	2.39E-02	1.07E-12
Pb-209	2.58E-06	0.1974	1.17E-03	3.02E-09
Pb-210	3.76E-08	0.0457	2.71E-04	1.02E-11
Pb-211	1.87E-09	0.5187	3.07E-03	5.74E-12
Pb-212	4.82E-03	0.3217	1.91E-03	9.20E-06
Pb-214	2.14E-07	0.5481	3.25E-03	6.95E-10
Bi-209	5.97E-25	----	----	----
Bi-210	3.75E-08	0.3889	2.31E-03	8.63E-11
Bi-211	1.87E-09	6.733	3.99E-02	7.46E-11
Bi-212	4.82E-03	2.8247	1.67E-02	8.08E-05
Bi-213	2.58E-06	0.6963	4.13E-03	1.07E-08
Bi-214	2.14E-07	2.1436	1.27E-02	2.72E-09
Bi-215	1.53E-15	0.9228	5.47E-03	8.35E-18
Po-210	3.45E-08	5.4075	3.21E-02	1.11E-09
Po-211	5.10E-12	7.5944	4.50E-02	2.30E-13
Po-212	3.09E-03	8.9541	5.31E-02	1.64E-04
Po-213	2.53E-06	8.537	5.06E-02	1.28E-07
Po-214	2.14E-07	7.8335	4.64E-02	9.94E-09
Po-215	1.87E-09	7.5263	4.46E-02	8.33E-11
Po-216	4.82E-03	6.9064	4.09E-02	1.97E-04
Po-218	2.14E-07	6.1135	3.62E-02	7.76E-09
At-215	7.47E-15	8.178	4.85E-02	3.62E-16
At-217	2.58E-06	7.2011	4.27E-02	1.10E-07
At-218	4.07E-11	6.8053	4.03E-02	1.64E-12
At-219	1.57E-15	6.1343	3.64E-02	5.72E-17
Rn-217	3.10E-10	7.8856	4.67E-02	1.45E-11
Rn-218	4.07E-14	7.2626	4.31E-02	1.75E-15
Rn-219	1.87E-09	6.9456	4.12E-02	7.69E-11
Rn-220	4.82E-03	6.4047	3.80E-02	1.83E-04
Rn-222	2.14E-07	5.5903	3.31E-02	7.10E-09
Fr-221	2.58E-06	6.4582	3.83E-02	9.89E-08
Fr-223	2.62E-11	0.4415	2.62E-03	6.87E-14
Ra-223	1.87E-09	5.9895	3.55E-02	6.63E-11
Ra-224	4.82E-03	5.7893	3.43E-02	1.66E-04

Table A-2. Radionuclide Content and Radiolytic Heating for Glass in Spout (continued)

Isotope	Ci	Mev/d	W/Ci	W
Ra-225	2.59E-06	0.1194	7.08E-04	1.83E-09
Ra-226	2.14E-07	4.8716	2.89E-02	6.19E-09
Ra-228	3.41E-05	0.0163	9.66E-05	3.29E-09
Ac-225	2.58E-06	5.9338	3.52E-02	9.09E-08
Ac-227	1.90E-09	0.0853	5.06E-04	9.61E-13
Ac-228	3.41E-05	1.3166	7.80E-03	2.66E-07
Th-227	1.85E-09	6.1955	3.67E-02	6.81E-11
Th-228	4.82E-03	5.5202	3.27E-02	1.58E-04
Th-229	2.60E-06	5.1772	3.07E-02	7.99E-08
Th-230	3.89E-05	4.7702	2.83E-02	1.10E-06
Th-231	3.95E-05	0.1891	1.12E-03	4.43E-08
Th-232	4.34E-05	4.0829	2.42E-02	1.05E-06
Th-234	2.41E-04	0.0728	4.32E-04	1.04E-07
Pa-231	1.07E-08	5.158	3.06E-02	3.26E-10
Pa-233	7.09E-04	0.438	2.60E-03	1.84E-06
Pa-234	3.62E-07	1.8755	1.11E-02	4.02E-09
Pa-234m	2.41E-04	0.8334	4.94E-03	1.19E-06
U-232	4.66E-03	5.4135	3.21E-02	1.50E-04
U-233	2.16E-03	4.9085	2.91E-02	6.29E-05
U-234	1.03E-03	4.8587	2.88E-02	2.98E-05
U-235	3.95E-05	4.6891	2.78E-02	1.10E-06
U-235m	3.01E-02	0	0.00E+00	0.00E+00
U-236	1.19E-04	4.5723	2.71E-02	3.23E-06
U-237	4.56E-06	0.3433	2.04E-03	9.27E-09
U-238	2.41E-04	4.2691	2.53E-02	6.10E-06
Np-237	7.09E-04	4.9529	2.94E-02	2.08E-05
Np-239	4.55E-03	0.4469	2.65E-03	1.20E-05
Pu-238	1.14E-01	5.593	3.32E-02	3.78E-03
Pu-239	3.01E-02	5.2442	3.11E-02	9.35E-04
Pu-240	2.29E-02	5.2559	3.12E-02	7.15E-04
Pu-241	1.85E-01	0.0054	3.20E-05	5.92E-06
Am-241	3.80E-01	5.6379	3.34E-02	1.27E-02
Am-243	4.55E-03	5.4402	3.22E-02	1.47E-04
Cm-242	1.05E-11	6.2156	3.68E-02	3.86E-13
Cm-243	1.85E-03	6.1624	3.65E-02	6.77E-05
Cm-244	4.07E-02	5.9014	3.50E-02	1.42E-03
Totals:	**1.79E+03**			**4.57E+00**

Table A-3. Radionuclide Content and Radiolytic Heating for Glass in Refractory

Isotope	Ci	Mev/d	W/Ci	W
Co-60	1.33E-02	2.6007	1.54E-02	2.05E-04
Sr-90	1.07E+02	0.1957	1.16E-03	1.24E-01
Y-90	1.07E+02	0.9331	5.53E-03	5.91E-01
Tc-99	5.22E-02	0.1013	6.01E-04	3.13E-05
Cs-137	2.13E+02	0.1884	1.12E-03	2.38E-01
Ba-137m	2.01E+02	0.6617	3.92E-03	7.89E-01
Eu-154	5.53E-01	1.5223	9.02E-03	4.99E-03
Hg-206	2.54E-16	0.5426	3.22E-03	8.16E-19
Tl-206	1.78E-14	0.5399	3.20E-03	5.70E-17
Tl-207	2.96E-09	0.4975	2.95E-03	8.73E-12
Tl-208	1.81E-04	3.9716	2.35E-02	4.25E-06
Tl-209	1.43E-08	2.8302	1.68E-02	2.41E-10
Tl-210	1.67E-11	4.0331	2.39E-02	4.00E-13
Pb-209	6.64E-07	0.1974	1.17E-03	7.77E-10
Pb-210	1.34E-08	0.0457	2.71E-04	3.62E-12
Pb-211	2.97E-09	0.5187	3.07E-03	9.13E-12
Pb-212	5.03E-04	0.3217	1.91E-03	9.58E-07
Pb-214	7.96E-08	0.5481	3.25E-03	2.59E-10
Bi-209	1.46E-25	----	----	----
Bi-210	1.33E-08	0.3889	2.31E-03	3.07E-11
Bi-211	2.97E-09	6.733	3.99E-02	1.18E-10
Bi-212	5.03E-04	2.8247	1.67E-02	8.42E-06
Bi-213	6.64E-07	0.6963	4.13E-03	2.74E-09
Bi-214	7.96E-08	2.1436	1.27E-02	1.01E-09
Bi-215	2.43E-15	0.9228	5.47E-03	1.33E-17
Po-210	1.22E-08	5.4075	3.21E-02	3.92E-10
Po-211	8.10E-12	7.5944	4.50E-02	3.65E-13
Po-212	3.22E-04	8.9541	5.31E-02	1.71E-05
Po-213	6.50E-07	8.537	5.06E-02	3.29E-08
Po-214	7.96E-08	7.8335	4.64E-02	3.70E-09
Po-215	2.97E-09	7.5263	4.46E-02	1.32E-10
Po-216	5.03E-04	6.9064	4.09E-02	2.06E-05
Po-218	7.96E-08	6.1135	3.62E-02	2.89E-09
At-215	1.19E-14	8.178	4.85E-02	5.75E-16
At-217	6.64E-07	7.2011	4.27E-02	2.83E-08
At-218	1.51E-11	6.8053	4.03E-02	6.10E-13
At-219	2.50E-15	6.1343	3.64E-02	9.10E-17
Rn-217	7.97E-11	7.8856	4.67E-02	3.73E-12
Rn-218	1.51E-14	7.2626	4.31E-02	6.51E-16
Rn-219	2.97E-09	6.9456	4.12E-02	1.22E-10
Rn-220	5.03E-04	6.4047	3.80E-02	1.91E-05
Rn-222	7.96E-08	5.5903	3.31E-02	2.64E-09
Fr-221	6.64E-07	6.4582	3.83E-02	2.54E-08
Fr-223	4.17E-11	0.4415	2.62E-03	1.09E-13
Ra-223	2.97E-09	5.9895	3.55E-02	1.05E-10
Ra-224	5.03E-04	5.7893	3.43E-02	1.72E-05
Ra-225	6.66E-07	0.1194	7.08E-04	4.72E-10
Ra-226	7.97E-08	4.8716	2.89E-02	2.30E-09
Ra-228	3.21E-05	0.0163	9.66E-05	3.10E-09
Ac-225	6.64E-07	5.9338	3.52E-02	2.34E-08
Ac-227	3.02E-09	0.0853	5.06E-04	1.53E-12
Ac-228	3.21E-05	1.3166	7.80E-03	2.51E-07
Th-227	2.95E-09	6.1955	3.67E-02	1.08E-10

Table A-3. Radionuclide Content and Radiolytic Heating for Glass in Refractory (continued)

	Isotope	Ci	Mev/d	W/Ci	W
	Th-228	5.02E-04	5.5202	3.27E-02	1.64E-05
	Th-229	6.70E-07	5.1772	3.07E-02	2.05E-08
	Th-230	1.52E-05	4.7702	2.83E-02	4.31E-07
	Th-231	6.92E-05	0.1891	1.12E-03	7.76E-08
	Th-232	4.18E-05	4.0829	2.42E-02	1.01E-06
	Th-234	1.16E-04	0.0728	4.32E-04	5.01E-08
	Pa-231	1.78E-08	5.158	3.06E-02	5.43E-10
	Pa-233	8.49E-04	0.438	2.60E-03	2.21E-06
	Pa-234	1.74E-07	1.8755	1.11E-02	1.93E-09
	Pa-234m	1.16E-04	0.8334	4.94E-03	5.73E-07
	U-232	4.41E-04	5.4135	3.21E-02	1.41E-05
	U-233	5.85E-04	4.9085	2.91E-02	1.70E-05
	U-234	2.84E-04	4.8587	2.88E-02	8.18E-06
	U-235	6.92E-05	4.6891	2.78E-02	1.92E-06
	U-235m	3.72E-02	0	0.00E+00	0.00E+00
	U-236	2.08E-04	4.5723	2.71E-02	5.64E-06
	U-237	5.08E-06	0.3433	2.04E-03	1.03E-08
	U-238	1.16E-04	4.2691	2.53E-02	2.94E-06
	Np-237	8.49E-04	4.9529	2.94E-02	2.49E-05
	Np-239	6.72E-03	0.4469	2.65E-03	1.78E-05
	Pu-238	1.41E-01	5.593	3.32E-02	4.67E-03
	Pu-239	3.72E-02	5.2442	3.11E-02	1.16E-03
	Pu-240	2.85E-02	5.2559	3.12E-02	8.87E-04
	Pu-241	2.06E-01	0.0054	3.20E-05	6.61E-06
	Am-241	8.45E-01	5.6379	3.34E-02	2.82E-02
	Am-243	6.72E-03	5.4402	3.22E-02	2.17E-04
	Cm-242	4.49E-11	6.2156	3.68E-02	1.65E-12
	Cm-243	3.04E-03	6.1624	3.65E-02	1.11E-04
	Cm-244	6.77E-02	5.9014	3.50E-02	2.37E-03
Totals:		**6.30E+02**			**1.79E+00**

Table A-4. Total Radiolytic Heating Rate

Glass in Melter	2.85 W
Glass in Spout	4.57 W
Glass in Refractory	0.79 W
Total	**9.21 W**

APPENDIX 3.5.3 – PARAMETER AND VARIABLE LISTS FOR COMSOL® MULTIPHYSICS MODEL

Parameter List for COMSOL® Multiphysics Model

Parameter	Value or Formula
SidePlateTh	6[in]
TopPlateTh	4[in]
BottomPlateTh	4[in]
GlassSide	1.851377[ft]
FireBrick	7.838387[ft]
SteelCase	7.838387[ft]
Tamb	100[degF]
VolSteel	14.13[m^3]
VolFireBrick	9.27[m^3]
Vtot	VolSteel + VolSteel
k_304L	20[W/m/K]
rho_304L	7850[kg/m^3]
rho_FireBrick	1.07[g/cm^3]
cp_FireBrick	0.732[J/g/K]
flux	253.6[BTU/ft^2/h]
cp_304L	475[J/(kg*K)]
SteelTh	4[in]
ConcreteTh	1[ft]
FireT	1475[degF]
Rig	8.314[J/mol/K]
CaO_init	1 / 3 * CementRho / CaO_MW
CaSiO_init	2 / 3 * CementRho / CaSiO_MW
CaO_MW	56[g/mol]
CaSiO_MW	84[g/mol]
LDCC_Bulk	71.2[lb/ft^3]
CementRho	18.89[lb/ft^3]
Sand_rho	48.53[lb/ft^3]
BoundWater	3.78[lb/ft^3]
Total	BoundWater + Sand_rho + CementRho
BH2O_init	BoundWater / H2O_MW
H2O_MW	18[g/mol]
delH1	63.92[kJ/mol]
delH2	65.59[kJ/mol]
DelH_vap_Norm	40657[J/mol]
Tc	647.14[K]
AirGap	10[in]
Ea_Rg	3397[K]
Ar	15.426
ConcreteCP	765[J/kg/K]
glass_rho	2.6[g/cm^3]
glass_cp	810.9179[J/kg/K]
P0	1[atm]
Air_MW	28.84[g/mol]
gc	9.8[m/s/s]

Variable List for COMSOL® Multiphysics Model

Variable	Formula
glass_cp_old	((0.19242 + 0.001081 * T[1/degC]) / (1 + 0.00251 * T[1/degC]) * (T[1/degC] > 25) + 0.2 * (T[1/degC] <= 25))[BTU/lb/degF]
FireBrick_k	(1.47213e-7 * (T[1/degC])^2 + 1.40314e-4 * (T[1/degC]) + 0.102417)[W/m/K]
FireT	(1475[degF] - Tamb) * (t[1/s] <= 1800) + Tamb
Ave_k	VolSteel / Vtot * k_304L + VolFireBrick / Vtot * FireBrick_k
Ave_rho	(rho_304L * VolSteel + rho_FireBrick * VolFireBrick) / Vtot
Ave_cp	(cp_304L * VolSteel + cp_FireBrick * VolFireBrick) / Vtot
r1	exp(19.26158 - (151820[J/mol]) / (Rig*T))[1/s]
alpha	Ar * exp(-Ea_Rg / mod1.T)
r2	exp(r2_Min1(alpha) - r2_Min2(alpha)[J/mol] / (Rig*mod1.T))[1/s]
delH_Vap	gamma_func(mod1.T)
Tr	mod1.T / Tc
Trb	100[degC] / Tc
TBound	(FireT-Tamb) * (t[1/s] <= 1800) + Tamb
Concrete_effCp	ConcreteCP + (delH2 + delH_Vap) * BoundWater / Total / H2O_MW * Ea_Rg /T^2 * exp(-Ea_Rg / T)
CCaO	CaO_init * (1 - alpha)
CCaSiO	CaSiO_init * (1 - alpha)
CBH2O	BH2O_init - ((CaO_init - CCaO) + (CaSiO_init - CCaSiO))
Temperature	mod1.T * (mod1.T[1/degF] > 155) + 155[degF] * (mod1.T[1/degF] < 155)
BoundWaterConc	0 * (CBH2O < 3355) + CBH2O * (CBH2O > 3355)
CycleTime	flc2hs(sin(pi*t[1/s] / 43200), 0.01)
SS_516_k	(-1.4131e-5 * (T[1/degF])^2 + 0.0092585 * (T[1/degF]) + 39.440)[W/m/K]
SS_516_Cp	(6.49e-5 * (T[1/degF])^2 + 0.19059 * (T[1/degF]) + 447.66)[J/kg/K]
SS_516_rho	7749.7[kg/m^3]
TD	(((3.725e-4 - 3.7e-9 * T[1/degC] + 1.0624e-11 * (T[1/degC])^2))[ft^2/min]) * (glass_cp_old * glass_rho_old) * mat1.def.Cp
glass_rho_old	((181.45 - 3.68e-3 * T[1/degC]) / (1 + 0.000147 * T[1/degC]))[lb/ft^3]
gas_rho	P0 / Rig/T * Air_MW
AveGasDen	P0 / Rig / ((UpperWallT + LowerWallT) / 2)[K] * Air_MW
Ra	(AveGasDen * (P0 * Air_MW / Rig * abs(1 / UpperWallT – 1 / LowerWallT)[1/K]) *mat1.def.Cp * gc * AirGap^3) / (mat1.def.mu * mat1.def.k11)
Pr	mat1.def.Cp * mat1.def.mu / mat1.def.k11
Nu	0.069 * Ra^(1/3) * Pr^(0.074)
keff	mat1.def.k11 * Nu

Note: flc2hs is a continuous variable Heaviside step function in which the step change is applied using a continuous ramp. The first argument of this function is the independent variable value at the midpoint of the ramp, and the second argument is the width of the ramp from the midpoint to either end.

Note: mod1.T is the nodal temperature.

Note: The unit 1/degF in the formulas for SS_516_k and SS_516_Cp are input as a reciprocal unit to cancel the temperature units.

Note: Some parameters and variables are entered directly into the COMSOL® user interface and thus do not appear in the preceding lists.

4.0 CONTAINMENT

This chapter identifies the West Valley Melter Package (WVMP) containment system and describes how this package provides equivalent safety with the containment requirements of 10 CFR 71 (reference 4-1). Figure 4-1 shows a simplified cutaway view of the WVMP.

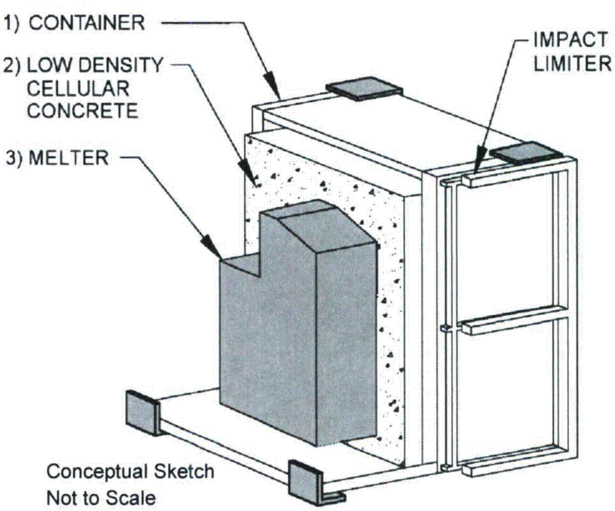

Figure 4-1. Components of the WVMP

The following information summarizes how the WVMP provides equivalent safety with the containment requirements, with more detailed information on the containment system and its performance under Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) following this discussion.

Although the WVMP is not leaktight, several factors ensure that under NCT or HAC, a release of radioactive contents will not reach the release limits specified under 10 CFR 71. In addition, the WVMP contains no valves, pressure relief mechanisms, or closure devices that could be operated intentionally or unintentionally.

Aspects of the WVMP that ensure any release remains less than the limits include:

Key Terms and Acronyms in this Chapter	
ARF	Airborne Release Fraction
DR	Damage Ratios
EF	Escape Fraction
HAC	Hypothetical Accident Conditions
LDCC	Low Density Cellular Concrete
LPF	Leak Path Factor
NCT	Normal Conditions of Transport
PBS	Polymeric Barrier System
RF	Respirable Fraction
RTV	Room Temperature Vulcanizing
WVMP	West Valley Melter Package (consisting of the container, the LDCC, and the melter with the Impact Limiter installed)

(1) Total radioactive content consists of 215 A_2 values, approximately 98 percent of the A_2s are contained within the residual borosilicate glass matrix adhered to the inside of the melter (reference 4-2). Based on the documented properties of the borosilicate glass, only a small fraction of the glass will become damaged, with an even smaller fraction becoming dispersible even under HAC.

(2) The melter in the WVMP remains intact after HAC, thus minimizing impact to the borosilicate glass and the Low Density Cellular Concrete (LDCC) located inside the melter.

(3) Radioactive contamination on the outside of the melter has been previously fixed in place using Bartlett's nuclear contamination control Polymeric Barrier System (PBS), a well-proven, hard-to- remove, impermeable material.

(4) The containment boundary is the container of the WVMP, but is not credited in the analyses (i.e., a leak path factor (LPF) = 1 is conservatively assumed for the container and associated penetrations).

(5) Besides the container of the WVMP, there are multiple barriers between the radioactive contents and the environment that minimize the potential releases of the radioactive contents, such as:

a. The annulus between the outside shell of the WVMP and the melter was filled with LDCC, with some of the LDCC entering the melter. The LDCC binds any loose contents on the outside of the melter, and minimizes the likelihood of escape, providing another barrier to the release of surface contamination previously fixed with PBS, thus minimizing its escape.

b. The LDCC external to the melter encases the melter shell within the container, which minimizes the dispersible contents from the glass that might otherwise be created, serving as another barrier to dispersal of radioactive contents in the event of a breach in the containment boundary.

c. Bartlett's PBS has an approximate life of around 20 years and is a strong fixative and further captures any surface contamination.

Periodic and pre-shipment leak test criteria are not applicable as a measure of containment integrity, since the WVMP is not leaktight. Instead, it is shown that for NCT the maximum permitted leak rate in 10 CFR 71.51(a)(1) will not be exceeded based on negligible damage to the LDCC and the glass, and multiple barriers minimizing release (reference 4-2) For HAC, it is shown the maximum permitted leak rate in 10 CFR 71.51(a)(2) cannot be exceeded because minimal content is releasable, and the multiple barriers with their torturous leak path must be overcome to result in release of radioactive content.

The package contains no explosive mixtures.

4.1 Description of the Containment System

Figure 4-2 shows the container before the melter was loaded into it.

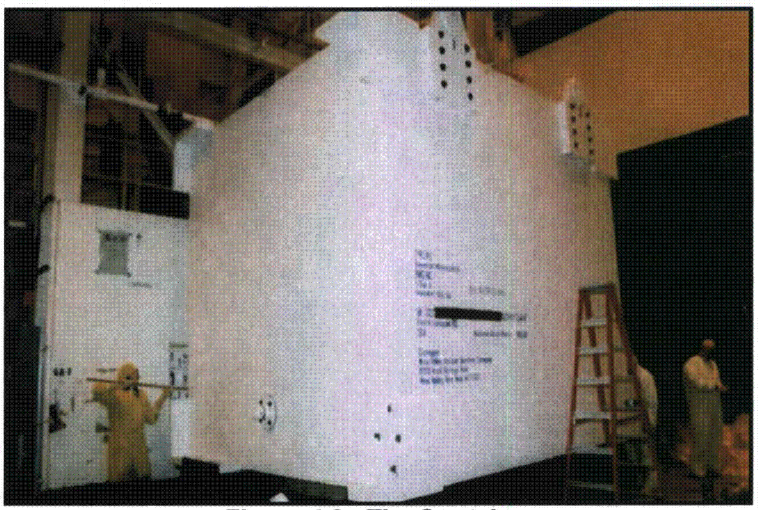

Figure 4-2. The Container

4.1.1 Containment Boundary

The container shown in Figure 4-2 forms the containment boundary for the WVMP. It serves as the outside container for the melter and the LDCC, but is not credited in the containment analyses (i.e., a LPF = 1 is conservatively assumed for the container and associated penetrations).

Engineering drawings used in fabrication of the container appear in Chapter 1. These drawings identify the dimensions, the materials of construction, and the types of welds used in the design.

The container is fabricated with ASTM SA-516, Grade 70 carbon steel for the package top, bottom, sides, end cover, and temporary attachments. The WVMP is approximately 15'9" long by 12'7" wide by 12'6.5" high with the dimensions of the container itself being 13'5" long by 12'4" wide by 12'4" high. The sides of the container are 6" thick and the top and bottom are 4" thick. Five sides are welded in place with the bolted side door on the sixth side. The empty container weighed approximately 208,000 lbs.

The container was designed, constructed, and procured under a NQA-1 program (reference 4-3) to provide containment under NCT. The Chapter 2 structural analysis concludes the package will undergo localized damage to the LDCC external to the melter and that the deformations to the bolted door do not result in any clear open gaps, even under HAC.

Figure 4-3, does not include the Impact Limiter, and illustrates the Containment System.

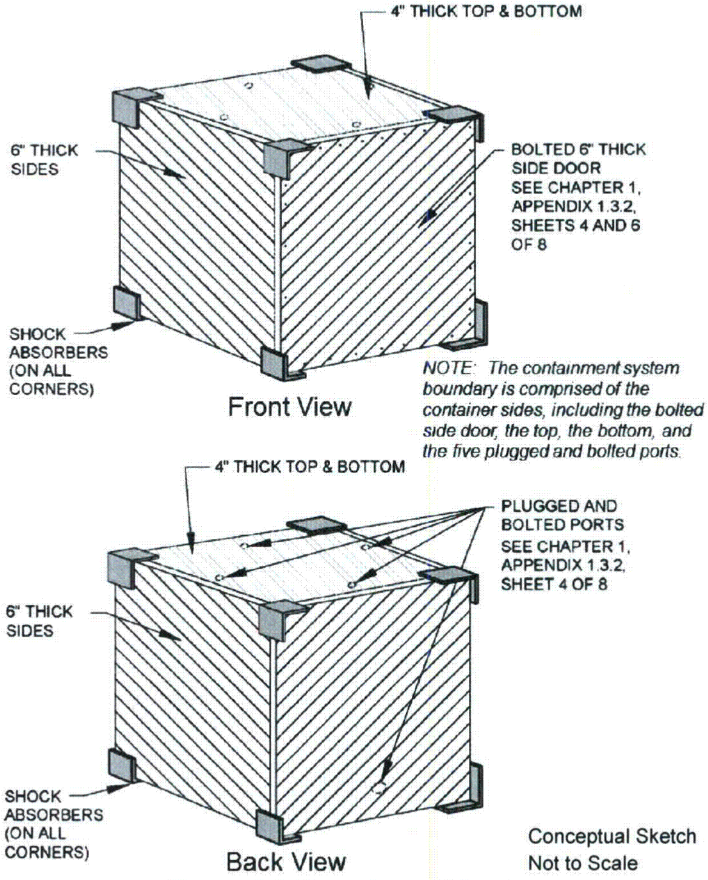

Figure 4-3 Containment System

4.1.2 Containment Penetrations

There are two types of containment penetrations associated with the WVMP. The first includes the five gasketed ports and details are shown on engineering drawing Sheet 4 in Chapter 1 Appendix 1.3.2. The gaskets are not credited in the containment analyses. These penetrations are 4.5" in diameter, stepped to 6.5" diameter for the outer half of the plate thickness, and are sealed with similarly step-sized steel plugs bolted in place. The other penetration consists of the bolted side door recessed into the package secured with 32 ASTM A193-B7 1½"-diameter bolts and details are shown on engineering drawing Sheet 6 in Chapter 1 Appendix 1.3.2. Although the bolted side door is sealed with a single piece of flat neoprene gasket compressed to ¼" thick by 4" wide on the face seal and the perimeter joint (1/4" by 6" width) is sealed with RTV, the gasket is not credited in the containment analyses.

The package is not vented and has no provision in its design to install one. See engineering drawings in Chapter 1, Appendix 1.3.2.

4.1.3 Special Requirements for Plutonium

Not applicable to the WVMP.

4.1.4 General Considerations

The requirements for Type A packages are not applicable to the WVMP.

The contents of the WVMP package contain approximately 3,554 curies of radioactivity, with less than 1E-1 A_2s conservatively calculated to be released under potential HAC as determined in Appendix 4.6.2. Most of the radioactive content is contained within the borosilicate glass matrix and adhered to the inside of the melter, with only a small quantity of surface contamination on the outside of the melter encapsulated by the PBS.

The original surface contamination on the outside of the melter contained approximately 2 A_2s.

Subsequently, the surface contamination (2.32 A_2s) was fixed to the surface of the melter with PBS. This material has an approximate life of around 20 years (reference 4-4), and is a strong fixative (reference 4-5). As part of preparing the WVMP for shipping, the melter was also placed within the container and encased in LDCC.

In sections 4.2 and 4.3 below, it is shown the multiple layers of protection, and immobilization added by the LDCC added to the internals of the melter and to the container, as well as the physical characteristics of the glass, the PBS, and the LDCC preclude leakage of dispersible materials from containment during both NCT and HAC.

Although the WVMP was not designed to be leaktight and cannot be leak tested, Appendix 4.6.2 shows that it will perform its intended safety function under the requirements specified in 10 CFR 71.

For hydrogen generation, the G values [molecules H_2/100ev] used for LDCC are: alpha G value = 0.6; beta G value = 0.03, and gamma G value = 0.03. For PBS the G values are: alpha G value =

0.04; the beta G value =0.04; and gamma G value =0.04. (Appendix 4.6.3). Conservatively assuming the box is sealed, the current time to 5% H_2 within the void space is > 20 years (Appendix 4.6.3).

4.2 Containment under Normal Conditions of Transport (Type B Packages)

For containment under NCT the WVMP demonstrates an equivalent level of safety. The WVMP does not credit any of the bolted penetrations or sealing surfaces as containment under NCT. The NCT equivalent safety containment analysis assumes the worst case damage to the container, the LDCC and the melter from the NCT analysis in Chapter 2. All of this material is assumed to be subject to potential release through the containment system under NCT.

The maximum permitted leakage rate under NCT cannot be exceeded during transport of the WVMP. 10 CFR 71.51(a)(1) states that the containment requirements for NCT are:

> ". . . there would be no loss or dispersal of radioactive contents--as demonstrated to a sensitivity of 10^{-6} A_2 per hour, no significant increase in external surface radiation levels, and no substantial reduction in the effectiveness of the packaging . . ."

The analyses described in Appendix 4.6.2, Section 5.2 determines two leak path factor (LPF) values, depending on location of the radioactive material. The first is LPF_{melter} and the second is LPF_{WVMP}. Anything external to the melter is assigned an $LPF_{WVMP} = 1$, which means that the WVMP with associated penetrations is not credited as providing any release reduction in the analyses. The second is the LPF_{melter} which is applied to radioactive material inside the melter. Since the maximum temperatures inside the melter during NCT and HAC are approximately equal, and significantly less than 100°C, increased pressure and decomposition effects of internal LDCC are similar and do not play a significant role, a single LPF_{melter} value for all associated scenarios can be applied, Appendix 4.6.2 calculates this value as LPF_{melter}=0.1.

Appendix 4.6.2, Section 5.3 analyses NCT. For the WVMP for impact used NCT Damage Ratios (DR) for borosilicate glass as 5E-5. With Chapter 2 estimating the NCT to have little effect on the LDCC, the impact to external LDCC is assumed to be a DR=0.06 %, an internal LDCC DR from impact is conservatively assumed to be 0.006%. Based on testing (reference 4-6) an Airborne Release Fraction (ARF) x respirable fraction (RF) of 2E-4 was applied to the borosilicate glass from impact, while an ARF of 1E-3 x RF of 1E-1 was applied to both the internal and external LDCC from impact. Considering the maximum NTC temperature and pressure increase calculated in chapter 3, an additional release mechanism at less than 25 psig, using an ARF of 5E-3 and a Respirable Fraction (RF) of 0.4 was applied to any LDCC fines external to the melter. Conservatively, decomposition/de-watering of the external LDCC was also considered with a DR set at 5%, and the corresponding ARF and RF for the external LDCC (under decomposition/de-watering set at 6E-3, and 1E-2, respectively). As the Chapter 3 maximum temperature and pressure are bounding, the elevated temperature releases include any chimney type effect.

As discussed in Section 4.1.1, the WVMP containment is welded on five sides, with the sixth side being the bolted side door. Containment is shown in Chapter 2 of this application to remain intact during NCT, precluding release of the radioactive contents, although no credit is taken for the container (LPF = 1). In summary, the NCT release is calculated to be less than 1E-6 A_2/hr. The WVMP package therefore satisfies the containment requirements of 10 CFR 71.51 under NCT.

4.3 Containment under Hypothetical Accident Conditions

In this section it is shown that the maximum permitted leakage rate under HAC cannot be exceeded during transport of the WVMP. 10 CFR 71.51(a)(2) states that the containment requirements for HAC are:

> ". . . there would be no escape of krypton-85 exceeding 10 A_2 in 1 week, no escape of other radioactive material exceeding a total amount A_2 in 1 week, and no external radiation dose rate exceeding 10 mSv/h (1 rem/h) at 1 m (40 in) from the external surface of the package."

For containment under HAC the WVMP demonstrates an equivalent level of safety. The WVMP does not credit any of the penetrations or sealing surfaces as containment under HAC. For equivalent safety the analysis assumes the worst case damage to the container, the LDCC and the melter. All of this material is assumed to be subject to potential release through the containment system under HAC.

The LPF values used for NCT remain applicable to HAC. Specifically, since no containment credit is taken for the WVMP, the LPF_{WVMP} = 1. Since the maximum temperatures inside the melter during NCT and HAC are approximately equal, and significantly less than 100°C, increased pressure and decomposition effects of internal LDCC are similar and do not play a significant role, the same LPF_{melter} value of 0.1 also applies.

The bulk of the radioactive content is contained within the borosilicate glass with the melter, as discussed previously.

Appendix 4.6.2, Section 5.4 analyses HAC. Because of the impact properties associated with the glass – (DR x "ARF x RF")$_{HAC}$ = 3E-4 x 1E-3 – most of the release is associated with the LDCC external to the melter with an assumed non-aerosol impact release of the LDCC external to the melter being the largest contributor, DR x EF (Escape Fraction, the total release associated with non-inhalation exposure) = 0.35 x 1 (refer to Appendix 4.6.2). Because of the small amount of dispersible radioactive materials, and the multiple barriers that protect the contents, dispersal of contents greater than the maximum permitted in 10 CFR 71.51(a)(2) will not occur.

As discussed at the beginning of this chapter, features of the WVMP that serve as barriers to excessive dispersal of the radioactive contents for the purposes of containment considerations include:

- The borosilicate glass with a maximum temperature of 146.3°F is contained within the melter, with LDCC sealing the three side penetrations into the melter (a combined LPF up to exiting the melter equal to 0.1) ;
- Testing has shown that the borosilicate glass has an extremely low dispersability (DR x "ARF x RF" = 3E-4 x 1E-3);
- Surface contamination on the melter has been fixed in place with three layers of Bartlett's PBS, which is impermeable and hard to remove

- The melter has been encased in LDCC (The LDCC external to the melter represents an additional barrier not numerically credited in Appendix 4.6.2); and
- The WVMP is welded on five of the six sides with the Chapter 2 structural analysis concluding that the container never has both a perimeter and face seal displacement (i.e., never any clear open gaps) under HAC (an additional barrier not numerically credited in Appendix 4.6.2, i.e., LPF=1.).

The analysis of the WVMP in Chapter 2 has shown that the 30-foot-drop HAC would result in localized damage to the LDCC along with small quantified levels of face seal displacement and/or perimeter seal displacement, but never a combination that results in any permanent clear open gaps. (i.e., a LPF = 1 is conservatively assumed for the WVMP (i.e. container) and associated penetrations).

Based on information in Appendix 4.6.2, the HAC-DR for impact of borosilicate glass is 3E-4, the external LDCC DR is 35% and the internal LDCC damage ratio is 3.5%. The corresponding HAC ARF x RF values are 1E-3 x 0.1 for impacted LDCC. A DR = 1 is conservatively applied to the LDCC external to the melter to account for decomposition/de-watering of the LDCC at maximum temperature of the external LDCC calculated in Chapter 3, with an ARF x RF equal to 6E-3 x 1E-2, based on unreactive powder. To account for the release of LDCC fines at elevated temperatures, a DR = 35% and the ARF x RF is set equal to 1E-1 x 7E-1. At the temperatures and pressures used bounding for HAC, a contribution for any chimney effect would be accounted for. Similar to the rest of the containment analyses, A leak path factor of 1 is applied to the WVMP (i.e., no credit applied). Since Chapter 2 did not show any impact to the melter under HAC, a leak path factor of 0.1 was determined (as described in Appendix 4.6.2) and, which accounts for the approximately 2 psig pressure increase inside the melter based on a maximum glass temperature of 146.3°F

As shown in Appendix 4.6.2, almost all of the release can be attributed from the external LDCC, with the A_2 contribution from non-airborne LDCC solids leaking out of the WVMP being much greater than the A_2 contribution from external LDCC fines from maximum temperature pressure (i.e., pressurization), being much greater than the A_2 from glass, decomposition/dewatering of the external LDCC, the impact to external LDCC, or the LDCC internal to the melter released from impact.

In summary, HAC could result in localized damage to the LDCC. However, the amount of radioactive material released would be limited by the multiple barriers to dispersal, and the amount that could pass through small breaches in the LDCC. With the conservative HAC assumptions, less than 1E-1 A_2s are released. This is less than the limit of 10 times an A_2 quantity per week for Kr-85 and 1 A_2 per week for all other isotopes, as specified in 10 CFR 71.51(a)(2), and the package therefore meets the release limits specified by 10 CFR 71.

4.4 Leakage Rate Tests for Type B Packages

The WVMP does not credit any of the gaskets installed in the containment boundary in the analysis. The WVMP was not designed to be a leaktight package and cannot be leak tested.

The NCT release is calculated, with very conservative assumptions, to be less than 1E-7 A_2/hr and satisfies the containment requirements of 10 CFR 71.51 under NCT (Appendix 4.6.2). For HAC containment calculations, less than 1E-1 A_2s are released under HAC using conservative assumptions (Appendix 4.6.2). This is significantly less than the limit of an A_2 quantity per week for Kr-85 and 1 A_2 per week for all other isotopes, as specified in 10 CFR 71.51(a)(2), The package meets the release limits for NCT and HAC specified by 10 CFR 71.

The container was fabricated to NQA-1 requirements to the design drawings identified in Chapter 1 Appendix 1.3.2. The welding was performed In compliance with 10 CFR 71.119. All welds were visually examined and magnetic particle inspected. The applicable requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section EII, Article ND-5300, Acceptance Standards (reference 4-8) were implemented in connection with fabrication of the container. Chapter 8, section 8.1.2 provides more fabrication detail.

Upon receipt, in accordance with the site QA program and receipt inspection requirements identified in site procedures, visual inspections and measurements (reference 4-9) confirmed the container:

- Did not show any visible shipping damage;
- Met specifications on the purchase order, including gaskets; and
- No suspect or counterfeit parts were used.

The acceptance criteria for these inspections included compliance with the specified requirements. Chapter 8, section 8.1.1 provides more acceptance detail.

The bolted side door was secured per manufacturer's instructions after the content was installed. Chapter 7, section 7.1.2 provides more operations detail.

4.5 Conclusion

The WVMP is not leaktight. Analysis shows the releases under NCT and HAC will meet the release limits specified in 10 CFR 71.51 and the package can be deemed acceptable for equivalent safety.

4.6 Appendix

This appendix contains the following information:

4.6.1 List of references

4.6.2 E. T. Ketusky, *Estimated WVMP (West Valley Melter Package) Release Rates Under Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC)*, X-CLC-G-00121, Rev. 1, Savannah River Site, March 25, 2015. (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Request for Withholding*)

4.6.3 E. T. Ketusky, *West Valley Grouted Melter Package (GMP) Estimated Time to 5% Hydrogen*, F-CLC-G-0004, Rev. 0, Savannah River Site, November, 2014. (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Request for Withholding*)

APPENDIX 4.6.1 – REFERENCES

4-1 10 CFR Part 71, *Packaging and Transportation of Radioactive Material.*

4-2 *Structural Evaluation of WVMP to Specific Requirements of 10 CFR 71.71*, M-CLC-A-00497, Savannah River National Laboratory, Aiken, SC, October 2014. (see Chapter 2)

4-3 *Quality Assurance Requirements for Nuclear Facility Applications*, NQA-1, American Society for Mechanical Engineers, New York, New York, 2004.

4-4 *Stabilization of Residue Plutonium in L-9 Hood in Product Removal Room of PUREX With Polymeric Barrier System*, WHC-SD-SQA-CSA-508, Rev. 0, Chiao, T., Westinghouse Hanford Company, Richland, Washington. (provided)

4-5 *Decontamination Using Remote-Deployed Nitrocision Technology*, Chilson L. and L. B. Winkler, WM2011 Conference, February 27 – March 3, 2011, Phoenix, Arizona. (provided)

4-6 *Impact Testing of Vitreous Simulated High-Level Waste in Canisters*, BMWL-1903 UC-70, Pacific Northwest National Laboratory, Richland Washington, May 1975. (provided)

4-7 *Leak Path Factors for Radionuclide Releases from Breached Confinement Barriers and Confinement Areas*, 000-00c-MGRO-01500-000-00A, Bechtel SAIC Company, LLC, Las Vegas, Nevada, 2007. (provided)

4-8 *ASME Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, New York, 2004.

4-9 *Material Receiving Inspection and Release (MRIR) Report #04-1152*, West Valley Nuclear Services Company, West Valley, New York, October 15, 2004. (provided)

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5.0 SHIELDING EVALUATION

This chapter describes the radiation shielding design of the West Valley Melter Package (WVMP) and provides an evaluation of that design. The WVMP is comprised of (1) the Grouted Melter Package (GMP), consisting of the melter and Low Density Cellular Concrete (LDCC) inside the steel container; and (2) the Impact Limiter (IL). Figure 5-1 shows the different components of the WVMP.

This shielding evaluation demonstrates a level of safety equivalent to the performance requirements specified in 10 CFR 71.47 (reference 5-1), 10 CFR 71.51 (reference 5-1), and 49 CFR 173.441 (reference 5-2) for both Exclusive Use transport and Hypothetical Accident Conditions (HAC).

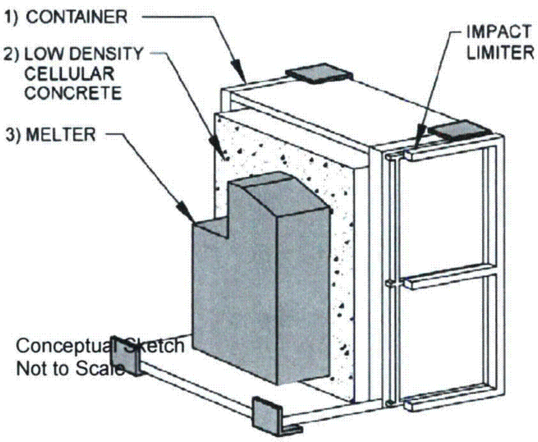

Figure 5-1. West Valley Melter Package Components

The Transport Index (TI) to be included on the WVMP Class 7 (Radioactive) label is to be determined by radiation measurement at the time of transport.

Key Terms and Acronyms in this Chapter	
GMP	Grouted Melter Package (consisting of the melter, LDCC inside the container, and the container itself)
IL	Impact Limiter
LDCC	Low Density Cellular Concrete
WVMP	West Valley Melter Package (consisting of the GMP with the IL installed)

5.1 Description of Shielding Design

5.1.1 Design Features

Figure 5-2 illustrates the GMP. The container was fabricated with ASTM SA516, Grade 70 carbon steel (4" thick top and bottom; 6" thick sides) and is approximately 14'11" long by 12'6" wide by 12'6" high as shown on detailed engineering drawing provided in Chapter 1. The density of the steel is 7.98 g/cm^3.[1]

The vitrification melter inside the container is encased with LDCC, which also entered the interior of the melter. The density of the LDCC is 1.12 g/cm^3.

Figure 5-3 illustrates the West Valley melter. The melter outer shell is made

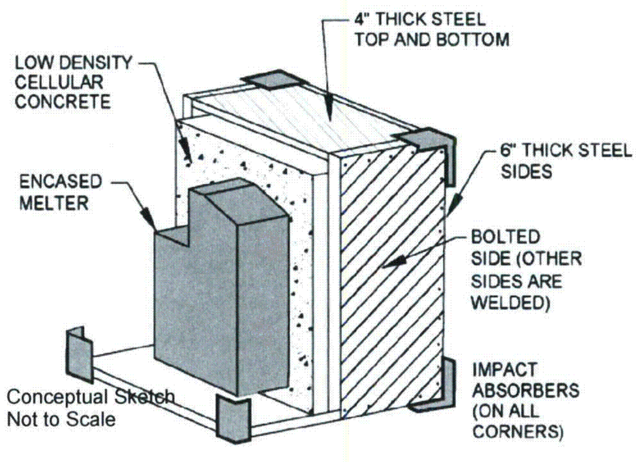

Figure 5-2. Grouted Melter Package

[1]Material properties used in the analyses, including densities, are listed in Table 5-7 below along with the sources of the values used.

of stainless steel. A cooling water jacket covers the sides and bottom of the outer shell. The shell interior is lined with refractory brick, which is a combination of Monofrax™ K-3 and Zirmul™. The density of this refractory material is 3.89 and 3.14 g/cm^3, respectively. The maximum envelope dimensions of the melter are 11'10" long, by 10'9¾" wide by 10'5½" high.

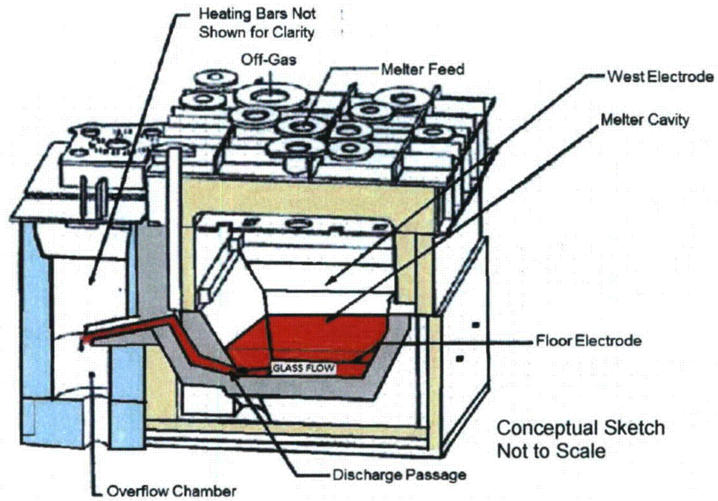

Figure 5-3. West Valley Melter

5.1.2 Summary Table of Maximum Radiation Levels

Shielding analyses were performed for the content as described in Section 1.2.2.

The Normal Conditions of Transport (NCT) shielding model includes all components of the package with geometric simplifications. The HAC shielding model assumes that the LDCC is consumed by HAC events. The dose rates from gamma radiation were calculated using the QADS Point Kernel Module of the SCALE Code System (reference 5-3) with its built-in attenuation and buildup coefficients. Table 5-1 summarizes the NCT and HAC maximum calculated dose rates and compares the results against the regulatory limits for shipment in commerce.

Table 5-1. Radiation Dose Rates for the Package

Location	NCT			HAC
	Surface	1 m	2 m	1 m
	Maximum Dose Rate (mr/hr)			
North Side	0.056	0.052	0.037	0.52
South Side	0.043	0.019	0.011	0.84
East Side	0.013	0.012	0.009	0.43
West Side	0.016	0.014	0.011	0.51
Bottom	80.40	16.73	7.50	201.63
Top	2.43	1.18	0.689	429.03
10 CFR 71 Limits	200	N/A(1)	10	1000

NOTE: (1) 1 m dose limit (TI≤10) does not apply since package is being shipped as Exclusive Use meeting dose limits of 10 CFR 71.47(b).

5.2 Source Specification

There are four source terms of radioactive material in the WVMP: the melter heel, the plugged discharge spout, the refractory material, and surface contamination on the exterior of the melter. Table 5-2 shows the gamma source content evaluated.

5.2.1 Gamma Source

Table 5-2. Source Content

Isotope	Heel (9/20/2002)	Spout (11/26/2001)	Refractory (7/18/2002)	Surface Contamination (4/20/2004)
	Mass (grams)			
H-3				2.00E-09
C-14	7.75E-04	4.96E-04		8.44E-04
K-40	2.12E+03	1.22E+03		
Mn-54	3.00E-06	2.02E-06		
Fe-55				6.64E-06
Co-60	1.34E-05	2.59E-05	5.80E-05	1.16E-06
Ni-59				6.35E-03
Ni-63	2.92E-03	1.90E-03		2.75E-04
Sr-90	3.01E-01	6.23E-01	1.04E+00	2.06E-02
Zr-95	2.01E-04	1.23E-04		
Tc-99	1.19E-01	9.30E-01	3.09E+00	6.16E-02
I-129				2.24E+00
Cs-137	8.21E+00	1.32E+01	3.24E+00	7.40E-02
Pm-147				7.42E-05
Eu-154	7.88E-04	1.08E-03	5.44E-03	1.09E-04
Th-228	1.06E-05	6.78E-06	2.78E-06	5.56E-08
Th-230	2.93E-03	1.88E-03	7.38E-04	1.48E-05
Th-232	6.15E+02	3.96E+02	3.81E+02	7.62E+00
U-232	3.73E-04	2.40E-04	2.25E-05	4.62E-05
U-233	3.48E-01	2.24E-01	6.07E-02	2.44E-03
U-234	2.57E-01	1.66E-01	4.49E-02	1.34E-03
U-235	2.85E+01	1.83E+01	3.20E+01	6.39E-01
U-236	2.88E+00	1.86E+00	3.26E+00	6.49E-02
U-238	1.11E+03	7.17E+02	3.45E+02	1.82E+01
Np-237	1.49E+00	1.00E+00	1.20E+00	2.40E-02
Pu-238	6.66E-03	7.36E-03	9.05E-03	2.21E-04
Pu-239	4.21E-01	4.85E-01	6.00E-01	1.59E-02
Pu-240	8.81E-02	1.01E-01	1.25E-01	3.01E-03
Pu-241	5.15E-03	3.31E-03	3.59E-03	7.17E-05
Am-241	1.45E-01	1.12E-01	2.50E-01	1.00E-02
Am-243	2.99E-02	2.28E-02	3.37E-02	6.71E-04
Cm-242	1.08E-05	1.31E-06	2.07E-06	4.14E-08
Cm-243	5.81E-05	5.08E-05	8.20E-05	1.64E-06
Cm-244	9.14E-04	8.17E-04	1.33E-03	2.64E-05

The contributing mechanisms for photon (gamma) production include: (1) nuclide decay, (2) decay of daughter products, (3) fission product decay, and (4) spontaneous fission. Table 5-3 shows the source spectrum and total source strength (photons/sec).

Table 5-3. Photon Source Spectra

Group	Energy Boundary (MeV)		Source Strength (p/s)			
	Lower	Upper	Heel	Spout	Refractory	Surface
1	8.00E+00	1.00E+01	3.87E+00	3.37E+00	5.56E+00	1.20E-01
2	6.50E+00	8.00E+00	1.82E+01	1.59E+01	2.62E+01	5.65E-01
3	5.00E+00	6.50E+00	9.31E+01	8.11E+01	1.34E+02	2.89E+00
4	4.00E+00	5.00E+00	2.32E+02	2.02E+02	3.34E+02	7.21E+00
5	3.00E+00	4.00E+00	6.93E+02	6.03E+02	9.92E+02	2.14E+01
6	2.50E+00	3.00E+00	9.50E+07	5.99E+07	5.96E+06	1.17E+07
7	2.00E+00	2.50E+00	3.97E+06	8.05E+06	1.36E+07	2.76E+05
8	1.66E+00	2.00E+00	7.79E+07	1.57E+08	2.65E+08	5.45E+06
9	1.33E+00	1.66E+00	6.61E+08	1.15E+09	2.48E+09	5.41E+07
10	1.00E+00	1.33E+00	4.06E+09	6.98E+09	1.94E+10	4.28E+08
11	8.00E-01	1.00E+00	4.83E+09	9.08E+09	1.93E+10	4.10E+08
12	6.00E-01	8.00E-01	1.61E+13	2.55E+13	6.38E+12	1.51E+11
13	4.00E-01	6.00E-01	2.27E+10	4.46E+10	7.09E+10	1.46E+09
14	3.00E-01	4.00E-01	3.78E+10	7.31E+10	1.05E+11	2.14E+09
15	2.00E-01	3.00E-01	6.47E+10	1.20E+11	1.50E+11	3.10E+09
16	1.00E-01	2.00E-01	2.55E+11	4.59E+11	4.82E+11	9.99E+09
17	5.00E-02	1.00E-01	4.80E+11	8.33E+11	7.34E+11	1.55E+10
18	1.00E-02	5.00E-02	3.15E+12	5.20E+12	2.79E+12	6.04E+10
		Total	2.02E+13	3.23E+13	1.08E+13	2.45E+11

The ORIGEN-S code (reference 5-4) was used to calculate the energy-dependent decay source terms in the SCALE eighteen group structure. The initial material compositions for the heel, spout, refractory, and surface contamination (Table 5-2) were decayed from the date listed until September 2014 to determine the buildup of daughter isotopes. The source spectrum was input into QADS for each source region.

5.2.2 Neutron Source

There are no significant neutron sources in the melter glass.

5.3 Shielding Model

Figures 5-2 and 5-3 respectively depict the GMP and melter schematically. Geometric models for QADS were developed using the information in Table 5-4 and Table 5-5. Figure 5-4 and Figure 5-5 show the NCT model. Figure 5-6 shows the HAC model developed from the NCT model by replacing the LDCC with void. There were no NCT or HAC tests for the WVMP. The NCT analysis showed no damage significant to the shielding and the HAC damage by analysis was bounded by the removal of the LDCC.

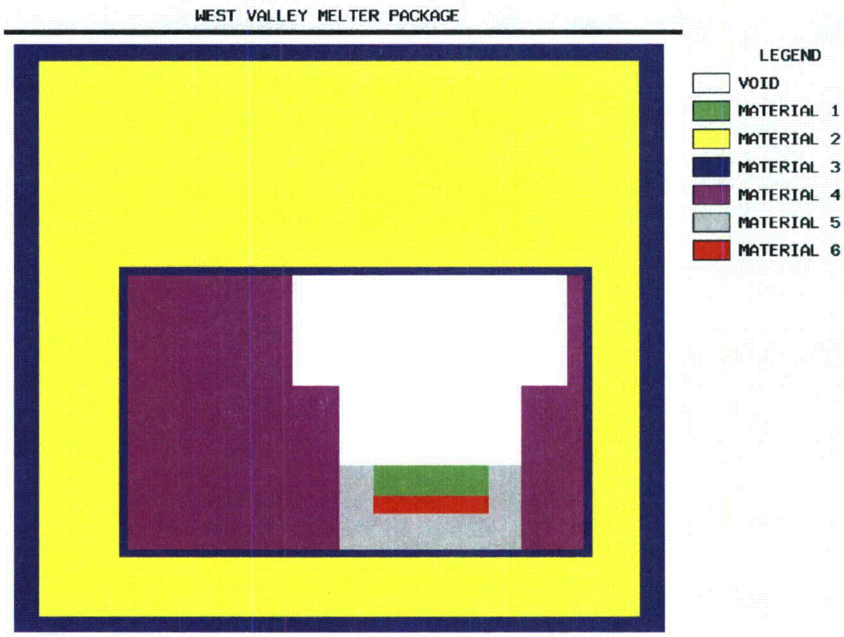

Figure 5-4. NCT Package Model Elevation View at Center of Melter

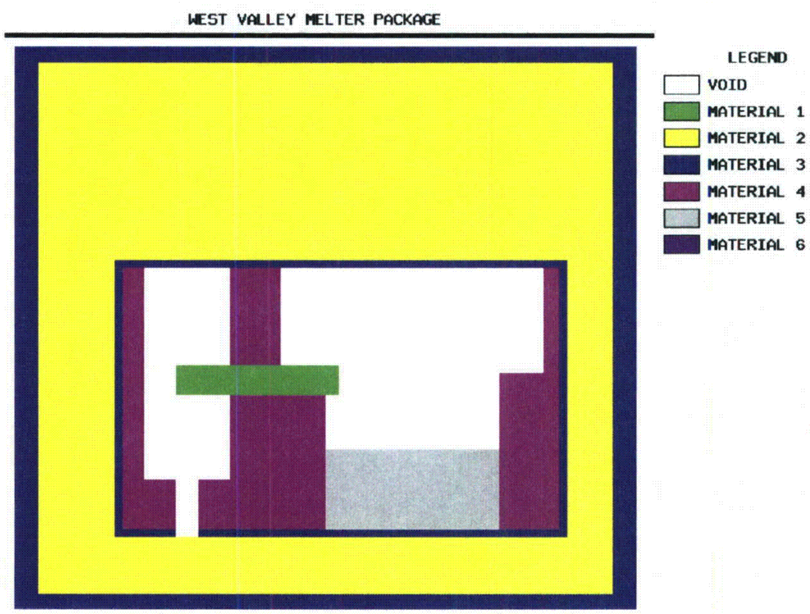

Figure 5-5. NCT Package Model Elevation View at Center of Plugged Spout

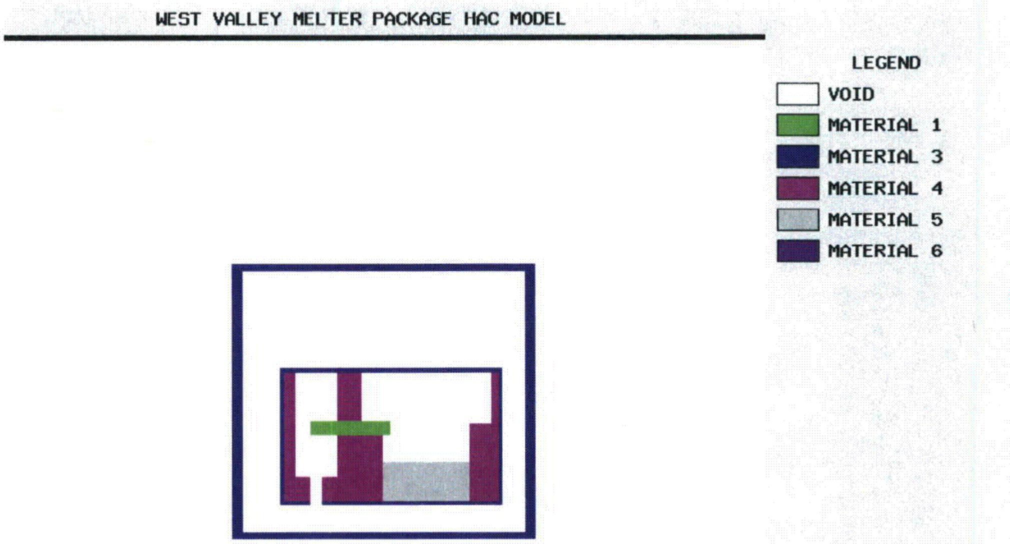

Figure 5-6. HAC Package Model

5.3.1 Configuration of Source and Shielding

Ten source configurations are modeled for the WVMP (see Engineering Calculation in Appendix 5.5.2):

- Uniformly distributed in the glass in melter heel,
- Uniformly distributed in the glass in the melter spout (modeled as a rectangular source),
- Glass in refractory brick above the melter heel modeled as uniform sources on each of the four vertical surfaces of the region above the melter heel,
- Surface contamination on the outside of the melter modeled as uniform sources on each of the four vertical surfaces of the steel surrounding the melter, and
- The source distribution in the melter spout modeled as a rectangle with the cross section equal to that of the cylinder.

The source term is modeled as uniformly distributed within each of the ten source regions in the model. Based on the nature of melter operation, with continuous mixing of the material during the melt, there would be no stratification of the radioactive material (reference 5-5).

Point detectors were modeled adjacent to the package and at two meters from the surface of the package for NCT cases. Point detectors were modeled at one meter from the surface of the damaged package for HAC cases. Table 5-6 lists the detector locations.

Table 5-4. Melter Geometry

Region	Parameter	English (inches)	Metric (cm)
Heel	Length	28.71	72.91
	Width	27.50	69.85
	Height	8.00	20.32
Middle	Length	45.41	115.34
	Width	68.00	172.72
	Height	20.00	50.80
Rectangular space above melter	Length	68.50	173.99
	Width	86.00	218.44
	Height	22.75	57.78
Melter Box Bottom	Length	118.00	299.72
	Width	99.00	251.46
	Height	73.00	185.42
	Thickness (1)	2.13	5.40
Melter Box Hat	Length	86.63	220.03
	Width	99.00	251.46
	Height	15.50	39.37
	Thickness (1)	2.13	5.40
Discharge Piping	Length	42.50	107.95
	Radius (2)	4.00	10.16

NOTES: (1) The thickness was conservatively modeled as 2.125".
(2) Radius inferred from lengths and mass of plug.

Table 5-5. Grouted Melter Package Model Dimensions(1)

Parameter	English (inches)	Metric (cm)
Length	144.00	365.76
Width	144.00	365.76
Height	156.00	396.24
Side Thickness	6.00	15.24
Top/Bottom Thickness	4.00	10.16

NOTE: (1) Conservative dimensions modeled.

Table 5-6. Detector Location for Surface of WVMP

Pt.	Location	Surface of Package Coordinate (cm)			1 m from Surface of Package Coordinate (cm)			2 m from Surface of Package Coordinate (cm)		
		x	z	y	x	z	y	x	z	y
1	North Side	148.2725	-25.4000	0.0000	248.2725	-25.4000	0.0000	348.2725	-25.4000	0.0000
2		148.2725	30.4800	-59.7694	248.2725	30.4800	-59.7694	348.2725	30.4800	-59.7694
3		148.2725	10.1600	0.0000	248.2725	10.1600	0.0000	348.2725	10.1600	0.0000
4		148.2725	18.4150	0.0000	248.2725	18.4150	0.0000	348.2725	18.4150	0.0000
5	South Side	-263.2075	-25.4000	0.0000	-363.2075	-25.4000	0.0000	-463.2075	-25.4000	0.0000
6		-263.2075	30.4800	-59.7694	-363.2075	30.4800	-59.7694	-463.2075	30.4800	-59.7694
7		-263.2075	10.1600	0.0000	-363.2075	10.1600	0.0000	-463.2075	10.1600	0.0000
8		-263.2075	18.4150	0.0000	-363.2075	18.4150	0.0000	-463.2075	18.4150	0.0000
9	East Side	0.0000	-25.4000	187.9600	0.0000	-25.4000	287.9600	0.0000	-25.4000	387.9600
10		-156.5275	30.4800	187.9600	-156.5275	30.4800	287.9600	-156.5275	30.4800	387.9600
11		-48.5775	30.4800	187.9600	-48.5775	30.4800	287.9600	-48.5775	30.4800	387.9600
12		0.0000	10.1600	187.9600	0.0000	10.1600	287.9600	0.0000	10.1600	387.9600
13		0.0000	18.4150	187.9600	0.0000	18.4150	287.9600	0.0000	18.4150	387.9600
14	West Side	0.0000	-25.4000	-187.9600	0.0000	-25.4000	-287.9600	0.0000	-25.4000	-387.9600
15		-156.5275	30.4800	-187.9600	-156.5275	30.4800	-287.9600	-156.5275	30.4800	-387.9600
16		-48.5775	30.4800	-187.9600	-48.5775	30.4800	-287.9600	-48.5775	30.4800	-387.9600
17		0.0000	10.1600	-187.9600	0.0000	10.1600	-287.9600	0.0000	10.1600	-387.9600
18		0.0000	18.4150	-187.9600	0.0000	18.4150	-287.9600	0.0000	18.4150	-387.9600
19	Bottom	0.0000	-121.9200	0.0000	0.0000	-221.9200	0.0000	0.0000	-321.9200	0.0000
20		-156.5275	-121.9200	-59.7694	-156.5275	-221.9200	-59.7694	-156.5275	-321.9200	-59.7694
21		-48.5775	-121.9200	-59.7694	-48.5775	-221.9200	-59.7694	-48.5775	-321.9200	-59.7694
22		0.0000	-121.9200	0.0000	0.0000	-221.9200	0.0000	0.0000	-321.9200	0.0000
23		0.0000	-121.9200	0.0000	0.0000	-221.9200	0.0000	0.0000	-321.9200	0.0000
24		-149.2250	-121.9200	-58.8169	-149.2250	-221.9200	-58.8169	-149.2250	-321.9200	-58.8169
25	Top	0.0000	254.0000	0.0000	0.0000	354.0000	0.0000	0.0000	454.0000	0.0000
26		-156.5275	254.0000	-59.7694	-156.5275	354.0000	-59.7694	-156.5275	454.0000	-59.7694
27		-48.5775	254.0000	-59.7694	-48.5775	354.0000	-59.7694	-48.5775	454.0000	-59.7694
28		0.0000	254.0000	0.0000	0.0000	354.0000	0.0000	0.0000	454.0000	0.0000
29		0.0000	254.0000	0.0000	0.0000	354.0000	0.0000	0.0000	454.0000	0.0000

5.3.2 Material Properties

Six materials are considered in the shielding models: borosilicate glass, steel, LDCC concrete, Monofrax™, Zirmul™, and Inconel. Table 5-7 lists the shield material densities and compositions.

Table 5-7. Material Compositions

	Glass [1]	LDCC [2]	Steel [3]	Monofrax™[4]	Zirmul™ [5]	Inconel [6]
Density (g/cc)	2.6	1.12	7.98	3.89	3.14	8.3
Element	**Weight Fraction**					
H		0.0100				
Li	0.0181					
B	0.0423					
C			0.0031			
O	0.4554	0.5320		0.4093	0.4064	
Na	0.0631	0.0290				
Mg	0.0058	0.0340		0.0362		
Al	0.0335			0.3070	0.2470	
Si	0.2031	0.3370	0.0023	0.0093	0.0821	0.025
P			0.0004			
S			0.0004			
K	0.0438					
Ca		0.0440				
Ti						0.025
Cr				0.1916		0.15
Mn			0.0103			
Fe	0.0892	0.0140	0.9837	0.0466	0.0009	0.07
Ni						0.73
Zr	0.0104				0.2636	
Th	0.0354					

NOTES:
(1) Derived from West Valley Nuclear Services Company Processing Equipment Characterization Results WMG Report 4005-RE-024, Revision 4 (reference 5-6).
(2) Concrete Regular, from Chapter 5 of SRNS-IM-2009-00035 (reference 5-7) with density corresponding to 70 lbs/ft^3.
(3) Grade SA516 Grade 70 from Mechanical and Physical Properties of Steels for Nuclear Applications
(4) Derived from the oxide compositions for MONOFRAX K-3 at http://www.rhi-ag.com/internet_en/products_solutions_en/glass2_en/glass_prod_en/glass_prod_fc_en/glass_prod_fc_monofrax_en/
(5) Derived from the chemical composition for Zircon Mullite at http://www.cumi-murugappa.com/emd/datasheet/ZIRMUL_DataSheet.pdf
(6) Chapter 5 of SRNS-IM-2009-00035 (reference 5-7).

5.4 Shielding Evaluation

5.4.1 Methods

Gamma dose rates from the source material are determined by using the point kernel code QADS. The shielding analysis is formally documented in Engineering Calculation N-CLC-G-00153 (Appendix 5.5.2). The appendix includes all details pertinent to the analyses.

5.4.2 Input and Output Data

The input and output files are listed in Appendix 5.5.3 and provided separately on a disk.

5.4.3 Flux-to-Dose-Rate Conversion

Photon dose conversion factors were obtained from the American National Standards Institute standard, ANSI/ANS-6.1.1-1977 (reference 5-8). The values from the 1977 version of the standard were used rather than those from the 1991 version of the standard because the photon dose conversion factors in the 1977 version more closely correspond to the response measured by instrumentation.

5.4.4 External Radiation Levels

The package external radiation levels for NCT and HAC conditions are tabulated in Table 5-1. The contents are analyzed with the compositions given in Table 5-2. A comparison of QADS model results with actual dose rate readings is provided in Appendix 5.5.4. All dose measurement points recorded for the WVMP are identified in Appendix 5.5.4.

5.4.5 Summary and Conclusions

The shielding evaluation for the package results in radiation dose rates that meet the requirements of 10 CFR 71 for limits for NCT and HAC.

5.5 Appendix

This appendix contains the following information:

5.5.1 List of References

5.5.2 Engineering Calculation N-CLC-G-00153, *Dose Rates Outside West Valley Melter Package*, with errata page (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Request for Withholding*)

5.5.3 Input/output Computer Files (provided)

5.5.4 Comparison of QADS and measured dose rates

APPENDIX 5.5.1 – REFERENCES

5-1 10 CFR Part 71, *Packaging and Transportation of Radioactive Material,* Washington, D.C., January 2012.

5-2 49 CFR 173, *Shippers - General Requirements for Shipments and Packagings*, Washington, D.C., October 2010.

5-3 *QADS: A Multidimensional Point-Kernel Analysis Module*, Volume 1, Book 3, Section S5, ORNL/TM-2005/39, Revision 5, Broadhead, B.L. and Emmett, M.B., Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 2005.

5-4 *ORIGEN-S: Scale System Module to Calculate Fuel Depletion, Actinide Transmutation, Fission Product Buildup and Decay, and Associated Radiation Source Terms*, Volume 2, Section F7, ORNL/TM-2005/39, Revision 5, Hermann, O.W., and Westfall, R.M., Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 2005.

5-5 *Characterization of DWPF Melter One Glasses*, WSRC-TR-2003-00477, Rev 0, Cozzi, A.D. and Pareizs, J.M., Westinghouse Savannah River Company, Aiken, South Carolina, October 2003. (provided)

5-6 *West Valley Nuclear Services Company Processing Equipment Characterization Results*, WMG Report 4005-RE-024, Revision 4, WMG, Inc., Peekskill, NY, August 2013. (provided)

5-7 *Savannah River Nuclear Solutions Criticality Safety Methods Manual*, Chapter 5, Standard Material Compositions for Nuclear Criticality Safety Calculations, SRNS-IM-2009-00035, Revision 3, Savannah River Nuclear Solutions, Aiken, South Carolina, January 2014. (provided)

5-8 *Neutron and Gamma-Ray Flux-to-Dose-Rate Factors*, ANSI/ANS-6.1.1-1977, American Nuclear Society, LaGrange Park, Illinois, March 1977.

APPENDIX 5.5.4 – COMPARISON OF QADS AND MEASURED DOSE RATES

Location		Maximum mrem/hr (readings at same distance unless noted otherwise) Rad Survey 173952	N-NCL-G-00153 Model	Comparison Check	Remarks
at 1 m or as noted	North Side	1.0 at 1ft	0.052 at 1m	Impacted Readings	Another package (the melter feed hold tank) is located in close proximity on north side and seems to impact the readings.
	South Side	0.1 at 1m	0.019 at 1m	Measurement threshold	0.1 mrem/hr is lowest measurable threshold of rad survey equipment.
	East Side	0.1 at 1m	0.012 at 1m	Measurement threshold	0.1 mrem/hr is lowest measurable threshold of rad survey equipment. All rad survey doses (all dist) =0.1.
	West Side	0.1 at 1m	0.014 at 1m	Measurement threshold	0.1 mrem/hr is lowest measurable threshold of rad survey equipment. All rad survey doses (all dist) =0.1.
	Bottom	not available	16.7 at 1m	not available	1 meter Rad survey reading not available. See on-contact portion of table.
	Top	0.7 at 1m	1.18 at 1m	Conservative	
on contact or as noted	North Side	0.7 on contact	0.056 at surface	Impacted Readings	MFHT is located in close proximity on north side and seems to impact the readings.
	South Side	1 on contact	0.043 at surface		Rad survey is maximum observed, the other reading was 0.5.
	East Side	0.1 on contact	0.013 at surface	Measurement threshold	0.1 mrem/hr is lowest measurable threshold of rad survey equipment. All rad survey doses (all dist) =0.1.
	West Side	0.1 on contact	0.016 at surface	Measurement threshold	0.1 mrem/hr is lowest measurable threshold of rad survey equipment. All rad survey doses (all dist) = 0.1.
	Bottom	30 on contact	80.4 at surface	Conservative	
	Top	2.8 on contact	2.43 at surface	Consistent	2.8 was max observed, the other reading was 1.0 on contact. Model shows slightly lower value from the highest measurement.

6.0 CRITICALITY EVALUATION

This chapter describes the criticality evaluation for the West Valley Melter Package (WVMP). The total quantity of fissile material associated with the WVMP is 81.56 grams consisting of the following fissile material radionuclides: Pu-239, Pu-241, U-233, and U-235. In the WVMP, approximately 99.2 percent (80.9 grams) of the fissile material is contained within the glass matrix. The approximate weight of the residual vitrified glass is 467 kilograms. The consistency of the compositions throughout the glass in the melter with no measurable stratification of actinides or noble metals is supported by sampling and studies (reference 6-1). The remaining quantity of fissile material, 0.8 percent (0.66 grams), is conservatively distributed on the exterior surface of the Melter body.

In performing the Criticality Evaluation for the WVMP, each of the four source terms was analyzed independently. For the residual glass source terms, the analysis uses the mass of the vitrified glass only. The 0.66 grams of fissile material of surface contamination is conservatively distributed on the exterior stainless steel surface of the Melter. Each of the independent glass source terms meet the Fissile Exempt criteria as identified in:

§71.15(c) (1) Low concentrations of solid fissile material commingled with solid nonfissile material, provided that:

- (i) There is at least 2000 grams of solid nonfissile material for every gram of fissile material, and
- (ii) There is no more than 180 grams of fissile material distributed within 360 kg of contiguous nonfissile material.

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

The WVMP meets the requirement of 10 CFR Part 71.15 (reference 6-2). The WVMP is exempt from the fissile material criteria of 10 CFR 71.55 and 71.59, and a criticality evaluation is not applicable.

The package is fissile exempt.

6.1 Appendix

This chapter contains a single appendix – the list of references.

References

6-1 *Characterization of DWPF Melter One Glasses,* WSRC-TR-2003-00477, Rev 0, A.D. Cozzi and J.M. Pareizs, Westinghouse Savannah River Company, Aiken, South Carolina, October 2003. (provided)

6-2 10 CFR Part 71, *Packaging and Transportation of Radioactive Material.*

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7.0 PACKAGE OPERATIONS

This chapter describes the operations (1) previously completed to load and stabilize the melter inside the Grouted Melter Package (GMP), (2) to attach the Impact Limiter (IL) to the GMP, and (3) to prepare the West Valley Melter Package (WVMP) for transport and unloading at the disposal site.

The design and fabrication of the one-time, exclusive use container were completed in 2004. The melter was loaded into the package in 2004 and the Low Density Cellular Concrete (LDCC) was added in 2013. The GMP components were procured, constructed, and loaded under a Quality Assurance (QA) program meeting the requirements of NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications* (reference 7-1).

Key Terms and Acronyms in this Chapter	
GMP	Grouted Melter Package (consisting of the melter, LDCC inside the container, and the container itself)
IL	Impact Limiter
LDCC	Low Density Cellular Concrete
RTV	room temperature vulcanizing
WVDP	West Valley Demonstration Project
WVMP	West Valley Melter Package (consisting of the GMP with the IL installed)

Upon receipt of NRC Special Authorization, the IL will be procured and installed under the West Valley NQA-1 QA program that meets the requirements of 10 CFR 71, Subpart H (reference 7-2).

The completed operations described in this chapter were performed in accordance with detailed written procedures and work instruction packages approved under the site contractor's[1] QA Program, which demonstrate an equivalent level of safety with 10 CFR 71, Subpart H, *Quality Assurance*, including the applicable record keeping, inspections, reporting, and advance notification requirements addressed in 10 CFR 71.91 (records), §71.93 (inspection and tests), and §71.95 (reports).

Upcoming package operations at the site will be accomplished to these same requirements. All operations will continue to be conducted in a manner consistent with the evaluations described in Chapters 2 through 6 while maintaining occupational radiation exposures as low as reasonably achievable (ALARA) as required by the *Standards for Protection Against Radiation* in 10 CFR 20.1101(b) (reference 7-3) and the equivalent DOE ALARA requirements such as those in 10 CFR 835, *Occupational Radiation Protection* (reference 7-4).

7.1 Package Loading

This section describes previously conducted activities associated with preparing the container for loading the melter. The activities included loading the melter into the container, securing the container bolted side door, filling the container with LDCC through ports located on top of the container, and securing the ports after completion of LDCC emplacement. The container with the melter and the LDCC comprises the GMP.

This section also describes future activities associated with the installation of the IL to the exterior of the GMP and preparing the WVMP for transportation. These activities ensure the WVMP is not damaged and radiation and surface contamination levels are within allowable regulatory limits.

[1]Since August 2011, CH2M HILL B&W West Valley, LLC (CHBWV) has been the site contractor. West Valley Environmental Services (WVES) was the previous site contractor. In 2004, when the melter was placed in its container, the West Valley Nuclear Services Company (WVNSCO) was the site contractor.

7.1.1 Preparation for Loading

The operations for preparing the container so the melter could be loaded into it are discussed herein. These operations specify the container is loaded and closed in accordance with detailed written procedures. No moderator or neutron absorber is required.

Preparation of the Melter

The melter was used from 1996 through 2002 to heat the high-level waste mixture and glass formers to turn them into homogenized molten glass. In September 2002, after completion of vitrification operations, the melter was used to process low-activity decontamination solutions. Prior to shutdown of the melter, the final diluted heel was removed to the extent practical using a vacuum extraction system developed by DOE. The melter was then shut down.

To prepare the melter for removal from the West Valley Demonstration Project (WVDP) Vitrification Facility and placement into a shielded transfer container, electrodes were cut and shield plugs installed. The exterior surface of the melter was coated with Bartlett Polymeric Barrier System (PBS) to ensure surface contamination was fixed. The PBS-coated melter was then pulled on rails into a shielded transfer container to facilitate its movement through a portion of the WVDP main process plant.

Preparation of the Container

The container was manufactured and delivered to the WVDP in 2004. Figure 7-1 shows the container when it arrived in 2004 with its bolted side door removed. Acceptance tests and inspections associated with the container are discussed in Chapter 8.

Upon receipt at the WVDP, the empty container was lifted off the incoming transport vehicle using a gantry crane and the lifting lugs installed by the manufacturer.

Figure 7-1. The Container upon Arrival at the Site

7.1.2 Loading of Contents

This subsection describes how the melter was placed in the container and how the LDCC was emplaced.

Loading of Melter into the Container

In 2004, using integral container transfer rails, the melter was moved into its container through the open side door. The bolted side door was then secured per manufacturer's instructions (reference 7-5) by:

- Cleaning the bolted side door plate gasket seating area and inspecting the interface surfaces of the neoprene gasket,
- Aligning and installing the gasketed side door plate to the container by aligning the side door lift tabs to the slots in the container's top skirt to guide it into position,
- Applying anti-galling lubricant to the threads of each of the 328" long by 1.5" diameter bolts and installing them with their washers through the bolted side door into the container, and
- Tightening the bolts to the manufacturer-specified final torque value of 500 lb-ft.

To secure the melter (sitting on rails) within the container during onsite movement, a horizontal securement device provided by the container manufacturer was then installed through a penetration port in the container. Additionally, vertical securement devices were installed through two penetration ports in the top of the container. The container was then lifted onto a heavy-load transport vehicle and moved to the interim storage area at the WVDP, placed on dunnage, and covered with a tarp to await placement of the LDCC.

Placement of the LDCC

The three securement devices (rods) installed in 2004 to support the movement of the container to the interim storage area were removed prior to placement of the LDCC. A final penetration cover was then installed where the horizontal securement device was removed (reference 7-6) by:

- Cleaning the penetration gasket seating areas and inspecting the interface surfaces of the neoprene gaskets,
- Installing and securing the gaskets on the 6" deep penetrations,
- Applying anti-galling lubricant to the threads of each of the 3¾" long by 5/16" diameter socket head cap screws,
- Positioning the gasketed plug into recessed area of the penetration, and
- Installing the socket head cap screws and tightening them to the manufacturer-specified final torque value of 35 lb-ft.

To identify a LDCC recipe that would provide a minimum 28-day compressive strength of 1,000 psi inside the container, a series of recipe development mock-ups were tested offsite in 2013 by a subcontractor knowledgeable of LDCC (reference 7-7). These studies indicated that if the wet density of the LDCC realized in the field after addition of a foam additive and prior to transfer to the container was between 68 and 72 lbs per cubic foot, the LDCC would achieve a minimum compressive strength of 1,000 psi after 28 days inside the container.

Upon the removal of the two vertical securement devices on top of the container, the same two top 5" diameter penetrations were used for emplacing the LDCC. One of the two penetrations was used for the LDCC fill pipe and the other for a ventilation hose and a bullet camera (and then switched between lift one and lift two).

The LDCC fill pipe was initially lowered into the annulus between the melter and the container to approximately three feet above the bottom of the container and then raised as the LDCC level in the annulus increased. In addition to filling the annulus between the melter and the container, during the LDCC placement process LDCC passively entered the melter cavity through three openings in the melter. Figure 7-2 shows the grouting taking place.

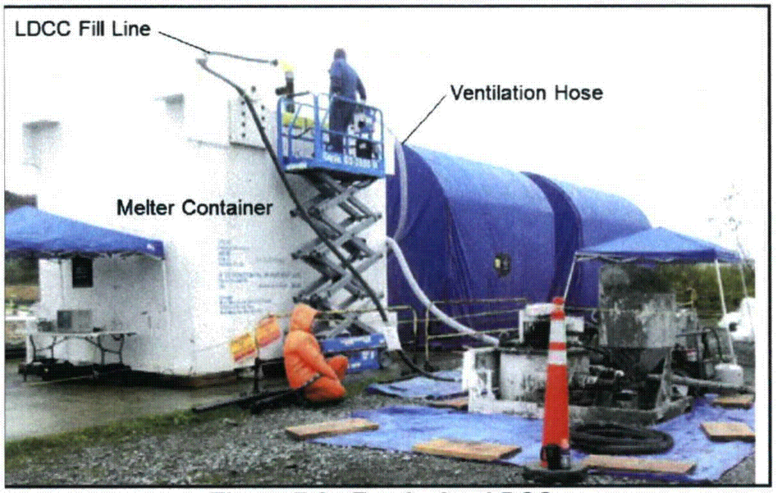

Figure 7-2. Emplacing LDCC

Two openings (open plenum/glass thermowell ports, each approximately 5" in diameter) are located on the top of the melter. A third opening is a non-plugged pour spout (approximately 6" in diameter) located in the bottom half of the melter side. During the grouting process, the level of the LDCC in the annulus was monitored using the bullet camera and by measuring dose rates on the outside of the container, which decreased as the LDCC level rose. As the LDCC level rose to the height of the pour spout, the annulus fill rate was significantly reduced indicating the entry of LDCC into the melter cavity as expected.

Similarly, when the LDCC rose to above the upper lip of the melter, the annulus fill rate also lagged, indicating additional filling of the melter cavity via the upper two melter openings. To manage the risk associated with LDCC entering and exiting the ports on top of the container (considering that LDCC placement was being conducted in open air), LDCC placement continued until the melter was completely encased in LDCC leaving the annulus approximately 93 percent full of LDCC with an air gap at the top of the GMP.

After LDCC placement activities were completed, the associated equipment was removed and the two ports on top of the GMP were closed (reference 7-8) by:

- Cleaning the penetration gasket seating areas and inspecting the interface surfaces of the neoprene gaskets,
- Installing and securing the neoprene gaskets onto the 4" deep plugs,
- Applying anti-galling lubricant to the threads of each of the 2¾" long by 5/16" diameter socket head cap screws,
- Positioning the gasketed plugs into the recessed area of the container penetrations, and

- Installing the socket head cap screws and tightening them to the manufacturer specified final torque value of 35 lb-ft.

The GMP was then reweighed and RTV applied to the gap between the bolted side door and the container.

7.1.3 Preparation for Transport

This subsection describes the confirmation of bolt torque, installation of the IL, and the other preparations for shipment of the WVMP.

Confirmation of Bolt Torque

Prior to installation of the IL, re-application of the original torque (500 lb-ft) to the bolts associated with the bolted side door of the containment boundary will be conducted. Re-application of the original torque (35 lb-ft) to the bolts associated with the gasketed ports will also be performed.

Installation of Impact Limiter

The IL will be installed on the bolted side door of the GMP. The IL will be fabricated and installed following receipt of NRC Special Authorization and prior to loading of the package onto the offsite transport vehicle.

Upon arrival at the WVDP site, the IL will be receipt inspected by CHBWV, verifying that no damage occurred to the structure during shipment and it complies with the procurement specification documentation. Installation will be performed in accordance with the CHBWV QA program and approved detailed written work instructions (reference 7-9). The installation process will include the following steps:

(1) The IL will be rigged to a mobile crane, boomed fork lift truck, or similar lifting device and transitioned from horizontal to vertical orientation.

(2) The IL will be positioned within the confines of the GMP shock absorbers snug against the lid and clamping devices will be installed to temporarily secure it in place.

(3) Fitment of the IL to the GMP will be inspected to verify that correct tolerances have been maintained.

(5) The IL retaining pin locations will be laid out and suitably marked.

(6) The IL main frame and the current GMP shock absorbers will be match drilled and reamed to required tolerances.

(7) The retaining pins will be installed.

(8) The clamping devices will be removed.

Other Preparations for Transport

Prior to the WVMP leaving the WVDP, the following steps will be performed in accordance with approved CHBWV procedures.

(1) The package will be marked per 10 CFR 71.85 (c), which states that *"The licensee shall conspicuously and durably mark the packaging with its model number, serial number, gross weight, and a package identification number assigned by NRC..."*

(2) Package tamper-indicating devices will be applied to bolted closures of the WVMP.

(3) Radiation surveys of the package (on contact and at one meter from the surface) and non-fixed (removable) contamination surveys will be performed per CHBWV's radiological program within 60 days of loading. The WVMP's exterior surface is expected to be free of removable contamination, and package exterior radiation levels will not exceed the limits specified in 10 CFR 71.47 at any time during transportation.

(4) WVMP will be marked and labeled in accordance with 49 CFR 172.300 and 172.400 respectively and the transport vehicle will be placarded in accordance with 49 CFR 172.500 (reference 7-10).

(5) Measurement of the WVMP surface temperature will be required prior to offsite transport.

Loading and Securement

The WVMP will be loaded and secured onto a heavy-haul trailer. The WVMP will be moved to a railcar at the transload facility and prepared for transport to the Waste Control Specialists (WCS) low-level waste disposal facility. These activities will be performed during the movement:

(1) Using a 350-ton minimum capacity gantry crane to move the WVMP to the heavy-haul trailer,

(2) Securing the WVMP to the heavy-haul trailer,

(3) Using the gantry crane to move the WVMP to the railcar, and

(4) Securing the WVMP to the railcar for transport.

The bolted-on lifting lugs shown on sheet 7 of Drawing 4005-DW-001 (see Chapter 1) will be utilized in lifting the WVMP. Securement lugs will be attached to the heavy-haul trailer and railcars to tie-down the WVMP. The tie-down systems are not a structural part of the package and are therefore not subject to 10 CFR 71 requirements.

The lifting hardware utilized during initial loading and subsequent transloading evolutions will accompany the shipment so that it can be utilized by WCS in handling of the WVMP.

7.2 Package Unloading

This subsection describes how the WVMP will be handled at the disposal facility.

7.2.1 Receipt of Package from Carrier

WCS personnel will perform radiation and contamination surveys of the WVMP upon its arrival at the WCS facility in accordance with WCS written policies and procedures. The WCS Onsite Transportation and Lift Plan for the WVMP will delineate detailed steps associated with tasks such as the following:

(1) Move the railcar so the WVMP is positioned under a 500-ton minimum capacity gantry system.

(2) Check the package tamper-indicating devices on bolted closures of the WVMP to ensure they remain intact.

(3) Remove equipment used to secure the WVMP to the railcar.

(4) Install the four lifting lugs to the WVMP.

(5) Install a suitable lifting assembly to connect the gantry crane to the WVMP.

(6) Using a 500-ton capacity gantry crane and this lifting assembly, lift the WVMP from the railcar, move it sideways toward the WCS Goldhofer transporter, position it on the deck of the transporter, and remove the rigging from the WVMP lifting lugs.

(7) Move the WVMP to a temporary staging area.

(8) Using the vertical lift capability of the Goldhofer, temporarily stage the WVMP on steel pipe stands.

(9) While the WVMP is being staged, dissemble the gantry system and transport it into the disposal cell to be reassembled.

(10) Transport the WVMP using the Goldhofer from the staging area down into the disposal cell via the current access ramp and into position it underneath the gantry crane.

(11) Rig and lift the WVMP package using the hydraulic gantry system.

(12) Lower the WVMP on WCS-provided saddles.

7.2.2 Removal of Contents

This subsection is not applicable. The WVMP is a one-time use package. The entire WVMP will be disposed of at WCS. The WVMP will not be opened at the WCS.

7.3 Preparation of Empty Package for Transport

This section is not applicable. The WVMP will be disposed of at WCS. Therefore, empty package transport requirements are not applicable for the WVMP.

7.4 Other Operations

The WVMP surface temperature must be above 3°F at West Valley prior to shipment and during packaging operations at WCS. The weather forecasts along the route shall predict ambient temperatures above 3°F.

Other weather restrictions normally associated with the utilization of cranes to perform lifts such as loading and unloading the WVMP (e.g., wind speed) also apply.

7.5 Appendix

This chapter includes a single appendix: 7.5.1 – List of references

APPENDIX 7.5.1 – REFERENCES

7-1 NQA-1, *Quality Assurance Requirements for Nuclear Facility Applications*, American Society for Mechanical Engineers, New York, New York, 2008.

7-2 10 CFR Part 71, *Packaging and Transportation of Radioactive Material.*

7-3 10 CFR Part 20.1101(b), *Standards for Protection Against Radiation.*

7-4 10 CFR Part 835, *Occupational Radiation Protection.*

7-5 *Remove Melter from Vitrification Facility*, WVNSCO work instruction package VFS-112008-WIP, West Valley Nuclear Services Company, West Valley, December 2004. (provided)

7-6 *Weigh and Prepare Melter Container TC 474 for Grouting at the Rail Packaging and Staging Area*, CHBWV work instruction package W1303663, CH2M Hill-B&W West Valley, LLC, West Valley, New York, completed October 2013. (provided)

7-7 *Melter Waste Package Grouting Implementation/QA Plan*, Revision 2. CH2M Hill-B&W West Valley, LLC, West Valley, New York, October 23, 2013. (provided)

7-8 *Grout Melter Container TC-474 at the Rail Packaging and Staging Area*, CHBWV work instruction package W1303694, CH2M Hill-B&W West Valley, LLC, West Valley, New York, completed November 2013. (provided)

7-9 *Administration of Work Instruction Packages*, EP-5-002, Revision 37, CH2M Hill-B&W West Valley, LLC, West Valley, New York, March 19, 2014. (provided)

7-10 49 CFR Part 172, *Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, and Training Requirements.*

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter describes the completed acceptance tests for the West Valley Melter Package (WVMP), including those for the container and the Low Density Cellular Concrete (LDCC) used to fill the container and the melter, and those to be accomplished on the Impact Limiter (IL) to be installed on the bolted side door of the Grouted Melter Package (GMP). The design and fabrication of the one-time, exclusive use container were completed in 2004, the melter was loaded into the container in 2004, the LDCC added in 2013.

The container was procured as a 49 CFR 173.411 Industrial Packaging Type 2 (IP-2) package with the associated fabrication and quality assurance (QA) requirements (reference 8-1). The container was fabricated in accordance with American Welding Society (AWS) Structural Code D1.1 (reference 8-2). The WVMP provides an equivalent level of safety with the requirements of NUREG/CR-3019, *Recommended Welding Criteria for Use in the Fabrication of Shipping Containers for Radioactive Materials* (reference 8-3) and the ASME *Boiler and Pressure Vessel Code*, Subsection ND (reference 8-4) as detailed in Appendix 8.3.2.

The new IL is to be installed before shipment to Waste Control Specialists (WCS) for disposal. The fabrication and examination for the IL construction will be per ASME Code, Section III, Subsection NF, in accordance with Table 4-1 of NUREG/CR 3854, *Fabrication Criteria for Shipping Containers* (reference 8-5).

No maintenance program is required for the one-time use package.

8.1 Acceptance Tests

The acceptance tests and inspections that were performed on the container were accomplished under the West Valley Demonstration Project (WVDP) Quality Assurance (QA) program in accordance with written procedures, as were the acceptance tests and inspections of the LDCC used to fill the melter and container void spaces (reference 8-6). These tests and inspections confirmed the container was fabricated in accordance with the drawings identified in Chapter 1 and the LDCC meets the comprehensive strength requirements established by the designer of the GMP. The acceptance tests and inspections for the IL will be accomplished to the same requirements.

Key Terms and Acronyms in this Chapter	
GMP	Grouted Melter Package (consisting of the melter, LDCC inside the container, and the container itself)
IL	Impact Limiter
LDCC	Low Density Cellular Concrete
WVDP	West Valley Demonstration Project
WVMP	West Valley Melter Package (consisting of the GMP with the IL installed)

8.1.1 Visual Inspections and Measurements

This subsection summarizes visual inspections and measurements that were completed on the container and the LDCC used to fill it and the melter void spaces and those inspections and measurements to be performed on the IL.

The Container

The container was fabricated at American Tank and Fabricating Company of Cleveland, Ohio to NQA-1 (reference 8-7) requirements and the design drawings provided in Chapter 1. Upon receipt at the WVDP in 2004, in accordance with the site QA program and receipt inspection requirements identified in site procedures, visual inspections and measurements (reference 8-8) confirmed that the container:

- Did not show any visible shipping damage;
- Met specifications on the purchase order, including gaskets; and
- That no suspect or counterfeit parts were used.

The acceptance criteria for these inspections included compliance with the specified requirements.

The process for taking action on nonconformances involved identifying unacceptable items with a QA hold tag and segregating them. An issue report would then be generated to document and address the nonconformance. Nonconforming items would be dispositioned based on their condition as "use-as-is", "rework", "repair," "scrap," or "return to vendor". The QA hold tag would only be removed by a QA representative after approval of the resolution and completion of the necessary action.

Low Density Cellular Concrete

The level of the LDCC in the annulus was visually monitored as the mixture was being poured using the bullet camera. LDCC placement continued until the melter was completely encased. The following day, after the LDCC placement equipment was removed from the top ports of the GMP, personnel visually re-confirmed that the melter was completely encased in LDCC. The GMP is approximately 93 percent full[1].

The tests confirm the LDCC meets the minimum compressive strength requirements as discussed in Section 8.1.5 below.

Impact Limiter

Upon arrival at the WVDP site, the IL will be receipt inspected by CHBWV, verifying the following conditions:

- It does not show any shipping damage,
- Meets specifications on the purchase order, and
- No suspect or counterfeit parts were used.

Acceptance criteria for these IL inspections includes compliance with the specified engineering and procurement requirements to include key dimensions and associated tolerances, proper fit to the

[1]The 93 percent value corresponds to a void space of approximately 10 inches at the top of the container. This space resulted from concerns to avoid LDCC overflow and spreading radioactive contamination given that LDCC was being poured outdoors in the open air. The void space was considered in the modeling described in Chapter 2 and Chapter 4.

GMP component, and receipt of proper documentation of material certification. Any nonconforming characteristics will be reviewed in accordance with the WVDP QA Program and recommended dispositions proposed and approved. Items that deviate from design requirements whose disposition is "use-as-is" or "repair" will be subject to design control measures commensurate with those applied to the original design. Any such dispositions and corrective actions will be formally documented, with technical justification provided.

8.1.2 Weld Examinations

This section describes welding examinations used to verify fabrication of the container in accordance with the specified drawings, codes, and standards and those welding examinations to be performed on the IL.

Container

The container was fabricated at American Tank and Fabricating to NQA-1 requirements and the design drawings identified in Chapter 1. Welding was performed in accordance with American Welding Society Structural Code D1.1, *Structural Welding Code – Steel* (reference 8-2). In compliance with 10 CFR 71.119, welds were visually examined and magnetic particle inspected in accordance with this code (reference 8-9).

As shown in Appendix 8.3.2, the applicable requirements of the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, Section III, Article ND-5300, *Acceptance Standards* (reference 8-4) were implemented by the WVDP and its container subcontractor in connection with fabrication of the container.

Impact Limiter

Prior to installation onto the GMP, visual examinations and magnetic particle examinations will be performed on the IL welds. The acceptance criteria shall be those specified in the ASME Boiler and Pressure Vessel Code, Section III, Subsection NF, Article NF-5300, *Acceptance Standards* (reference 8-4).

During the installation of the IL, the retaining pins will be secured in place with a bevel weld performed by certified welders using WVDP qualified procedures (reference 8-10).

8.1.3 Structural and Pressure Tests

Chapter 2 documents the analyses that demonstrate the WVMP structural integrity. Based on analysis showing an appropriate safety factor, no pressure test was performed.

The analysis confirms the WVMP integrity under Normal Conditions of Transport provides assurance the radioactive materials will remain contained in the package. Therefore, the package meets the requirements of 10 CFR 71 (reference 8-11) under Normal Conditions of Transport. In the event of a breach of containment under Hypothetical Accident Conditions, the released radioactivity levels would be within the limits of 10 CFR 71 as discussed in Chapter 4.

8.1.4 Leakage Tests

Leakage tests are not applicable to the WVMP because there is no pressure vessel or other leak-testable boundary associated with the package. The package meets the release limits of 10 CFR 71 for NCT and HAC.

The NCT release is calculated, with very conservative assumptions, to be less than 1E-7 A_2/hr and satisfies the containment requirements of 10 CFR 71.51 under NCT (Appendix 4.6.2). The leak path factor used for NCT is for a closed container with no seals.

Less than 1E-1 A_2s are released under HAC using conservative assumptions (Appendix 4.6.2). This is less than the limit of 10 times an A_2 quantity per week for Kr-85 and 1 A_2 per week for all other isotopes, as specified in 10 CFR 71.51(a)(2), for HAC containment calculations, the worst case package damage, as determined by the HAC analysis described in Chapter 2 as summarized in section 2.7.8, was used for the leak path.

The package meets the release limits specified by 10 CFR 71 for NCT and HAC.

The container was fabricated to NQA-1 requirements to the design drawings identified in Chapter 1 Appendix 1.3.2. The welding was performed to an equivalent level of safety with 10 CFR 71.119. All welds were visually examined and magnetic particle inspected. An equivalent level of safety to the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Article ND-5300, Acceptance Standards (reference 8-4) were implemented in connection with fabrication of the container (Appendix 8.3.2). Section 8.1.2 provides more fabrication detail.

Upon receipt, in accordance with the site QA program and receipt inspection requirements identified in site procedures, visual inspections and measurements (reference 8-12) confirmed the container:

- Did not show any visible shipping damage;
- Met specifications on the purchase order, including gaskets; and
- No suspect or counterfeit parts were used.

The acceptance criteria for these inspections included an equivalent level of safety with the specified requirements. Section 8.1.1 provides more acceptance detail.

The bolted side door was secured per manufacturer's instructions after the content was installed. Chapter 7, section 7.1.2 provides more operations detail.

8.1.5 Component and Material Tests

This subsection describes component and material tests that have been performed on the container and the LDCC and those to be performed on the IL.

Container

Component and material tests were performed on components of the container that affect package performance. Certified material test reports confirmed the components and materials meet the acceptance criteria (reference 8-12). The West Valley receipt inspection confirmed that the gaskets meet the requirements of the purchase order (reference 8-6).

Low Density Cellular Concrete

During the LDCC placement process in 2013, one sample from each of the LDCC truck loads was taken to confirm that the 68 to 72 pounds per cubic foot wet density criteria was met (reference 8-13). Test cylinders cast from each truck load were tested after 28 days and confirmed the LDCC had acceptable compressive strength. The 28-day compressive strengths for all the cylinders exceeded 1,000 psi (reference 8-14).

Impact Limiter

All plate material shall be provided with certified material and chemical test reports. These tests shall include determination of the nil-ductility transition temperature for materials three inches thick and over. All base metals and filler materials utilized will be qualified for notch toughness. All welding will be performed in accordance with approved procedures.

8.1.6 Shielding Tests

Shielding tests are not applicable for the WVMP. The WVMP is a single use package shipping a unique content that has already been loaded and sealed. The packaging design does not include any features specifically credited with shielding. The calculated dose rates are based upon a bounding estimate of the contents and the package built to the certified design using certified materials. The calculated dose rates bound the measured dose rates and are within the regulatory limits.

8.1.7 Thermal Tests

Thermal acceptance tests are not applicable. The packaging design does not incorporate active heat transfer features nor are passive heat transfer mechanisms particularly sensitive to normal variations in the materials of construction or fabrication methods. The WVMP materials are capable of withstanding temperatures within its design envelope as shown in Chapter 3.

8.1.8 Miscellaneous Tests

No additional tests prior to use of the package are applicable. No tests other than those described above are necessary for the WVMP (either the GMP or the IL).

NOTE

> Appendix 8.3.2 includes a series of tables that show how the WVMP complies with ASME requirements on materials, design, fabrication, examination, and welding.

8.2 Maintenance Program

No maintenance program is applicable for the WVMP for the following reasons:

- The WVMP is a single-shipment package used for transportation and disposal of the melter.
- The WVMP is a sealed enclosure with no instrumentation or operating control devices that are relied upon for maintaining and monitoring its integrity during the shipment.
- The initial acceptance tests and inspections as described herein and the pre-shipment routine determinations to be performed in accordance with 10 CFR 71.87 criteria.

8.2.1 Structural and Pressure Tests

Not applicable. A maintenance program and associated tests are not required for this package.

8.2.2 Leakage Tests

Not applicable. A maintenance program and associated tests are not required for this package.

8.2.3 Component and Material Tests

Not applicable. A maintenance program and associated tests are not required for this package.

8.2.4 Thermal Tests

Not applicable. A maintenance program and associated tests are not required for this package.

8.2.5 Miscellaneous Tests

Not applicable. A maintenance program and associated tests are not required for this package.

8.3 Appendix

This chapter contains two appendices:

8.3.1 List of References

8.3.2 ASME Requirement Comparison Tables

APPENDIX 8.3.1 – REFERENCES

8-1 *WMG Certificate of Conformance, WVDP-TC-474, WVNSCO Purchase Order 19-104320-C-LH, West Valley Demonstration Project Melter DOT package, revised, WMG, Inc., Peekskill, New York, July 2013.* (Proprietary information withheld under 10 CFR 2.390, *Public Inspections, Exemptions, Request for Withholding*)

8-2 *Structural Welding Code – Steel*, D1.1, American Welding Society, Miami, Florida, 2004

8-3 *Recommended Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials*, NUREG/CR-3019, Lawrence Livermore National Laboratory, Livermore, California, March 1984.

8-4 *ASME Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, New York, 2004.

8-5 *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854 (UCRL-53533), Lawrence Livermore National Laboratory, Livermore, California, March 1985.

8-6 *Receipt Inspection*, Quality Assurance Procedure QP 10-2, Revision 15, CH2M Hill-B&W West Valley, LLC, West Valley, New York, October 22, 2013. (provided)

8-7 *Quality Assurance Requirements for Nuclear Facility Applications*, NQA-1, American Society for Mechanical Engineers, New York, New York, 2004.

8-8 Material Receiving Inspection and Release (MRIR) report #04-1152, West Valley Nuclear Services Company, West Valley, New York, October 15, 2004. (provided) .

8-9 Nondestructive Test Reports MT-110-04, VT-35-04, X-R-I Testing Division of X-Ray Industries, Inc., Troy, Michigan, October 13, 2004. (provided)

8-10 *WVDP Site Welding Manual*, WVDP-352, Revision 5, CH2M Hill-B&W West Valley, LLC, West Valley, New York, July 11, 2012. (provided)

8-11 10 CFR Part 71, *Packaging and Transportation of Radioactive Material.*

8-12 Certified Test Reports 2004, various reports Including: Receiving Inspection and Material Validation – Steel Plate; Steel Warehouse, Certificate of Analysis and Tests; United States Steel Corporation Metallurgical Test Reports; Bethlehem Steel Test Certificates; Report of Tests and Analysis; Fastenal Certificate of Compliance; Cardinal Fastener Test Certification; Wrought Washer Mfg. Certificate of Compliance; Steel Dynamics Chemical/Physical Certification; Nova Machine Products Corporation Material Test Report; Dyson Corp. Certified Test Report; Technical Stamping Material Certification; and Sabre Steel Inc. Certificate of Conformance. (provided)

8-13 Supplier Surveillance Reports SR-13-078 (10/31/2013) and SR-13-085 (11/06/2013), CH2M Hill-B&W West Valley, LLC, West Valley, New York, 2013. (provided)

8-14 Grout Compressive Strength Test Reports, ASTM C-1019, Ticket Numbers 522, 523, 524, 526, 544, 546, and 547, Quality Inspection Services, Inc., Buffalo, New York, December 9, 2013. (provided)

8-15 *West Valley Melter Package (WVMP) — Comparison of AWS D1.1, Structural Welding Code and ASME Section III, Subsection ND Welding Requirements*, SRNL-L4430-2015-00001, D.N. Maxwell, SRNL Material Science and Technology, March 2015, (provided)

APPENDIX 8.3.2 – ASME REQUIREMENT COMPARISON TABLES

The container was procured as a 49 CFR 173.411 Industrial Packaging Type 2 (IP-2) package with the associated fabrication and quality assurance (QA) requirements (reference 8-1). The container was fabricated in accordance with American Welding Society (AWS) Structural Code D1.1 (reference 8-2).

The WVMP provides an equivalent level of safety with the requirements of NUREG/CR-3019, Recommended Welding Criteria For Use in the Fabrication of Shipping Containers for Radioactive Materials (reference 8-3) and the ASME Boiler and Pressure Vessel Code, Subsection ND (reference 8-34) as detailed in this appendix. The letter report *West Valley Melter Package (WVMP) — Comparison of AWS D1.1, Structural Welding Code and ASME Section III, Subsection ND Welding Requirements*, provides detailed comparison (reference 8-15).

The fabrication and examination for the IL construction is per ASME Code, Section III, Subsection NF, in accordance with NUREG/CR 3854, Table 4-1(reference 8-4).

Table 1. Material Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-2121	Materials shall be restricted to those listed in Tables 1A, 1B and 3.	The WVMP demonstrates an equivalent level of safety. SA516-70 and SA-36 are listed in Table 1A and within the permitted thickness. The ASME (SA) and ASTM (A) material specifications are identical.
ND-2221	Coupon and specimen location shall be as required by the material specification. Note that the ASME/ASTM material specification (Sect. II Part A Specification SA 20/A 20M-89, Section 11.2 states; the longitudinal axis of the tension test specimens shall be transverse to the final rolling direction of the plate).	The WVMP demonstrates an equivalent level of safety. Per the Certified Material Test Reports (CMTRs), coupons were taken in accordance with ASTM A516/ASME SA516.
ND-2128	Bolting material to be listed in Table 3.	The WVMP demonstrates an equivalent level of safety. ASTM 193-B7 is in Table 3.
ND-2130	Material CMTRs to be supplied.	The WVMP demonstrates an equivalent level of safety. CMTRs for SA-516, SA-36, and Bolts were supplied.
ND-2311	Pressure retaining material shall be impact tested, unless LST is set above Table ND-2311-1 values.	The WVMP demonstrates an equivalent level of safety. Appendix 2.12.2 analysis justifies LST = 3°F for 6 inch thick.
ND-2400	Welding Materials ASME Subsection ND requires fracture toughness testing.	The WVMP demonstrates an equivalent level of safety. Although the filler metal CMTRs verifying tensile, chemistry, and impact testing are not available, the weld filler material used met the AWS 5.XX Specification as specified in the

Table 1. Material Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
	ASME Section III, Subsection ND requires filler material testing for tensile and chemistry.	applicable AWS D1.1 welding procedure specification. Moreover, the filler material specifications for both ASME (SFA) and AWS (A5.XX) are identical and require impact testing for the FCAW, SMAW, and SAW consumables when purchased to the applicable specification. Lowest service temperature was set to 3°F to address the lack of fracture toughness testing.
ND-2440	Suitable storage and handling of electrodes flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.	The WVMP demonstrates an equivalent level of safety. AWS D1.1, Section 5.3 covers, in detail, the storage and handling requirements of welding consumables and electrodes. Compliance was verified through the quality program and CWI oversight.

Table 2. Design Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-3100	Loading and Design Criteria are specified.	The WVMP demonstrates an equivalent level of safety. The loads are per the CFR and are consistent with ND-3100. The design criteria are per ND-3100.
ND-3300	Design Requirements are specified.	The WVMP demonstrates an equivalent level of safety. The Stress Limits used in Chapter 2 structural analysis are in compliance with RG 7.6 and consistent with ND-3300.
ND-3350	Weld Joint requirements: The walls of the rectangular GMP are fabricated of single slabs. The only structural welds are on the corner joints. ND-3350 is targeted to circular vessels constructed of pieced plates. The best match to the corner joint is ND-3350, Category D.	The WVMP demonstrates an equivalent level of safety. The corner joints feature partial groove welds on both inside and outside edges with reinforcing fillets on the inside. ND-3350 permits partial groove welds. Weld joints meet the requirements of AWS D1.1 prequalified joint designs. The weld attributes on the 4 inch and 6 inch base material are in Table 6.

Table 3. Fabrication Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-4100	Material control requirements are specified. This includes material examination, repair of discontinuities, material identification and weld preparation. Welding material shall meet the requirements of ND-2400. Reference Table 1.	The WVMP demonstrates an equivalent level of safety. Base material examination, repair of discontinuities, weld preparation, and material identification meet the requirements of AWS D1.1. AWS D1.1 provides a level of assurance, combined with the CWI overview, that the correct material was used in the fabrication of the WVMP.
ND-4200	Forming, fitting, and aligning requirements are specified.	The WVMP demonstrates equivalent level of safety. These requirements are focused on circular vessels. There are no features of the GMP sensitive to tolerance or fit-up beyond those already controlled by material specifications and construction drawings. Weld joint requirements are already discussed in ND-3350.
ND-4300 and ND-4400	Welding Qualifications are specified. ASME Section III, Subsection ND requires qualification of procedures and personnel to be performed in accordance with ASME Section IX and additional requirements specified in ND-4300.	The WVMP demonstrates an equivalent level of safety. The welding procedure specifications (WPS) were performed in accordance with AWS D1.1 prequalified/qualified procedures as applicable, with one exception. WPS 2.108 is prequalified for use with ASTM A36 base material and requires a 150° F minimum preheat. The procedure was used to weld joints on base material A/SA516 that required a minimum preheat of 225° F. The disposition is to use as is based on the following: both materials are grouped as AWS prequalified materials, both are approved for use in the specified joint detail of AWS D1.1(B-U3c-S), and the filler material used (SFA 5.23, Classification EA1) meets the base metal/filler material strength relationships for SA516. Reference Table 5, ND-4600, for preheat disposition. Welders were qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.
ND-4600	Preheat, interpass and post-weld heat treatment are specified.	The WVMP demonstrates an equivalent level of safety. An appropriate level of preheat was performed in accordance with the AWS D1.1 applicable prequalified WPS requirements. Reference Table 5, ND-4600. The weld attributes on the 4 inch and 6 inch base material are in Table 6.

Table 4. Examination Requirements ASME/WVMP Compliance

ASME Sect. III, Div. 1, Subsection ND-5200		WVMP Compliance
Section	**Requirements**	**Compliance Method**
ND-5230	Radiography is not required when the weld joint is not a full penetration weld.	The WVMP demonstrates an equivalent level of safety. Visual and magnetic particle examinations (VT/MT) were performed, post weld, on all welded joints in accordance with AWS D1.1 requirements except welds 37 and 38. These welds were not examined, are not load bearing, and were dispositioned accordingly. Reference NCR No. (1)04-002. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
ND-5280	Based on Storage Tanks to WVMP similarity. Bottom-to Sidewall, Roof to sidewall joints shall be examined visually. Alternatively, MT or PT may be substituted.	The WVMP demonstrates an equivalent level of safety. Visual and magnetic particle examinations (VT/MT) were performed, post weld, on all welded joints in accordance with AWS D1.1 requirements except welds 37 and 38. These welds were not examined, are not load bearing, and were dispositioned accordingly. Reference NCR No. (1)04-002. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
ND-5340 and ND-5350	Acceptance standards for MT and VT are specified.	The WVMP demonstrates an equivalent level of safety. There are slight differences in the acceptance criteria with AWS D1.1 allowing a larger and greater number of rounded indications as compared to ASME Section III, ND requirements. However, the differences are insignificant and the AWS D1.1 acceptance criteria have proven to provide an adequate level of safety. Visual and magnetic particle examination performed the results were acceptable The weld attributes on the 4 inch and 6 inch base material are in Table 6.
ND-5500	ASME Section III, Subsection ND requires NDE personnel certification in accordance with SNT-TC-1A.	The WVMP demonstrates an equivalent level of safety. Documents contained in the welding documentation package revealed NDE personnel certification to SNT-TC-1A, proper eye examination, certified welding inspector (CWI) credentials and examinations meeting the applicable requirements of AWS D1.1

Table 5. Welding Requirements NUREG & AWS/West Valley Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
Base Materials – *ND-2000 (except ND-2300 and ND-4100)* NUREG/CR-3019 and ASME Subsection ND require fracture toughness testing. ND-2121(a) - Pressure retaining material shall conform to the requirements of one of the specifications for materials listed in Tables 1A, 1B, and 3, Section II, Part D, Subpart 1..... ND 2121(e) - Welding and brazing materials used in manufacture of items shall comply with an SFA specification in Section II, Part C, except as otherwise permitted in Section IX, and shall also comply with the applicable requirements of this Article. ND2531 - Plates shall be examined in accordance with the requirements of the material specification.	Base Materials Used – SA/A36, A572 grade 50/60 (sub. A633 E/C), SA/ASTM516 grade 70 – Thickness (1/8" 1/2", 1", 2", 4" 6") Welding Materials Used – E71T-1 (spec. A5.20), ER70S-3 (spec. A5.18), E81T1-A1M (spec. A5.29), E7018 (spec. A5.1), and EA1 (spec. A5.23) Visual examination prior to welding.	The WVMP demonstrates an equivalent level of safety. Base material approved by ASME and AWS, same SA (ASME specification designation) and ASTM specifications applicable. Base materials prior to welding receive a visual examination based on AWS D1.1. Receipt inspection reports for the SA/A516 six inch material documents MT examination. SFA Specifications required in Section III are identical to AWS A5 specifications. Lowest service temperature was set to 3°F to address the lack of fracture toughness testing. The WVMP accepts gaps in the containment boundary (from analysis in Chapter 2) under HAC and released damaged material (see Chapter 4). Additional fractures or gaps do not increase or decrease the release fraction or the packages ability to meet 10 CFR 71 release criteria.
Welding Materials – *ND-2400* NUREG/CR-3019 and ASME Subsection ND require addressing fracture toughness. ASME Section III, Subsection ND requires filler material testing for tensile and chemistry. Suitable storage and handling of electrodes flux, and other welding material shall be maintained. Precautions shall be taken to minimize absorption of moisture by fluxes and cored, fabricated, and coated electrodes.	Welding Materials Used – E71T-1 (spec. A5.20), ER70S-3 (spec. A5.18), E81T1-A1M (spec. A5.29), E7018 (spec. A5.1), and EA1 (spec. A5.23) AWS D.1.1 Section 5.3 covers in detail the storage and handling requirements of welding consumables and electrodes.	The WVMP demonstrates an equivalent level of safety Filler metal CMTRs verifying tensile, chemistry, and impact testing are not available. The weld filler material used met the AWS 5.X Specification as documented in the applicable AWS D1.1 welding procedure specification. However, The filler material specifications for both ASME (SFA) and AWS (A5.XX) are identical and require impact testing for the FCAW, SMAW, and SAW consumables when purchased to the applicable specification. Storage and handling of welding materials requirements are met. Compliance was verified through the quality program and CWI oversight. The WVMP accepts gaps in the containment boundary (from analysis

Table 5. Welding Requirements NUREG & AWS/West Valley Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
		in Chapter 2) under HAC and released damaged material (see Chapter 4). Additional fractures or gaps do not increase or decrease the release fraction or the packages ability to meet 10 CFR 71 release criteria.
Joint Preparation – *ND-4200* ASME Section III, Subsection ND specifies weld requirements based on weld type.	Weld Joint/Welds - Complete/partial joint penetration v-groove, fillet and plug welds.	The WVMP demonstrates an equivalent level of safety. Weld joint preparation, groove type, weld type, and welding profiles used in the fabrication met the AWS D1.1 prequalified joint designs. The corner joints feature partial groove welds on both inside and outside edges with reinforcing fillets on the inside. ND-3350 permits partial groove welds. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
Welding – *ND-4400* ASME Section IX approved welding processes. Welding preparation and welding profile requirements.	Welding Processes – FCAW, GTAW, SMAW, and SAW	The WVMP demonstrates an equivalent level of safety. The WVMP used approved welding processes. Welding preparation, fabrication, and weld profiles met the requirements of AWS D1.1. The weld attributes on the 4 inch and 6 inch base material are in Table 6.
Qualification Procedure/Personnel – *ND-4300* ASME Section III, Subsection ND requires qualification to be performed in accordance with ASME Section IX and additional requirements specified in ND-4300.	Welding Procedure Specifications – Prequalified and qualified.	The WVMP demonstrates an equivalent level of safety. The welding procedure specifications (WPS) were performed in accordance with AWS D1.1 prequalified/qualified procedures as applicable, with one exception, WPS 2.108, R1. WPS 2.108 is prequalified for use with ASTM A36 base material and requires a 150° F minimum preheat. The procedure was used to weld joints on base material A/SA516 that required a minimum preheat of 225° F. The disposition on the base material is to use as is based on the following: both materials are grouped as AWS prequalified materials, both are approved for use in the specified joint detail of AWS D1.1(B-U3c-S), and the

Table 5. Welding Requirements NUREG & AWS/West Valley Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
	Welder Performance Qualifications – Performed in accordance with ASME Section IX.	filler material used (SFA 5.23, Classification EA1) meets the base metal/filler material strength relationships for SA516. Reference Table 5, ND-4600, for preheat disposition. AWS D1.1 requires qualification for processes and materials of certain types and also allows the use of prequalified procedures. The FCAW, SMAW, and SAW processes used in this application are prequalified; the GTAW process used is qualified in accordance with the appropriate section of AWS D1.1, "Certain welding processes in conjunction with certain related types of joints have been thoroughly tested and have a long record of proven satisfactory performance. These WPSs and joints are designated as prequalified and may be used without tests or qualification." The essential and nonessential variables and mechanical testing of the AWS prequalified and qualified WPSs are equivalent to ASME Section IX. The welder performance qualifications were performed in accordance with ASME Section IX mandated in ASME Section III, ND-4300 and is allowed by AWS D1.1 when approved by the Engineer. The Engineer is defined as a duly designated individual who acts for, and in behalf of, the Owner on all matters within the scope of the code.
Heat Treatment – *ND-4600* Except as otherwise permitted in ND-4622.7, all welds, including repair welds, shall be post weld heat treated.	Prequalified preheat requirements - 225^0 F for minimum thickness greater than 2 ½" and PWHT if specified by engineer and/or purchase requirements.	The WVMP demonstrates an equivalent level of safety. An appropriate level of preheat was performed in accordance with the applicable AWS D1.1 prequalified welding procedure with the exception to the welds made using WPS 2.108, R1, that required a minimum preheat of 225°F. These welds according to

Table 5. Welding Requirements NUREG & AWS/West Valley Compliance

NUREG/CR-3019 – Containment Related Welds, Category II; ASME Section III, Sub. ND	Fabrication Code – AWS D1.1, 2004 Edition	WVMP Compliance Method
		the WPS were made using a minimum preheat of 150°F. *The welds are expected to function as* designed with no cracking issues due to the following: • At minimum a 150° F preheat was performed. • Welding Processes (FCAW and SAW multiple electrodes) used produce a high deposition rate with high heat input which produces a slow cooling rate, permitting hydrogen diffusion. • Low hydrogen consumables were used – AWS A5.20 and A5.23 Electrode Specifications. • Low to medium restraint. • Post weld visual and magnetic examinations were acceptable. Also, these welds are reinforced by the shock absorbers and had little influence on the structural analysis (referenced Chapter 2). No PWHT documentation was available. No PWHT is credited in the WVMP. The WVMP accepts gaps in the containment boundary (from analysis in Chapter 2) under HAC and released damaged material (see Chapter 4) I. Additional fractures or gaps do not increase or decrease the release fraction or the packages ability to meet 10 CFR 71 release criteria.

Table 6. WVMP Weld Attributes for the Partial Penetration Welds on the 4" and 6" Thick Joints

Weld #	Dwg #	Item#	"T"(1)	Joint Type(2)	Final Inspection VT/MT CWI Report(3)	WPS(s)(4)	WPS Critical Variables (AWS D1.1)(5)				
							Process	Material	Filler Matl./Spec (6)	Preheat (Min.)	PWHT
4	4	1 - 4	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
6	4	1 - 4	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
7	4	1 - 3	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
8	4	1 - 3	4" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
9	5	2 - 3	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
10	5	2 - 3	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3	FCAW / Prequalified	AWS Group II	E71T-1 / SFA 5.20	225°F	No Record
20	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 / SFA 5.23	225°F / 150°F (8)	No Record
21	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 / SFA 5.23	225°F / 150°F (8)	No Record
22	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16"	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ;	225°F / 150°F (8)	No Record

Table 6. WVMP Weld Attributes for the Partial Penetration Welds on the 4" and 6" Thick Joints

Weld #	Dwg #	Item#	"T"(1)	Joint Type(2)	Final Inspection VT/MT CWI Report(3)	WPS(s)(4)	WPS Critical Variables (AWS D1.1)(5)				
							Process	Material	Filler Matl./Spec (6)	Preheat (Min.)	PWHT
				FiC					EA1 / SFA 5.23		
23	2	2 - 4	6" to 6"	SB/BS, 1" DoB, 5/16" FiC	Yes	7.032, R3 /2.108, R1	FCAW / SAW Prequalified	AWS Group II (7)	E71T-1 / SFA 5.20 ; EA1 / SFA 5.23	225°F / 150°F (7)	No Record

NOTES:

(1) T = Thickness

(2) SB = Single Bevel; BS = Both Sides; DoB = Depth of Bevel; FiC = Fillet inside Corner

(3) Reference NDE Report Number VT-35-04.

(4) Welding Procedure Specification.

(5) Welds performed by qualified welders for the procedures listed.

(6) Filler material specifications are acceptable by both the AWS D1.1 and Section IX of the ASME Boiler and Pressure Vessel Code and match the base material requirements for strength and ductility.

(7) Base material used for welds number 20, 21, 22, and 23 is SA516. One of the WPSs used for making these welds (WPS - 2.108, Revision 1) state that welding is to be performed on A36 base material only. The disposition is to use as is based on the following; both materials are grouped as AWS prequalified materials, both are approved for use in the specified joint detail of AWS D1.1 (B-U3c-S), and the filler material used (SFA 5.23, Classification EA1) meets the base metal/filler material strength relationships for SA516.

(8) Welds 20, 21, 22 and 23 had welds specified with two WPS. One specifies 225°F and other specified 150°F preheat. These welds are reinforced by the welded on shock absorbers and had little influence on the structural analysis (see Chapter 2 analysis). Reference Table 5, Heat Treatment NB-4600.