BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

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8. Notes/Comments

The entire design report was prepared jointly by Jason Viggato and Samuel Ocampo.

NOTICE OF OPEN CHANGE DOCUMENTS - THIS DOCUMENT IS IMPACTED BY THE LISTED CHANGE DOCUMENTS AND CANNOT BE USED WITHOUT THEM.

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1) CACN-001, DATED 07/24/2008

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00A	This design analysis supersedes and revises the previous document ANL-VDC-ME-000001 REV 00 to report the results of the finite element analyses and evaluations of the latest naval waste package. All pages are affected. Change bars are not used because the changes are extensive.	98	98	M. M. Lewis	D. G. McKenzie IV	N/A [EGS signature not required when 00A was issued]	M.J. Anderson 3/15/04
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DISCLAIMER

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ACRONYMS

ASME	American Society of Mechanical Engineers
B&PVC	Boiler and Pressure Vessel Code
BOD	Basis of Design
DOE	U.S. Department of Energy
ETF	Expended Toughness Fraction
EWA	Element Wall-Averaged
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
HLW	High-Level Waste
HVAC	Heating, Ventilation, and Air Conditioning
IED	Information Exchange Document
IICD	Integrated Interface Control Document
ITS	Important To Safety
ITWI	Important To Waste Isolation
LA	License Application
MCNP	Monte Carlo N-Particle
NNPP	Naval Nuclear Propulsion Program
NSDB-LA	Nuclear Safety Design Bases for License Application
OCB	Outer Corrosion Barrier
PCSA	Preclosure Safety Analyses
PDC	Project Design Criteria
QA	Quality Assurance
RPM	Repository Project Management

SFCs	Spent Fuel Canisters
SI	Stress Intensity
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratory
SS	Stainless Steel
TAD	Transportation, Aging, and Disposal
TEV	Transport and Emplacement Vehicle
UNS	Unified Numbering System for Metals and Alloys
WP	Waste Package(s)
YMP	Yucca Mountain Project

1. PURPOSE

A design methodology has been developed for the waste packages (WP) that satisfies the requirements of the Yucca Mountain Project (YMP). The practicability of this design methodology has been demonstrated in this report. This report provides a description of the design requirements and cites the specific evaluations as the basis for meeting those requirements.

The purpose of this report is to document how the design methodology has been applied to the naval waste package configurations. The design methodology is described in the *Waste Package Component Design Methodology Report* (Reference 2.2.40) as augmented by the *Execution Plan for the Thermal-Structural Discipline Workflow for Design, Design Revisions, and Prototyping of Waste Packages and Related Components* (Reference 2.2.30). The design methodology is intended to provide designs that satisfy the safety and operational requirements of the YMP. Three waste package configurations have been selected to illustrate the application of the methodology during the License Application (LA) process. These three configurations are the Transportation, Aging, and Disposal (TAD) canister bearing waste package, the 5–Defense High-Level Waste (DHLW)/United States Department of Energy spent nuclear fuel (DOE SNF) short (5–DHLW/DOE SNF Short) co-disposal waste package, and the naval canistered SNF long (Naval SNF Long) waste package. Design work for the other four waste packages will be completed at a later date using the same design methodology. These include the TAD canister bearing long waste package, the 5–DHLW/DOE SNF long co-disposal waste package, the DOE 2–Multi-Canister Overpack/2–Defense High-Level Waste (2–MCO/2–DHLW) co-disposal waste package, and the naval canistered SNF short (Naval SNF Short) waste package.

This report demonstrates that the design methodology can be applied successfully to the configurations and supports the License Application for construction of the repository. This report summarizes design features that show the designs are in compliance with applicable design requirements. Design requirements are contained in the *Basis of Design for the TAD Canister-Based Repository Design Concept* (BOD) (Reference 2.2.24) and the *Project Design Criteria Document* (PDC) (Reference 2.2.39). Additional design requirements are derived from the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25), which defines credible preclosure event sequences during normal operations.

It is important to note that the design authority's responsibility is limited to implementing the controlled design requirements such that compliance can be demonstrated (with the use of performance confirmation data as necessary) only up to the time of repository closure. The responsibility for demonstrating any future postclosure state with respect to compliance with design requirements rests with Sandia National Laboratory the YMP Lead Laboratory and for canisters enclosed in the waste packages, the Naval Nuclear Propulsion Program (NNPP). Further, the Lead Laboratory retains responsibility for demonstrating how and to what extent compliance with the design requirements contributes to barrier capability.

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2.3 DESIGN CONSTRAINTS

None

2.4 DESIGN OUTPUTS

This document provides the basis for the naval waste package designs as embodied in the drawings of these components. The design outputs include naval short and long configuration drawings (References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20 and 2.2.21). This document also provides information to support the License Application.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 The dimensions, masses, materials and load paths used in the development of this design report, corresponding to the naval waste package configuration drawings (References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20 and 2.2.21) are assumed to be the same as the final definitive design. The rationale for this assumption is that the design of the naval waste packages (References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20 and 2.2.21) are created for the License Application (LA). This assumption is used in Section 6.1.1.3.

3.1.2 The *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25) is used for screening event sequences (e.g., based on design features for other systems) and to further define the credible event sequence scenarios. A QA: N/A source is used since the latest revision of the BOD (Reference 2.2.24) does not sufficiently describe the credible event sequences for the naval waste package. This assumption is used in Section 6.2.3.

3.1.3 Event sequences defined by the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25) which are satisfied by the addition of design features to preclude the event or considered to be not credible will not be addressed by this design report. The rationale for this is that the Preclosure Safety Analyses (PCSA) group will screen out the event sequences for inclusion into the *Nuclear Safety Design Bases for License Application* (NSDB-LA) (Reference 2.2.2) at a later date, and satisfaction of design requirements resulting from these event sequences will be addressed by later revisions of the BOD (Reference 2.2.24). This assumption is used in Section 6.2.3.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 It is assumed that the results from thermal calculations performed for the TAD waste package may be used to demonstrate compliance with thermal requirements applicable to the naval waste package. The rationale for this is that the TAD and naval long waste packages are identical in size (References 2.2.16, 2.2.17, 2.2.18, 2.2.59, 2.2.60, 2.2.61) and that the thermal output of the TAD waste canister used in the calculations bounds that of the naval waste canister. This assumption is used in Sections 6.2.1.7, 6.2.1.17, 6.2.3.3, 6.2.3.8, 6.2.3.9, 6.2.3.10, 6.2.3.11, 6.2.3.12, 6.2.3.13, 6.2.3.14, 6.2.3.15.

3.2.2 In the event sequence where a loaded Transport and Emplacement Vehicle (TEV) is overdriven into an emplaced WP (Reference 2.2.25, Section 4.3.6) the structural response of the Naval WP is assumed to be less than and bounded by the structural response of a 5-DHLW/DOE SNF Short Co-disposed WP in a similar event sequence. The rationale for this assumption is that the peak structural response during this event sequence is in the bottom lid of the outer corrosion barrier (OCB) (Reference 2.2.54, Section 7) due to the TEV pushing the WP into the next emplaced WP in the drift. The TEV collision induced stresses in the bottom lid of the 5-DHLW/DOE SNF Short Co-disposed WP will be higher than those induced in the bottom lid of the Naval WP due to the larger diameter of the 5-DHLW/DOE SNF Short Co-disposed WP (Reference 2.2.71, Section 10.2, Table 24, Case 17). This assumption is used in Sections 6.2.3.6, 6.2.3.7, and 6.2.3.17.

3.2.3 It is assumed that the event sequence where the waste package is caught on the TEV structure and dragged along the invert surface, resulting in the waste package falling off the emplacement pallet and against TEV structures (Reference 2.2.25, Section 4.3.8) is less severe than the event sequence where a loaded TEV is overdriven into an emplaced WP (Reference 2.2.25, Section 4.3.6). The rationale for this is that the momentum of the TEV in the dragging scenario is less due to the fact that it will be starting from rest and is unloaded, compared to the collision scenario where the TEV is moving at full speed and is loaded with the waste package. A waste package dragged along the invert surface will most likely impact one of the invert beams, resulting on a line contact across the lid or a point contact on the sleeve. This is less severe than the point contact on the lid with an angled 2-MCO/2-DHLW WP, the case used in Reference 2.2.54. This assumption is used in Section 6.2.3.7.

3.2.4 It is assumed that the event sequence where a drip shield emplacement gantry collides with an emplaced waste package (Reference 2.2.25, Section 4.4.3) is less severe and bounded by the event sequence where a loaded TEV collides with an emplaced waste package. The rationale for this is that the loaded TEV (mass of 300 *tons* (272 *MT*) max and top speed of 1.705 *mph* (0.762 *m/sec*) per References 2.2.75 and 2.2.74 respectively) has a much larger momentum compared to the loaded drip shield emplacement gantry (mass of 100 *tons* (90.7 *MT*) max and top speed of 1.705 *mph* (0.762 *m/sec*) per References 2.2.72 and 2.2.73 respectively). This assumption is used in Section 6.2.3.17.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This document was developed in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1). The naval waste packages are classified as important to safety (ITS) and important to waste isolation (ITWI) (Reference 2.2.24, Section 12.1.2). Therefore, the approved version is designated QA: QA.

The *Execution Plan for the Thermal-Structural Discipline Workflow for Design, Design Revisions, and Prototyping of Waste Packages and Related Components* (Reference 2.2.30) is QA: N/A. It is used to augment the *Waste Package Component Design Methodology Report* (Reference 2.2.40).

The *Value Study Report—Waste Package Reevaluation* (Reference 2.2.27) is QA: N/A. It is referenced for historical purposes only.

The *Yucca Mountain Science and Engineering Report* (Reference 2.2.52) is QA: N/A. It is referenced for historical purposes only.

The *BSC Position on the Use of the ASME Boiler and Pressure Vessel Code for the Yucca Mountain Waste Packages* (Reference 2.2.15) is QA: N/A. It is used to augment the *Yucca Mountain Review Plan, Final Report* (Reference 2.2.45).

The *Emplacement and Retrieval Drip Shield Emplacement Gantry Mechanical Equipment Envelope* (Reference 2.2.72) is QA: N/A. It is used to augment the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25).

The *Drip Shield Gantry Mechanical Equipment Envelope Calculation* (Reference 2.2.73) is QA: N/A. It is used to augment the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25).

The *TMRB Decision Proposal, Revise TDR-MGR-MD-000037, Postclosure Modeling and Analyses Design Parameters* (Reference 2.2.68) is QA: N/A. It is referenced for historical purposes only.

The *Preliminary Preclosure Nuclear Safety Design Bases* (Reference 2.2.2) is QA: N/A. It has been incorporated by reference to the BOD (Reference 2.2.24).

The *Regulatory Guidance Agreement, Regulatory Guide 1.84, Rev. 33 - Design, Fabrication, and Materials Code Case Acceptability, ASME Section III* (Reference 2.2.77) is QA: N/A. It is used to provide guidance on the use of *Regulatory Guide 1.84* (Reference 2.2.78).

4.2 USE OF SOFTWARE

Microsoft Excel 2003 (Version 11.8169.8172) SP3, which is a component of Microsoft Office 2003, is used for performing calculations and plotting in Section 6.2.3.5. Usage of Microsoft Office in this calculation constitutes Level 2 software usage, as defined in *IT-PRO-0011*

(Reference 2.1.3, Attachment 12). Microsoft Office 2003 is listed in the current Level 2 Usage Controlled Software Report, as well as the *Repository Project Management Automation Plan* (Reference 2.1.4, Table 6-1).

Microsoft Excel 2003 (Version 11.8169.8172) SP3 was executed on a PC running the Microsoft Windows XP Professional 5.1.2600 Service Pack 2 Build 2600 operating system. The calculations are confirmed by hand calculations and the plot is verified by visual inspection.

4.3 WASTE PACKAGE COMPONENT DESIGN METHODOLOGY

The design methodology for waste package components (including the emplacement pallet and drip shield) is described in the *Waste Package Component Design Methodology Report* (Reference 2.2.40). Common design work practices and design changes are controlled within the design group through the *Execution Plan for the Thermal-Structural Discipline Workflow for Design, Design Revision, and Prototyping of Waste Packages and Related Components* (Reference 2.2.30). Design methodology can be viewed simply as gathering all the design input information; making reasonable assumptions; selecting analyses methods and computational tools; and showing that design criteria are satisfied.

Inputs to the design come from project requirements, interfaces with other organizations, and specific technical information. Top level requirements originate from the U.S. Department of Energy (DOE) and include regulations such as *10 CFR Part 63* (Reference 2.2.1). These requirements flow to design through two documents, the BOD (Reference 2.2.24) and the PDC (Reference 2.2.39). Waste package component designs that interface with other parts of the YMP, include ties to fabrication and handling facilities, preclosure safety analysis, and performance assessment. Within Engineering and Repository Project Management (RPM), engineering drawings and reports provide the interfaces. The interfaces with science and performance assessment (Sandia National Laboratory (SNL), the YMP Lead Laboratory) are through Information Exchange Documents (IED) and Interface Definition Documents. Exchanged information includes physical dimensions and material properties for use in structural and thermal calculations.

Simplifying assumptions are used to bound design parameters. Assumptions are listed and justified in specific calculation reports. Qualified computer programs are used and the numeric results are used to show that design criteria are satisfied. A few simple hand calculations are also performed.

5. LIST OF ATTACHMENTS

None

6. BODY OF CALCULATION

6.1 DESIGN DESCRIPTION

The waste isolation system is an important element of a repository. The primary component of the system is the waste package. As defined in *10 CFR 63* (Reference 2.2.1), a waste package includes the waste form and any containers, shielding, packing, and other absorbent materials immediately surrounding it. The invert material, emplacement pallet, and drip shield do not immediately surround the waste package, so they are not considered part of the waste package. The designs of the naval waste packages are described in Sections 6.1 and 6.2. The general configurations, justification of design features, material selections, and guidance for use of codes and standards are provided. Figure 1 shows an exploded view of the naval waste package. Figure 2 shows the waste package on an emplacement pallet.

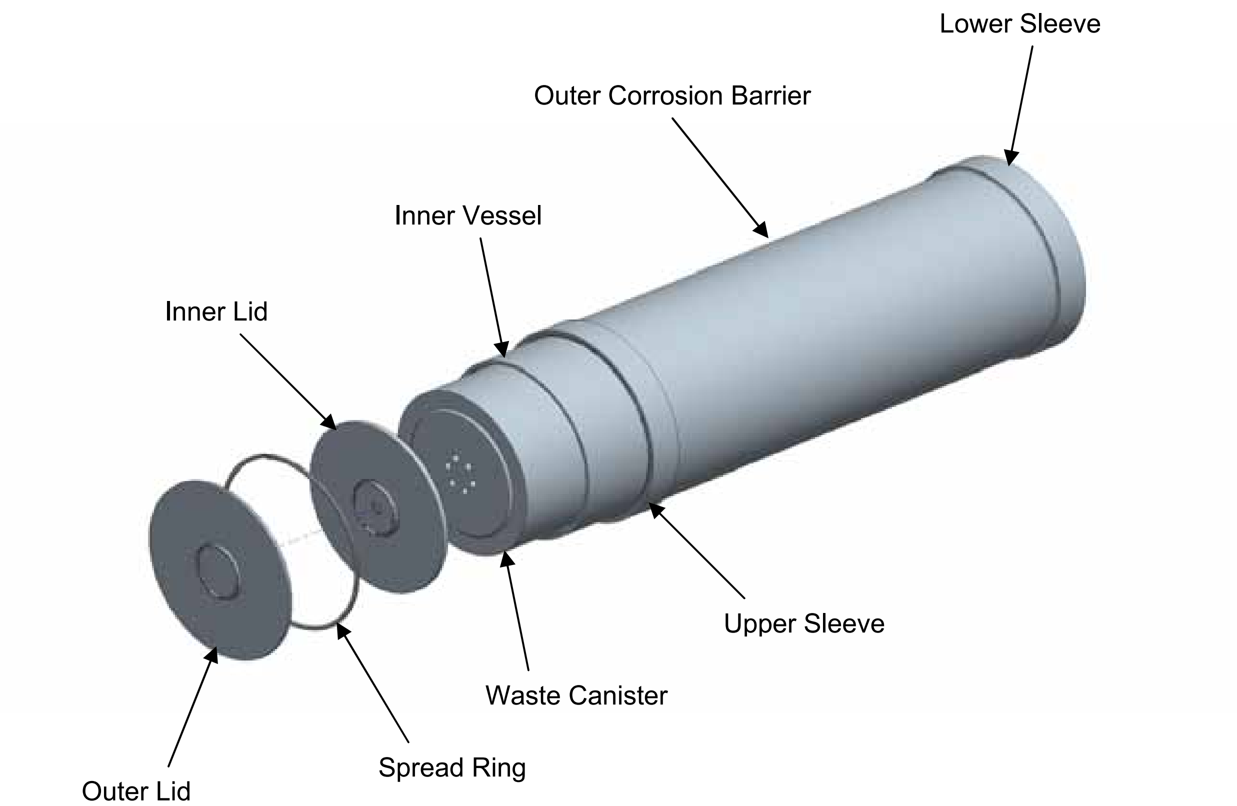

Figure 1. Naval Waste Package

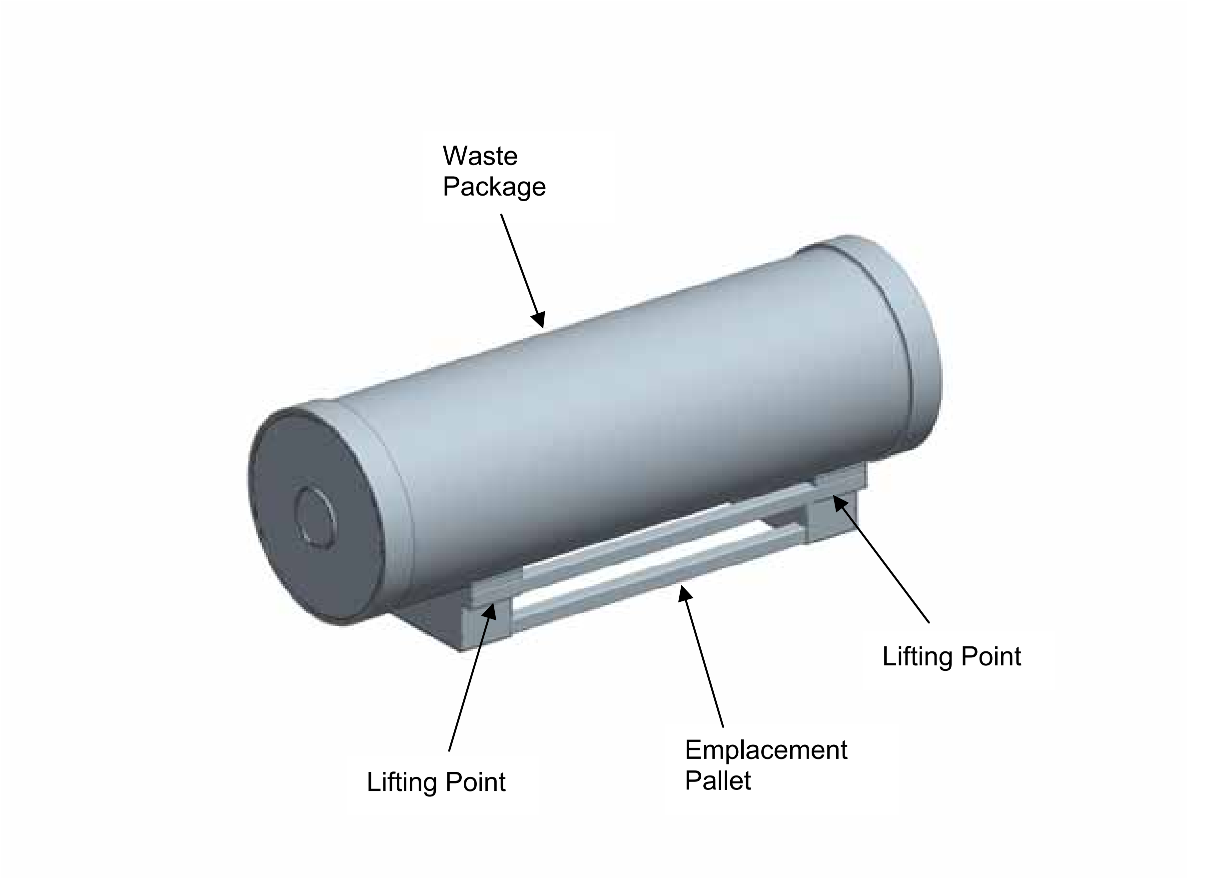

Figure 2. Waste Package on an Emplacement Pallet

6.1.1 Design of the Waste Package

6.1.1.1 Naval Waste Package Configurations

Naval spent nuclear fuel arrives at the repository in canisters suitable for long-term disposal. There is one canister per waste package. Because the naval fuel arrives in canisters of two sizes (one short and one long), the DOE has developed two waste package design configurations for it. No additional features are necessary for structural support, heat transfer, and criticality control. The two naval waste package configuration drawings are provided by References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20 and 2.2.21.

There are a number of major components that comprise the waste package. A standard nomenclature has been established for referring to these components. This nomenclature is shown in Table 1.

Table 1. Standard Nomenclature for Waste Package Components

Preferred Terminology	Acceptable for Clarity or Brevity	Description
Upper Sleeve		The welded circular attachment that serves as additional structural support for the outer corrosion barrier.
Lower Sleeve		The welded circular attachment that serves as additional structural support for the outer corrosion barrier.
Outer Corrosion Barrier	Outer Barrier Alloy 22 Shell	The Alloy 22 (UNS N06022) shell (sides and the outer corrosion barrier bottom lid)
Outer Lid	Final Alloy 22 Lid	The outermost lid, Alloy 22 (UNS N06022)
Spread Ring		The ring that, when spread into position, mechanically holds the inner vessel lid in place
Inner Vessel Lid	Inner Lid	The stainless steel lid that seals the Inner Vessel
Inner Vessel	Stainless Steel Vessel	The inner vessel that is the ASME B&PVC-stamped pressure vessel
Shell Interface Ring	Interface Ring	The stainless steel ring that sits between the support ring and the inner vessel
Inner Vessel Support Ring	Support Ring	The Alloy 22 (UNS N06022) ring that keeps the inner vessel off of the bottom of the outer corrosion barrier

6.1.1.2 Justification of Design Features

The outer lid is designed with a flat top. This is a result of the value engineering study in *Value Study Report—Waste Package Reevaluation* (Reference 2.2.27, Attachment III). The outer lid weld is low-plasticity burnished to reduce residual stresses (Reference 2.2.24, Section 12.2.4.7). The bottom sleeve is extended past the outer corrosion barrier to form a skirt that acts as an energy absorber should the waste package be impacted on that surface. The part that extends has a tapered surface to allow for proper drainage when the waste package is horizontal.

To eliminate the possibility of induced stress corrosion cracking, the inner vessel and outer corrosion barrier have a gap in between, both radially and axially. The axial gap is at least 10 *mm* (Reference 2.2.28, Section 7), and the radial gap will be at least 1 *mm* (0.0394 *in*) (Reference 2.2.14, Tables 4 and 5, p. 13). These distances account for differences in thermal expansion values for Alloy 22 (UNS N06022) and Type 316 stainless steel (SS) (UNS S31600).

The shell interface ring is added as a measure to absorb energy. Its placement alleviates high stresses from occurring in the inner vessel bottom corner. The support ring is added to prevent the weight of the canister from creating a force in the middle of the bottom lid of the outer corrosion barrier when the waste package is in the vertical position. The support ring elevates the inner vessel and prevents it from contacting the outer corrosion barrier bottom lid.

6.1.1.3 Dimensions

The cavity lengths and diameters for the naval long and short waste packages are determined from the overall dimensions of the naval SNF canisters. Since there are two canister lengths (Reference 2.2.37, Figure C-17) there are two waste package configurations to accommodate them. The cavity length of the waste packages is approximately 25.4 *mm* (1.0 *in*) greater than the length of the naval canisters. For the naval long waste package the cavity length is 5.410 *m*

(213.0 *in*), and for the naval short waste package the cavity length is 4.775 *m* (188.0 *in*). Since both canisters share a common overall diameter, the waste package cavity diameter for both configurations is 1.720 *m* (67.7 *in*), allowing 30.5 *mm* (1.2 *in*) of diameter clearance. Dimensions of the two waste packages can be found in References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20, 2.2.21 (Assumption 3.1.1).

6.1.1.4 Material Selection

The following material selection analysis was excerpted from *Yucca Mountain Science and Engineering Report* (Reference 2.2.52, Section 3.4).

6.1.1.4.1 Material Selection Criteria

The selection of materials from which reliable waste packages could be fabricated followed a multistep analysis and design process. It began by analyzing the critical functions of a particular waste package and its various components. In selecting a material for a component, the designers considered both the material's availability and the critical functions the component will serve as part of the waste package. Major components and performance criteria were identified for selecting fabricating materials (Reference 2.2.43, Section 3). The major components are:

- Structural vessel
- Corrosion-resistant barrier
- Fill gas
- Canister guide for HLW and DOE SNF canister

Not every waste package design configuration requires canister guides; it varies according to the waste form each will hold. In the case of the naval waste packages, only the first three components apply.

The criteria that contribute to performance are:

- Mechanical performance (strength)
- Chemical performance (resistance to corrosion and microbial attack)
- Predictability of performance (understanding the behavior of materials)
- Compatibility with materials of the waste package and waste form
- Ease of fabrication using the material
- Previous experience (proven performance record)
- Thermal performance (heat distribution characteristics)
- Neutronic performance (criticality and shielding).

Reasonableness of cost was considered as a discriminator.

6.1.1.4.2 Corrosion-Resistant Materials

Corrosion performance has been determined to be the most important criterion for a long waste package lifetime. Essential performance qualities therefore include a material's resistance to general and localized corrosion, stress corrosion cracking, and hydrogen-assisted cracking and embrittlement. The effects of long-term thermal aging are also important. To address the performance requirements for the waste package, the DOE has initiated studies to gain a better understanding of the processes involved in predicting the rate of waste package material corrosion over the regulatory period.

Combinations and arrangements of materials as containment barriers were carefully considered from several perspectives. In the process, analysts considered such criteria as (1) material compatibility (e.g., galvanic/crevice corrosion effects); (2) the material's ability to contribute to defense in depth (e.g., because it has a different failure mode from other barriers); (3) the material's ease of fabrication; and (4) the potential impact of thin, corrosion-resistant materials used as containment barriers on a repository's essential operations, such as waste package loading, handling, and emplacement.

The major objectives centered on understanding the temperature and humidity conditions that exist at different times for a range of thermal operating modes in a particular unsaturated zone, then designing the waste packages accordingly. Since the properties of any material selected for a corrosion barrier will inevitably be influenced by the temperature and humidity conditions in a repository of a particular design at a particular site, selecting the right corrosion-resistant material became one of the most important priorities.

After assessing potential materials available for waste package corrosion barriers, analysts selected nickel- and titanium-based alloys as the most promising candidate materials for corrosion resistance in an oxidizing environment. Using a corrosion-resistant material as the outer corrosion barrier of the waste package significantly lowers the risk of waste package failure from corrosion. Alloy 22 (UNS N06022) was selected as the preferred material for the outer corrosion barrier because it has excellent resistance to corrosion in the environment expected at Yucca Mountain; it is easier to weld than titanium; and it has a better thermal expansion coefficient match to Type 316 SS (UNS S31600) than titanium. A structurally strong material (stainless steel) was chosen for the inner layer of the waste package.

Alloy 22 (UNS N06022) also offers benefits in the areas of program and operating flexibility. It is extremely corrosion-resistant under conditions of high temperature and low humidity, such as those that will prevail for hundreds to thousands of years in a repository designed to allow a relatively high thermal output from the waste packages.

6.1.1.4.3 Structural Materials

The major functional requirement of the structural material for the inner layer of the waste package is to support the corrosion-resistant outer material. Type 316 SS (UNS S31600 with additional controls on carbon and nitrogen) was selected for the structural layer. This material provides the required strength; has a better compatibility with Alloy 22 (UNS N06022) than carbon steel; and provides an economical solution to functional requirements.

6.1.1.4.4 Fill Gas

The fill gas can be a significant conductor of heat from the waste form to the inner vessel, so thermal performance was deemed one of the most important criteria in choosing a gas. The fill gas should not degrade other components of the waste package, so compatibility with other materials was another important criterion. Helium is inert and is routinely used as the fill gas for fuel rods, which indicates that helium will have an excellent compatibility with spent nuclear fuel. It is also neutrally buoyant, which reduces thermal stratification of the fill gas. Based on a review of data on thermal conductivity, it was chosen over other candidate gases, such as nitrogen, argon, and krypton.

6.1.1.5 Data and Parameters for Waste Package Materials

The sources of material properties are listed in the *Waste Package Component Design Methodology Report* (Reference 2.2.40, Tables 1 and 2). The main sources are listed as the ASME B&PVC (Reference 2.2.6), and the ASM Metals Handbook (Reference 2.2.5). However, Sections 6.1.1.11, 6.1.1.12 and 6.1.1.13 in the same reference also indicate that when the temperature-dependent material properties are not available from these sources, either normalized elevated temperature material properties based on vendor data or room temperature (20°C) material properties are used in the calculations.

6.1.1.6 ASME Code Position

The basis for the selection and application of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC) to the waste package is documented in the document entitled, *BSC Position on the Use of the ASME Boiler and Pressure Vessel Code for the Yucca Mountain Waste Packages* (Reference 2.2.15). This section summarizes the salient points of that document with regard to the design of the waste packages.

Yucca Mountain Review Plan, Final Report (Reference 2.2.45) provides specific guidance on the appropriateness of using the ASME B&PVC (Reference 2.2.6) in the design of waste packages (e.g., Section 2.1.1.7.2.3 (1)); however, it does not prescribe the exact implementation of the ASME B&PVC.

In any discussion of the ASME B&PVC, it is important to first note that it is a pressure vessel safety code and that its primary mission is to assure structural adequacy for pressure loading. Any other use of the ASME B&PVC, such as the use of the conservative material properties contained in it or failure limits for non-pressure loading, must be justified on insight into the structural phenomena that are postulated to occur. For the waste packages, component sizing and thickness are not determined by pressure loads but rather by dynamic events that the waste package might experience. Therefore, the application of the ASME B&PVC design rules for dynamic loading of the waste packages must be carefully scrutinized to ensure that the rules are properly applied.

For the application of the ASME B&PVC, Section III, Division I, Subsection NC (Reference 2.2.6), has been selected by Bechtel SAIC Company (BSC) for the code-compliant design and fabrication of the waste packages. It is important to differentiate the parts of the waste package to which the code apply. There are three major assembled components of the waste package. These are (1) the Type 316 SS inner vessel, (2) the Alloy 22 (UNS N06022) outer corrosion barrier, and (3) the divider plate assemblies (applicable to co-disposal waste packages only). With regard to the code design, the only one of these parts that is considered a pressure vessel is the Type 316 SS inner vessel.

With regard to the hermeticity of the inner vessel and integrity of the same against pressure loads, no currently postulated dynamic structural event involves simultaneous over-pressurization of the inner vessel. For over-pressurization, the capability of the spread ring and seal weld combination to retain the design pressure is assured by a helium leak check. While the seal welds are anticipated to be sound welds, no credit for resistance against dynamic events is taken for these welds. Therefore, for dynamic structural events where the inner vessel in the vicinity of the seal welds may be reasonably anticipated to experience significant loads, these welds are not credited to maintain the hermeticity of the inner vessel. In such cases, it must be shown that the outer corrosion barrier does not breach to maintain containment of the waste form.

For the other components of the waste package, the ASME B&PVC is only used as guidance, either through the use of conservative material properties or conservative stress limits. For credible preclosure event sequences and the assessment of those event sequences, the code and supporting code interpretations are used to formulate layered defensible material failure criteria.

It should be noted that if a waste package suffers a nontrivial dynamic event for which adequate long-term performance cannot be assured, the waste form would be repackaged in a new waste package and the original waste package permanently removed from service.

6.1.1.7 Naval Canister Surface Temperatures

The thermal interface between BSC and NNPP has been established as the naval canister surface temperatures. BSC supplied preliminary expected naval canister temperatures in a surface facility and the emplacement drift to NNPP in *Calculation of the Naval Long and Short Waste Package Three-Dimensional Thermal Interface Temperatures* (Reference 2.2.47). Based on these temperatures, thermal analysis at NNPP relies on the naval canister surface temperature staying below 320°*F* (160°*C*) during normal operations, but may exceed 320°*F* (160°*C*) for no more than 30 days during an off-normal event (loss of heating, ventilation, and air conditioning (HVAC)), and never more than 400°*F* (204°*C*). These temperature limits are reaffirmed in Reference 2.2.42.

6.1.1.8 Criticality

Due to the confidential nature of naval reactor fuel, no criticality calculations will be performed by BSC Engineering. The U.S. Navy has provided an addendum to the *Disposal Criticality Analysis Methodology Topical Report* (Reference 2.2.32), which outlines the criticality methodology used by the NNPP. Any assumptions concerning criticality are beyond the scope of this document.

6.2 DESIGN REQUIREMENTS

Design requirements include those requirements that flow to design through the BOD (Reference 2.2.24) and PDC (Reference 2.2.39), as well as requirements derived by the nature of the engineered design solution or imposed by interfaces with postclosure performance assessment. Requirements imposed by the BOD (Reference 2.2.24) and PDC (Reference 2.2.39) are described in Sections 6.2.1 through 6.2.3 and are related to use of engineering codes and standards. They require the naval waste packages to be designed in accordance with practices outlined in the ASME Pressure Vessel Code (Reference 2.2.6). The fabrication requirements are passed on to the vendor via the fabrication specification (Reference 2.2.23). Each design requirement is compared to design features, drawings, and/or calculations for the naval waste packages and then a description of how the design satisfies the requirement is given.

6.2.1 Naval Waste Package Design Criteria

Requirement 6.2.1.1: Section 5.1.1 of the PDC (Reference 2.2.39) requires that structural design of the waste package be in accordance with ANSI N14.6-1993 (Reference 2.2.12), NUREG-0612 (Reference 2.2.22) and 2001 ASME Boiler and Pressure Vessel Code (Reference 2.2.6), Section II and III, Division I. American Society of Mechanical Engineers (ASME) Section III Code Cases identified in *Regulatory Guide 1.193* (Reference 2.2.76) shall not be used. RGA REG-CRW-RG-000071, *Agreement for Regulatory Guide 1.84, Rev. 33 - Design, Fabrication, and Materials Code Case Acceptability, ASME Section III* (Reference 2.2.77) has adopted Regulatory Guide 1.84 (Reference 2.2.78), to allow the option of using NRC approved ASME Section III code cases.

Satisfaction of Requirement 6.2.1.1: Key parameters (including material density, yield strength, tensile strength, and Modulus of Elasticity) that are used in the structural analysis (e.g. Reference 2.2.35) are taken from (Reference 2.2.6). The structural analysis (e.g. Reference 2.2.35) follows the most appropriate method of classifying local primary membrane stress as defined by (Reference 2.2.6, Section III, Division 1, Appendix XIII, XIII-1123(j)). The requirement for ANSI N14.6-1993 (Reference 2.2.12) was intended for the trunnion collar, a component now deleted from the waste package configuration. NUREG-0612 (Reference 2.2.22) governs lifting procedures for heavy loads at nuclear power plants. There is nothing in the document that pertains to structural design requirements relating to components similar to waste packages. Updates to the PDC (Reference 2.2.39) will include removal of these requirements. ASME Section III Code Cases identified in *Regulatory Guide 1.193* (Reference 2.2.76) are not used. Therefore, Requirement 6.2.1.1 is satisfied.

Requirement 6.2.1.2: Section 5.1.2 of the PDC (Reference 2.2.39) requires that metallurgical design of the waste package be in accordance with *2001 ASME Boiler and Pressure Vessel Code* (Reference 2.2.6), Section III, Division I, Subsection NC. American Society of Mechanical Engineers (ASME) Section III Code Cases identified in *Regulatory Guide 1.193* (Reference 2.2.76) shall not be used.

Satisfaction of Requirement 6.2.1.2: Material properties (tensile strength, yield strength, maximum allowable stress) that are used in the structural analysis (e.g. Reference 2.2.35) are taken from (Reference 2.2.6). ASME Section III Code Cases identified in *Regulatory Guide 1.193* (Reference 2.2.76) are not used. Therefore, Requirement 6.2.1.2 is satisfied.

Requirement 6.2.1.3: Section 12.2.1.1 of the BOD (Reference 2.2.24) requires that the naval waste package shall be capable of operating over a range of thermal conditions, and with the subsurface facility, shall maintain an emplacement drift line load (average linear thermal power) of 1.45 *kW*/meter.

Satisfaction of Requirement 6.2.1.3: The naval canister surface temperatures are calculated in Reference 2.2.47 (Attachment V on CD) and transmitted to the NNPP for use in their thermal analysis. Section 6.2 of Reference 2.2.47 outlines the boundary conditions which are taken as the peak drift wall temperature for a typical 1.45 *kW/m* drift segment, with the naval waste package placed between two 11.8 *kW* 21-PWR waste packages. Operational constraints are expected to limit placement of naval waste packages to 1.45 *kW/m* drift segments with waste package maximum thermal power of 11.8 *kW*. If greater line loads are considered in the future, the analysis basis can be (and must be) modified. Therefore, Requirement 6.2.1.3 is satisfied.

Requirement 6.2.1.4: Section 12.2.1.2 of the BOD (Reference 2.2.24) requires that the naval waste package design shall comply with the agreements established under the Integrated Interface Control Document (IICD) (Reference 2.2.37) to ensure compatibility of Naval SNF waste forms with repository surface facility interfaces, including canister handling interfaces and compatibility between transportation equipment (e.g., transporters) and transported items (e.g., casks and canisters) with mechanical and envelope interfaces.

Satisfaction of Requirement 6.2.1.4: The naval short and long waste package configuration drawings (References 2.2.20 and 2.2.17) show cavity heights of 188.00 *in* (4775.2 *mm*) and 213.00 *in* (5410.2 *mm*) respectively. The inner vessel inside diameter for both naval waste packages is 67.70 *in* (1719.6 *mm*). These dimensions are in compliance with those shown in figures C-18 and C-19 of the IICD (Reference 2.2.37). Therefore, Requirement 6.2.1.4 is satisfied.

Requirement 6.2.1.5: Section 12.2.1.4 of the BOD (Reference 2.2.24) requires that the waste packages shall be loaded with only one Naval SNF canister.

Satisfaction of Requirement 6.2.1.5: The naval short and long waste package configuration drawings (References 2.2.20 and 2.2.17) show an inner vessel inside diameter of 67.70 *in* (1719.6 *mm*). This diameter provides just enough clearance to fit one naval SNF canister as shown in the IICD (Reference 2.2.37) figure C-17. Therefore, Requirement 6.2.1.5 is satisfied.

Requirement 6.2.1.6: Section 12.2.2.1 of the BOD (Reference 2.2.24) requires that the engineered barrier system shall be designed so that, working in combination with natural barriers, there is reasonable expectation that, for 10,000 years following disposal, the reasonably maximally exposed individual receives no more than an annual dose of 15 *mrem* (0.15 *mSv*) from releases from the undisturbed Yucca Mountain disposal system.

Satisfaction of Requirement 6.2.1.6: SNL, the YMP Lead Laboratory, has responsibility to provide postclosure analysis of the engineered barrier system (which includes the waste package) with respect to annual dose rates. Therefore, Requirement 6.2.1.6 is expected to be satisfied.

Requirement 6.2.1.7: Section 12.2.2.2 of the BOD (Reference 2.2.24) requires that the naval waste package design shall be capable of disposing the waste forms with a maximum thermal power of 11.8 *kW*.

Satisfaction of Requirement 6.2.1.7: Reference 2.2.79 shows that TAD waste packages are capable of operating over a range of thermal conditions well beyond 11.8 *kW* (Reference 2.2.79, Tables 22 and 23). Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1), we can conservatively conclude that the naval waste package is capable of operating in the same range of thermal conditions. Therefore, Requirement 6.2.1.7 is satisfied.

Requirement 6.2.1.8: Section 12.2.2.3 of the BOD (Reference 2.2.24) requires that the naval SNF waste package inner vessel shall have one lid and be made of Type 316 SS (UNS S31600), and the outer corrosion barrier shall have one lid and be made of Alloy 22 (UNS N06022). The waste package outer barrier shall be comprised of Alloy 22 with a minimum thickness of 25 *mm* for naval waste packages. For post closure mechanical calculations and analysis, a corrosion allowance of at least 2mm per side shall be accounted for on exposed waste package surfaces. Calculations will be performed using material properties at 150°*C* or greater. The waste package Alloy 22 will be manufactured to ASTM B 575-99a (Reference 2.2.55) with the additional more restrictive, elemental and chemical composition allowable specifications:

(a) Cr = 20.0 to 21.4%
(b) Mo = 12.5 to 13.5%
(c) W = 2.5 to 3.0%
(d) Fe = 2.0 to 4.5%

<u>Satisfaction of Requirement 6.2.1.8</u>: The naval waste package configuration drawings (References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20 and 2.2.21) show waste package components satisfying the material usage and thickness requirements. SNL, the YMP Lead Laboratory, has responsibility to provide postclosure mechanical calculations and analysis. With the issuance of the first revision to the *Postclosure Modeling and Analyses Design Parameters* report (Reference 2.2.67), the range of alloying constituents in Alloy 22 was restricted from that shown in the applicable material specification (Reference 2.2.55). This was part of a larger group of restrictions on design as approved by the Technical Management Review Board (Reference 2.2.68), which were included in that report. This restriction will be incorporated in the design as a part of the normal design change process as dictated by Engineering Procedure EG-PRO-3DP-G04B-00005, *Configuration Management* (Reference 2.1.5), supplemented by the guidance in the discipline-specific execution plan (Reference 2.2.30). It should be noted that the restrictions apply to the upper portion of the range of the alloying concentrations. Testing has shown that Alloy 22 produced at the higher end of the alloying concentrations of ASTM B 575-99a (Reference 2.2.55) often does not meet the minimum material properties required by the material specification (Reference 2.2.70, Section 5.7.1). Therefore, the alloying concentrations listed in a) through d) are unlikely to have any practical consequences to waste package design or fabrication. Therefore, Requirement 6.2.1.8 is expected to be satisfied.

Requirement 6.2.1.9: Section 12.2.2.4 of the BOD (Reference 2.2.24) requires that the naval SNF waste package system shall be designed to permit retrieval during the preclosure period so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated.

<u>Satisfaction of Requirement 6.2.1.9</u>: The design of the waste package system includes an emplacement pallet that allows retrieval of the waste package during the preclosure period. The structural analysis of the emplacement pallet (Reference 2.2.29) showed acceptable stress levels

under lifting with in-drift temperatures and reduced material thickness due to corrosion. Therefore, Requirement 6.2.1.9 is satisfied.

Requirement 6.2.1.10: Section 12.2.2.5 of the BOD (Reference 2.2.24) requires that the waste package surface temperature shall be kept below 300°*C* for the first 500 years and below 200°*C* for the next 9,500 years to eliminate postclosure issues (i.e. phase stability).

Satisfaction of Requirement 6.2.1.10: The thermal calculation (Reference 2.2.46) showed that the waste package surface temperature stayed well below 300 °*C* (572°*F*) for the first 500 years and below 200°*C* (392°*F*) for the next 9,500 years in all twenty cases analyzed. However, the fundamental responsibility for demonstrating long-term thermal performance is the responsibility of the Lead Laboratory. Therefore, Requirement 6.2.1.10 is satisfied.

Requirement 6.2.1.11: Section 12.2.3.1 of the BOD (Reference 2.2.24) and Table A-1, item A.21.1 of the NSDB-LA (Reference 2.2.2) requires that the naval waste package shall have a mean frequency of breach involving a non-seismic event impact or drop of less than 1E-03 over the preclosure period.

Satisfaction of Requirement 6.2.1.11: Satisfaction of all the naval SNF waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25) are addressed in Section 6.2.3. The PCSA group is responsible for determining the naval waste package mean frequency of failure for all credible event sequences. Therefore, Requirement 6.2.1.11 is satisfied.

Requirement 6.2.1.12: Section 12.2.3.2 of the BOD (Reference 2.2.24) and Table A-1, item A.21.2 of the NSDB-LA (Reference 2.2.2) requires that an emplaced naval waste package shall have a mean frequency of breach of less than 1E-04 over the preclosure period from seismic events covering the spectrum of seismic events less severe than that of a frequency of 1E-07/yr, including the relative motion of the waste package with its surroundings and rockfall.

Satisfaction of Requirement 6.2.1.12: Satisfaction of all the naval SNF waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25) are addressed in Section 6.2.3. The PCSA group is responsible for determining the naval waste package mean frequency of failure for all credible event sequences. Therefore, Requirement 6.2.1.12 is expected to be satisfied.

Requirement 6.2.1.13: Section 12.2.3.6 of the BOD (Reference 2.2.24) and Table A-1, items A.21.3 and A.21.4 of the NSDB-LA (Reference 2.2.2) requires that the naval waste package in a TEV shall have a mean frequency of breach of less than 1E-04 over the preclosure period from seismic events covering the spectrum of seismic events less severe than that of a frequency of 1E-07/yr. The mean frequency of a naval waste package breach outside of a facility nuclear confinement HVAC area shall be less than 1E-04 over the preclosure period.

Satisfaction of Requirement 6.2.1.13: Satisfaction of all the naval SNF waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25) are addressed in Section 6.2.3. The

PCSA group is responsible for determining the naval waste package mean frequency of failure for all credible event sequences. Therefore, Requirement 6.2.1.13 is expected to be satisfied.

Requirement 6.2.1.14: Section 12.2.3.7 of the BOD (Reference 2.2.24) and Table A-1, items A.20.1 and A.20.2 of the NSDB-LA (Reference 2.2.2) requires that the naval SFCs be designed to ensure nuclear criticality safety. The mean frequency of each event sequence involving a breach of a naval SFC shall be less than 0.2 over the preclosure period.

Satisfaction of Requirement 6.2.1.14: Due to the confidential nature of naval nuclear fuel, no criticality calculations will be performed by BSC Engineering. The NNPP is responsible for verifying that the loaded waste package meets all criticality criteria. The PCSA group is responsible for determining the naval waste package mean frequency of failure for all credible event sequences. Therefore, Requirement 6.2.1.14 is expected to be satisfied.

Requirement 6.2.1.15: Section 12.2.4.1 of the BOD (Reference 2.2.24) requires the Characteristics and interfaces of the waste packages shall be maintained in the following IEDs:

- *IED Waste Package Configuration*, 800-IED-WIS0-02101-000 (Reference 2.2.36)

- *IED Waste Package Characteristics - 1999 Design Basis Waste Stream [Sheet 1 of 1]*, 800-IED-WIS0-01401-000 (Reference 2.2.62)

- *IED Waste Package Decay Heat Generation-Basis Reference Case*, 800-IED-WIS0-00701-000 (Reference 2.2.49)

- *IED Waste Package Decay Heat Generation Design Basis and Thermal Information*, 800-IED-WIS0-00801-000 (Reference 2.2.50)

- *IED Seismic Data*, 800-IED-MGR0-00701-000 (Reference 2.2.48)

- *IED Waste Package Radiation Characteristics [Sheet 1 of 1]*, 800-IED-WIS0-01301-000 (Reference 2.2.51)

- *IED Waste Package Weld Characteristics [Sheet 1 of 1]*, 800-IED-WIS0-01001-000 (Reference 2.2.63)

- *IED Emplacement Drift Configuration and Environment,* 800-IED-MGR0-00501-000 (Reference 2.2.64)

- *IED Emplacement Drift Invert,* 800-IED-MGR0-00601-000 (Reference 2.2.65)

- *IED Interlocking Drip Shield,* 800-IED-SSE0-00101-000 (Reference 2.2.66).

The interface for the emplaced waste packages shall be controlled through the Emplacement Drift Configuration and Environment IED. Also, the interface for the waste package component masses and weld volumes shall be controlled through the Waste Package Configuration IED**.**

The interface for the waste packages in the LA-design inventory shall have the quantities, dimensions, materials, and characteristics controlled through the Waste Package Configuration IED(s). Materials that have not been previously analyzed and included in the Waste Package Configuration IEDs shall not be placed in the naval SNF waste package.

Interfaces for the design basis bounding dose rate calculations for waste packages and representative neutron flux shall be controlled through the Waste Package Radiation Characteristics IED. Interfaces for the design waste package decay heat shall be controlled through the Waste Package Decay Heat Generation IEDs.

Satisfaction of Requirement 6.2.1.15: All characteristics and interfaces of the waste packages are maintained in all the above mentioned IEDs (References 2.2.36, 2.2.62, 2.2.49, 2.2.50, 2.2.48, 2.2.51, 2.2.63, 2.2.64, 2.2.65, 2.2.66). The Emplacement Drift Configuration and Environment IED (Reference 2.2.64) contains the subsurface temperature and humidity data as provided by the Lead Laboratory. The Waste Package Configuration IED (Reference 2.2.36) contains the waste package component masses, quantities, dimensions, materials and weld volumes as provided by BSC Engineering. The Waste Package Radiation Characteristics IED (Reference 2.2.51) contains the design basis bounding dose rate calculations for waste packages and representative neutron flux data as provided by the Lead Laboratory. The Waste Package Decay Heat Generation IEDs (References 2.2.49 and 2.2.50) contain the design waste package decay heat data as provided by the Lead Laboratory. Therefore, Requirement 6.2.1.15 is satisfied.

Requirement 6.2.1.16: Section 12.2.4.3 of the BOD (Reference 2.2.24) requires that the waste package barrier radial gap between the inner vessel and outer corrosion barrier shall be at least 1 *mm* and a maximum of 5 *mm* for the as fabricated package. The waste package barrier longitudinal gap shall be at least 30 *mm* (between stainless steel lid and Alloy 22 lid).

Satisfaction of Requirement 6.2.1.16: The naval waste package configuration drawings (References 2.2.16, 2.2.17, 2.2.18, 2.2.19, 2.2.20, 2.2.21) show a nominal radial gap of 4.8 *mm* (0.188 *in*) and a nominal axial gap (between the bottom of the outer lid and the top of the inner lid lifting feature) of 44.5 *mm* (1.75 *in*). These gaps minimize internal pressurization and tangential stress of the WP OCB due to thermal expansion. Therefore, Requirement 6.2.1.16 is satisfied.

Requirement 6.2.1.17: Section 12.2.4.4 of the BOD (Reference 2.2.24) requires that the waste package shall be designed to accommodate internal pressurization of the waste package including effects of high temperature and fuel rod gas release.

Satisfaction of Requirement 6.2.1.17: The naval long WP is identical in size to the TAD WP, which in turn is designed for 21-PWR assemblies. Therefore, we can assume that the calculated internal pressure at elevated temperatures for the 21-PWR WP is applicable to the naval long WP (Assumption 3.2.1). The maximum calculated 21-PWR WP internal pressure is 0.6 *MPa* (87 *psi*) at an elevated temperature of 600*°C* (1112*°F*) (Reference 2.2.58, Table 1). This value is considerably less than the maximum allowable internal pressure of 1.01 *MPa* (146 *psi*) at 600*°C* (1112*°F*) for the naval WP (Reference 2.2.57, Table 6-1). Due to the confidential nature of naval reactor fuel the NNPP is responsible for determining the effect of fuel gas rod release to the internal pressure of the naval waste package. Therefore, Requirement 6.2.1.17 is expected to be satisfied.

Requirement 6.2.1.18: Section 12.2.4.6 of the BOD (Reference 2.2.24) requires that the waste package shall be fabricated in a controlled manner that results in minimal defects. The damage to the waste package corrosion barrier that displaces material (i.e. scratches) shall be limited to 1.6 *mm* (1/16 *in*) in depth. Modifications to the waste package corrosion barrier that deform the surface, but do not remove material (i.e. dents), shall be limited to having a width at least 5 times greater than the depth, but no dent that would result in the Alloy 22 deforming into the stainless steel barrier is acceptable. The waste package will be inspected at the fabricator location to ensure that the as-fabricated waste package meets specified requirements.

The waste package outer corrosion barrier fabrication welds shall be nondestructively examined by radiographic examination, and ultrasonic testing, for flaws equal to or greater than 1/16 *inch* or as required by the applicable specification. Outer corrosion barrier fabrication welds shall be liquid penetrant examination by the applicable specification.

Welding flaws 1/16 *inch* and greater for the outer corrosion barrier shall be repaired, and criteria for acceptable marring shall be followed, in accordance with written procedures that have been accepted by the design organization prior to their usage.

The welding techniques for the fabrication welds shall be constrained to GMAW (gas metal arc welding) except for short-circuiting mode, and GTAW (gas tungsten arc welding) for Alloy 22 (UNS N06022) material, limited to <45 *kJ/in*.

<u>Satisfaction of Requirement 6.2.1.18</u>: The *Waste Package Fabrication Specification* (Reference 2.2.23, Section 3.5) specifies that the outer surfaces of the waste package shall have a surface roughness of 125 µinch (3.2 *µm*) or better. There are no exceptions for scratches or any similar surface defects. The fabrication specification (Reference 2.2.23) covers weld examination in Section 6.1, weld flaw repair in Section 5.5.1.5, and welding techniques in Section 5.5.1.1. Therefore, Requirement 6.2.1.18 is satisfied.

Requirement 6.2.1.19: Section 12.2.4.7 of the BOD (Reference 2.2.24) requires that all waste package welding materials shall be verified immediately prior to usage to prevent incorrect material usage.
a) The Alloy 22 outer lid will be sealed utilizing the gas tungsten arc weld (GTAW) process, limited to <45 *kJ/in*. The weld mass shall be less than 0.104 *lb/in* (18.5 *g/cm*) of weld.

b) The Alloy 22 outer lid weld will be nondestructively examined using VT, ET, and UT. Flaws greater than 1/16" shall be repaired.

c) The Alloy 22 outer lid weld will be stress mitigated using low-plasticity burnishing to a compressive depth of at least 3 *mm*.

d) Process control to ensure there has been adequate stress mitigation on the welds will be performed. Following the stress mitigation, the final closure weld will be reexamined using VT, ET, and UT.

Satisfaction of Requirement 6.2.1.19: The waste package closure welding and inspection requirements are part of the Waste Package Closure System which falls under the responsibility of the Mechanical Handling Closure and Loadout Group. Therefore, Requirement 6.2.1.19 is expected to be satisfied.

Requirement 6.2.1.20: Section 12.2.4.8 of the BOD (Reference 2.2.24) requires that after fabrication and before inserting the inner vessel, the waste package outer corrosion barrier shall be solution annealed and quenched.

a) The minimum time for solution annealing will be 20 minutes at 2,050°*F* (1,121 °*C*) + 50°*F* (28 °*C*) / -0°*F* (0°*C*).
b) The waste package shall be quenched at a rate greater than 275°*F* (153°*C*) per minute to below 700°*F* (371°*C*).
c) After solution annealing and quenching, the waste package surface temperature will be kept below 300°*C* to eliminate postclosure issues (i.e., phase stability), except for short-term exposure (closure-weld, etc.).

Satisfaction of Requirement 6.2.1.20: Requirements "a" and "b" are controlled via the *Waste Package Fabrication Specification* (Reference 2.2.23, Section 5.6). The thermal calculation (Reference 2.2.46) showed that the waste package surface temperature stayed well below 300°*C* (572°*F*) for the first 500 years and below 200°*C* (392°*F*) for the next 9,500 years in all twenty cases analyzed, which satisfies requirement "c". Therefore, Requirement 6.2.1.20 is satisfied.

Requirement 6.2.1.21: Section 12.2.4.9 of the BOD (Reference 2.2.24) requires that the naval waste package shall be certified as suitable for emplacement by process control and/or inspection to ensure surface marring is acceptable per derived constraint. The surface marring constraints are: The damage to the waste package corrosion barrier that displaces material (i.e. scratches) shall be limited to 1.6 *mm* (1/16 *in*) in depth. Modifications to the waste package corrosion barrier that deform the surface, but do not remove material (i.e. dents), shall not leave residual tensile stresses greater than 257 *MPa*.

Satisfaction of Requirement 6.2.1.21: Mechanical Handling is responsible for this requirement as defined in the BOD (Reference 2.2.24, Section 13.2.3.1.37). Therefore, Requirement 6.2.1.21 is expected to be satisfied.

Requirement 6.2.1.22: Section 12.2.4.10 of the BOD (Reference 2.2.24) requires that the waste package surface finish shall be specified to be at least 125 *μinch* roughness as defined in ASME B46.1 (Reference 2.2.7). Modifications to the waste package corrosion barrier that deform the surface, but do not remove material (i.e. dents), shall not leave residual tensile stresses greater than 257 *MPa*.

Satisfaction of Requirement 6.2.1.22: The *Waste Package Fabrication Specification* (Reference 2.2.23, Section 3.5) specifies that the outer surfaces of the waste package shall have a surface roughness of 125 *μinch* (3.2 *μm*) or better. There are no exceptions for scratches or any similar surface defects. Therefore, Requirement 6.2.1.22 is satisfied.

Requirement 6.2.1.23: Section 12.2.4.11 of the BOD (Reference 2.2.24) requires that the median probability of defects for the manufacture, handling, and emplacement of the naval waste packages shall be less than 4.14 x 10-5 per waste package. For TSPA purposes this distribution is the probability that a waste package will be early-failed. Performance of the waste package in post-closure will be demonstrated by the Lead Laboratory.

Satisfaction of Requirement 6.2.1.23: The pertinent fabrication requirements are controlled via the *Waste Package Fabrication Specification* (Reference 2.2.23, Sections 3 and 5). The Science document (Reference 2.2.33, Section 6.2.15) concludes that the implementation of those fabrication requirements achieve this reliability. Therefore, Requirement 6.2.1.23 is satisfied.

Requirement 6.2.1.24: Section 12.2.4.12 of the BOD (Reference 2.2.24) requires that the naval WP cavities shall be verified to be dry and backfilled with helium to achieve < 0.43 *gram-mole* of H_2O in a 7 m^3 volume after drying. This drying process shall limit oxidizing gases to below 1 *gram-mole* to prevent cladding degradation.

Satisfaction of Requirement 6.2.1.24: This requirement is part of the Waste Package Closure System which falls under the responsibility of the Mechanical Handling Closure and Loadout Group as defined in the BOD (Reference 2.2.24, Section 29.2.1.3). Therefore, Requirement 6.2.1.24 is expected to be satisfied.

Requirement 6.2.1.25: Section 12.2.4.13 of the BOD (Reference 2.2.24) requires that the waste package shall be handled in a controlled manner to minimize defects; surface contamination; exposure to adverse substances; impacts; and tension loads during fabrication, handling, transport, storage, emplacement, installation, operation, and closure activities.

Satisfaction of Requirement 6.2.1.25: All fabrication, handling and transport related requirements are controlled by the fabrication specification (Reference 2.2.23). Mechanical Handling is responsible for compliance to the remainder of this requirement as defined in the BOD (Reference 2.2.24, Section 13.2.3.1.35). Hence, Requirement 6.2.1.25 is expected to be satisfied.

Requirement 6.2.1.26: Section 12.2.4.14 of the BOD (Reference 2.2.24) requires that the waste package closure systems operations shall be controlled. The waste package sealing process shall be remotely controlled in a manner that ensures safe waste package closure.

Satisfaction of Requirement 6.2.1.26: This requirement is part of the Waste Package Closure System which falls under the responsibility of the Mechanical Handling Closure and Loadout Group. Therefore, Requirement 6.2.1.26 is expected to be satisfied.

Requirement 6.2.1.27: Section 12.2.4.15 of the BOD (Reference 2.2.24) requires that the waste package lids and inerting caps shall be welded. The welding process shall be conducted in a manner to meet weld requirements.

Satisfaction of Requirement 6.2.1.27: This requirement is part of the Waste Package Closure System which falls under the responsibility of the Mechanical Handling Closure and Loadout Group. Therefore, Requirement 6.2.1.27 is expected to be satisfied.

Requirement 6.2.1.28: Section 8.2.1.23 of the BOD (Reference 2.2.24) requires that the tensile stresses imposed on the Alloy 22 components of both the waste package and the emplacement pallet in the nominal emplacement configuration shall be less than 257 *MPa*.

Satisfaction of Requirement 6.2.1.28: The structural analysis (Reference 2.2.29, Table 7-2) shows that the maximum tensile stresses for 21*°C* (70*°F*) and 250*°C* (482*°F*) are located in the OCB of the WP with values of 56.8 *MPa* (8,238 *psi*), which are significantly less than the 257 *MPa* (37,275 *psi*) limit. Therefore, Requirement 6.2.1.28 is satisfied.

6.2.2 Waste Package Fabrication Criteria

Requirement 6.2.2.1: Sections 5.2 and 5.2.1 of the PDC (Reference 2.2.39) state that waste packages shall be fabricated in accordance with the following:

ANSI/AWS A2.4-98 (Reference 2.2.4) provides the standard symbols for the welding, brazing, and nondestructive examination of nuclear components.

ANSI/AWS A5.32/A5.32M-97 (Reference 2.2.3) provides the specifications of welding shielding gases used in the welding processes of nuclear components.

ANSI N14.6-1993 (Reference 2.2.12) provides definitions for special lifting devices for shipping containers weighing 10,000 pounds or more.

ASME 2001 (Reference 2.2.6), Section II, provides the properties for the materials used in the design and fabrication of Class NF nuclear components.

ASME 2001 (Reference 2.2.6), Section III, Subsection NCA, provides the general requirements for the design and fabrication of nuclear power plant components.

ASME 2001 (Reference 2.2.6), Section III, Division 1, Subsection NB, NC, and NF.

ASME 2001 (Reference 2.2.6), Section V, provides the requirements for the nondestructive examination of nuclear components.

ASME 2001 (Reference 2.2.6), Section IX, provides welding and brazing qualifications for the welding of nuclear components.

ASME B46.1-2002 (Reference 2.2.7) provides surface texture (surface roughness, waviness, and lay) requirements for fabrication of nuclear components.

ASME Y14.36M-1996 (Reference 2.2.10) provides the requirements for surface texture symbols used in the designing of nuclear components.

ASME Y14.38-1999 (Reference 2.2.11) provides the requirements for abbreviations and acronyms used in the designing of nuclear components.

ASME Y14.5M-1994 (Reference 2.2.9) provides the requirements for dimensioning and tolerancing of drawing.

American Society of Mechanical Engineers (ASME) Section III Code Cases that shall not be used are those listed in *Regulatory Guide 1.193* (Reference 2.2.76).

Cleaning, packaging, shipping, receiving, storage, and handling of waste packages shall be in accordance with ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications* (Reference 2.2.8) Subparts 2.1 and 2.2. There are now additional quality assurance requirements applicable to the fabrication and construction activities identified in Table A-1 of the *Quality Management Directive* (Reference 2.1.2).

Satisfaction of Requirement 6.2.2.1: The specific applicable requirements from codes and standards are implemented by specification. Sections 2 through 9 of Reference 2.2.23 impose the specific, applicable sections from codes and standards for the Waste Package Design, Materials, Fabrication, and Examination and Testing. ASME Y14.38-1999 (Abbreviations and Acronyms) is not listed in the current version of the waste package specification (Reference 2.2.23) but updates are expected as the specification is a living document and the standards refer to common definitions. The requirement for ANSI N14.6-1993 (Reference 2.2.12) was intended for the trunnion collar, a component now deleted from the waste package configuration. Updates to the PDC (Reference 2.2.39) will include removal of this requirement. American Society of Mechanical Engineers (ASME) Section III Code Cases identified in *Regulatory Guide 1.193* (Reference 2.2.76) are not used. Therefore, Requirement 6.2.2.1 is expected to be satisfied as final design is completed.

6.2.3 Requirements as defined by the Hypothetical Event Sequences

The waste package shall not breach during normal operation or during credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.25). The requirements in this study are used as a supplement since the latest revision of the BOD (Reference 2.2.24) does not sufficiently describe the credible event sequences for the naval waste package (Assumptions 3.1.2 and 3.1.3).

Requirement 6.2.3.1: Section 4.1.2 of Reference 2.2.25 requires that the waste package shall not breach in an event where the waste package while inside the waste package transfer trolley is subjected to the dynamics imposed by vibratory ground motion.

Satisfaction of Requirement 6.2.3.1: Mechanical Handling is responsible for compliance to this requirement as defined in the BOD (Reference 2.2.24, Section 13.2.3.1.21). Therefore, Requirement 6.2.3.1 is expected to be satisfied.

Requirement 6.2.3.2: Section 4.1.6 of Reference 2.2.25 requires that the waste package shall not breach in an event where there is protracted loss of forced ventilation in the surface facility while the WP transfer trolley is laden with a waste package. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.2: The bounding steady-state analysis (Reference 2.2.13, Section 7, Table 15) showed that the maximum waste canister surface temperature was 381.7*ºF* (194.3 *ºC*) for off-normal conditions in the case of the naval short waste package inside the waste package transfer trolley. This is below the 400*ºF* (204 *ºC*) limit for the waste canister surface temperature (Reference 2.2.42). Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.2 is expected to be satisfied.

Requirement 6.2.3.3: Section 4.1.7 of Reference 2.2.25 requires that the waste package shall not breach in an event where a fire in any of the rooms in which the waste package transfer trolley may be present when laden with a sealed waste package. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.3: Results for a TAD waste package exposed to a fully engulfing, 800 *C* (1472 *F*) fire shows the TAD surface temperature increases from about 150 *C* (302 *F*) to 450 *C* (842 *F*) in 30 minutes (Reference 2.2.38), or the rate of increase is about 10 *C*/min (18 *F/min*). Fires in any room where the waste package transfer trolley is located are expected to be far less severe, both in duration and severity. During normal operating conditions the canister surface temperature reaches 157.9 *C* (316.3 *F*) for a sealed waste package inside the transfer trolley (Reference 2.2.13, Section 7, Table 16). A severe fire may cause the canister temperature to exceed the limit of 204.4 *C* (400 *F*) (Reference 2.2.42) in a few minutes, but is not credible. In a credible fire only a small part of the WP would be exposed to the flame, greatly reducing the thermal heat-up of the canister. Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1), a credible fire is unlikely to raise the canister surface temperature above the 204.4 *C* (400 *F*) limit (Reference 2.2.42). Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.3 is expected to be satisfied.

Requirement 6.2.3.4: Section 4.3.1 of Reference 2.2.25 requires that the waste package shall not breach in an event where one or more of the handling hooks in the TEV breaks resulting in an approximately horizontal drop of the waste package and emplacement pallet.

Satisfaction of Requirement 6.2.3.4: Analysis of this event sequence (Reference 2.2.35, Table 7-3 and Reference 2.2.53, Table 7-11) showed that the element wall-averaged (EWA) stress intensity (SI) ratio stayed below the project tiered second condition acceptance criterion of 0.77 (Reference 2.2.40, Section 7.1.4), based on the maximum possible drop height of 0.759 *m* (29.88 *in*) (runs 2 through 3) without the emplacement pallet and 0.508 *m* (20 *in*) with the emplacement pallet. Therefore, Requirement 6.2.3.4 is satisfied.

Requirement 6.2.3.5: Section 4.3.5 of Reference 2.2.25 requires that the waste package shall not breach in an event where the waste package while inside the TEV is subjected to the dynamics imposed by vibratory ground motion.

Satisfaction of Requirement 6.2.3.5: The analysis (Reference 2.2.35, Table 7-3) lists the ratios of EWA SI to true tensile strength. Using the velocities used and resulting EWA SI ratios for runs

2B, 4, and 5, we can determine (using the polynomial equation generated in Excel per Figure 3 below) a velocity of 5.76 *m/s* (18.9 *ft/sec*) before the EWA SI ratio reaches the project tiered second condition acceptance criterion of 0.77 (Reference 2.2.40, Section 7.1.4). The PCSA group is responsible for determining the probability of a credible seismic event resulting in the waste package moving at velocities reaching 5.76 *m/s* (18.9 *ft/sec*). Therefore, Requirement 6.2.3.5 is expected to be satisfied.

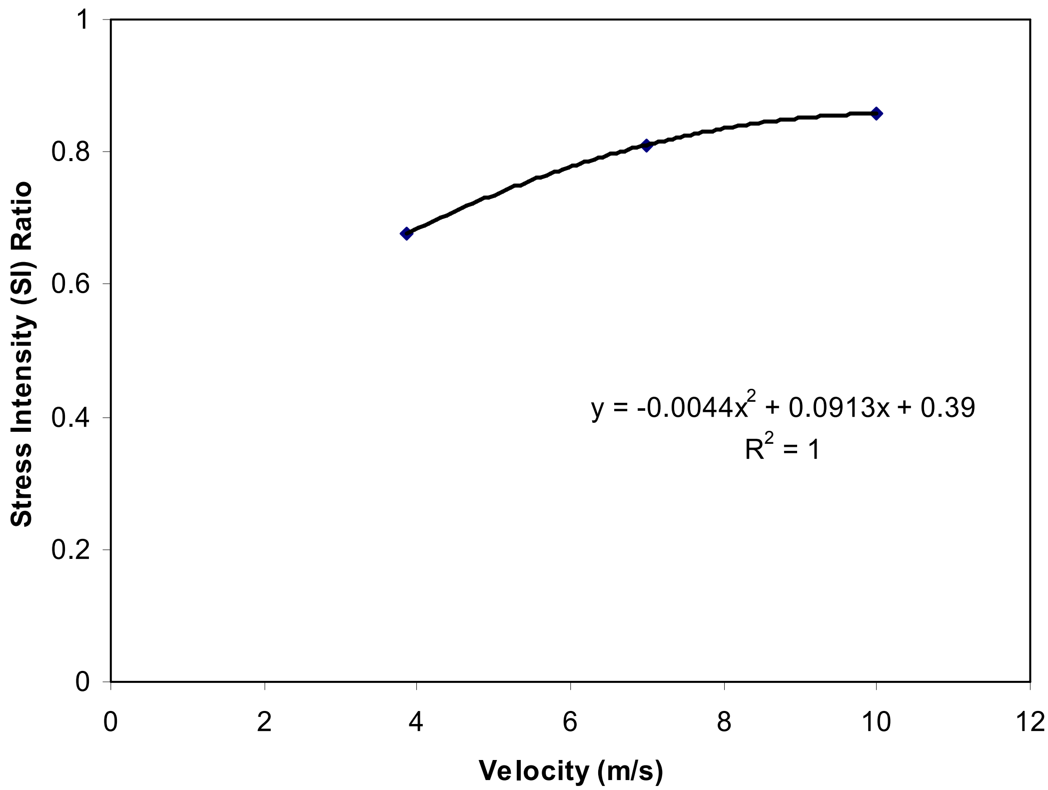

Figure 3. SI Ratio versus Velocity Trend

Requirement 6.2.3.6: Section 4.3.6 of Reference 2.2.25 requires that the waste package shall not breach in an event where an over-driven TEV collides with a line of emplaced waste packages.

Satisfaction of Requirement 6.2.3.6: The analysis (Reference 2.2.54, Table 7-2) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.40, Section 7.1.4) for both cases analyzed, meaning that the effects of the maximum stresses in the OCB due to TEV collision do not cause failure. Using Assumption 3.2.2, we can conservatively conclude that the EWA SI ratio for the naval waste package would be less. Therefore, Requirement 6.2.3.6 is satisfied.

Requirement 6.2.3.7: Section 4.3.8 of Reference 2.2.25 requires that the waste package shall not breach in an event where the waste package is caught on the TEV structure and dragged along the invert surface, resulting in the waste package falling off the emplacement pallet and against TEV structures.

Satisfaction of Requirement 6.2.3.7: The analysis (Reference 2.2.54, Table 7-2) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.40, Section 7.1.4) for both cases analyzed, meaning that the effects of the maximum stresses in the OCB due to TEV collision do not cause failure. Since the dragging of the emplaced waste package is bounded by the TEV collision (Assumptions 3.2.2 and 3.2.3), we can conservatively conclude that the EWA SI ratio for the naval waste package would be less. Therefore, Requirement 6.2.3.7 is satisfied.

Requirement 6.2.3.8: Section 4.3.11 of Reference 2.2.25 requires that the waste package shall not breach in an event where there is protracted loss of ventilation in the surface facility while the TEV is laden with the waste package. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.8: The steady-state analysis (Reference 2.2.34, Table 36) showed that the TAD waste package temperature inside the TEV remained around 167 *C* (333 *F*) without ventilation, using a heat load of 11.8 *kW* and 50 *C* (122 *F*) ambient temperature. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval waste package temperature will remain around 167 *C* (333 *F*) for the same conditions. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.8 is expected to be satisfied.

Requirement 6.2.3.9: Section 4.3.12 of Reference 2.2.25 requires that the waste package shall not breach in an event of a fire in any of the rooms in which the TEV may be present when laden with a waste package. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.9: Results for a TAD WP exposed to a fully engulfing, 800 *C* (1472 *F*) fire shows the WP temperature increases from about 150 *C* (302 *F*) to about 700 *C* (1292 *F*) in 30 minutes (Reference 2.2.38), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.34, Table 36) showed that the TAD WP temperature inside the TEV remained around 167 *C* (333 *F*) without ventilation, using a heat load of 11.8 *kW* and 50 *C* (122 *F*) ambient temperature. This is below the 300 *C* (572 *F*) naval WP temperature limit (Reference 2.2.24, Section 12.2.2.5). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.24, Section 12.2.2.5) in a few minutes, but is not credible. In a credible fire only a small part of the WP would be exposed to the flame and the duration of the fire would be very short, greatly reducing the thermal heat-up of the WP. Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval WP temperature is unlikely to go above the 300 *C* (572 *F*) limit (Reference 2.2.24, Section 12.2.2.5) in an event of a credible fire. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.9 is expected to be satisfied.

Requirement 6.2.3.10: Section 4.3.13 of Reference 2.2.25 requires that the waste package shall not breach in an event where there is protracted stoppage of the TEV during transit from the surface facilities to the subsurface entry portal while the TEV is laden with the waste package. Analysis of this event sequence will include the rate of delivery of all direct solar energy per unit of horizontal TEV surface. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.10: The steady-state analysis (Reference 2.2.34, Table 40) showed that the TAD waste package temperature inside the TEV remained around 165 *C* (329 *F*) without ventilation, using a heat load of 11.8 *kW* and 46.7 *C* (116 *F*) maximum ambient outdoor temperature with solar insolation. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval waste package temperature will be remain around 165 *C* (329 *F*) for the same conditions, and definitely not enough of an increase to go above the 300 *C* (572 *F*) limit. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.10 is expected to be satisfied.

Requirement 6.2.3.11: Section 4.3.14 of Reference 2.2.25 requires that the waste package shall not breach in an event of a fire involving the TEV when laden with a waste package that occurs outside the surface facilities and before passing into the subsurface entrance portal. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.11: Results for a TAD WP exposed to a fully engulfing, 800 *C* (1472 *F*) fire shows the WP temperature increases from about 150 *C* (302 *F*) to about 700 *C* (1292 *F*) in 30 minutes (Reference 2.2.38), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.34, Table 40) showed that the TAD waste package temperature inside the TEV remained around 165 *C* (329 *F*) without ventilation, using a heat load of 11.8 *kW* and 46.7 *C* (116 *F*) maximum ambient outdoor temperature with solar insolation. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.24, Section 12.2.2.5) in a few minutes, but is not credible. In a credible fire only a small part of the WP would be exposed to the flame and the duration of the fire would be very short, greatly reducing the thermal heat-up of the WP. Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval WP temperature is unlikely to go above the 300 *C* (572 *F*) limit (Reference 2.2.24, Section 12.2.2.5) in an event of a credible fire. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.11 is expected to be satisfied.

Requirement 6.2.3.12: Section 4.3.15 of Reference 2.2.25 requires that the waste package shall not breach in an event where there is a protracted stoppage of the TEV traversing the subsurface mains while the TEV is laden with the waste package. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.12: The steady-state analysis (Reference 2.2.34, Table 43) showed that the TAD waste package temperature inside the TEV remained around 139 *C* (282 *F*) without ventilation, using a heat load of 11.8 *kW* and 22 *C* (72 *F*) cold drift wall temperature. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval waste package temperature will be remain around 139 *C* (282 *F*) for the same conditions, and definitely not enough of an increase to go above the 300 *C* (572 *F*) limit. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.12 is expected to be satisfied.

Requirement 6.2.3.13: Section 4.3.16 of Reference 2.2.25 requires that the waste package shall not breach in an event of a fire involving the TEV laden with the waste package while it is traversing the subsurface mains. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.13: Results for a TAD WP exposed to a fully engulfing, 800 *C* (1472 *F*) fire shows the WP temperature increases from about 150 *C* (302 *F*) to about 700 *C* (1292 *F*) in 30 minutes (Reference 2.2.38), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.34, Table 43) showed that the TAD waste package temperature inside the TEV remained around 139 *C* (282 *F*) without ventilation, using a heat load of 11.8 *kW* and 22 *C* (72 *F*) cold drift wall temperature. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.24, Section 12.2.2.5) in a few minutes, but is not credible. In a credible fire only a small part of the WP would be exposed to the flame and the duration of the fire would be very short, greatly reducing the thermal heat-up of the WP. Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval WP temperature is unlikely to go above the 300 *C* (572 *F*) limit (Reference 2.2.24, Section 12.2.2.5) in an event of a credible fire. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.13 is expected to be satisfied.

Requirement 6.2.3.14: Section 4.3.17 of Reference 2.2.25 requires that the waste package shall not breach in an event where there is a protracted stoppage of the TEV traversing the emplacement drifts while the TEV is laden with the waste package. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.14: The steady-state analysis (Reference 2.2.34, Table 43) showed that the TAD waste package temperature inside the TEV remained around 139 *C* (282 *F*) without ventilation, using a heat load of 11.8 *kW* and 22 *C* (72 *F*) cold drift wall temperature. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval waste package temperature will be remain around 139 *C* (282 *F*) for the same conditions, and definitely not enough of an increase to go above the 300 *C* (572 *F*) limit. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.14 is expected to be satisfied.

Requirement 6.2.3.15: Section 4.3.18 of Reference 2.2.25 requires that the waste package shall not breach in an event of a fire involving the TEV when laden with a waste package that occurs while it is traversing the emplacement drifts. It must be shown that the ability of the waste package to confine the waste form is maintained and that the loss of margin to the off-normal cladding temperature is prevented.

Satisfaction of Requirement 6.2.3.15: Results for a TAD WP exposed to a fully engulfing, 800 *C* (1472 *F*) fire shows the WP temperature increases from about 150 *C* (302 *F*) to about 700 *C* (1292 *F*) in 30 minutes (Reference 2.2.38), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.34, Table 43) showed that the TAD waste package temperature inside the TEV remained around 139 *C* (282 *F*) without ventilation, using a heat load of 11.8 *kW* and 22 *C* (72 *F*) cold drift wall temperature. This is below the 300 *C* (572 *F*) naval waste package temperature limit (Reference 2.2.24, Section 12.2.2.5). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.24, Section 12.2.2.5) in a few minutes, but is not credible. In a credible fire only a small part of the WP would be exposed to the flame and the duration of the fire would be very short, greatly reducing the thermal heat-up of the WP. Since the TAD and naval long waste packages are similar in size (Assumption 3.2.1) we can conservatively conclude that the naval WP temperature is unlikely to go above the 300 *C* (572 *F*) limit (Reference 2.2.24, Section 12.2.2.5) in an event of a credible fire. Due to the confidential nature of the naval waste canisters the NNPP is responsible for verifying that the loss of margin to the off-normal cladding temperature is prevented. Therefore, Requirement 6.2.3.15 is expected to be satisfied.

Requirement 6.2.3.16: Section 4.4.2 of Reference 2.2.25 requires that the waste package shall not breach in an event where the waste package while horizontal inside the waste package transfer trolley on the waste package transfer carriage is subjected to the dynamics imposed by vibratory ground motion. The waste package is then ejected from the emplacement pallet and falls into the shielded enclosure of the waste package transfer trolley or TEV.

Satisfaction of Requirement 6.2.3.16: Using data from the analysis (Reference 2.2.35, Table 7-3) we calculated in Section 6.2.3.5 the velocity in which the WP reaches the project tiered second condition acceptance criterion EWA SI ratio of 0.77 (Reference 2.2.40, Section 7.1.4). Using Newton's equation of motion (Reference 2.2.69, Equation 15, p. 20) we can determine the drop height needed for the WP to reach this velocity:

$$V^2 = V_o^2 + 2gh$$

where,

V_o = initial velocity
V = final velocity
g = acceleration due to gravity
h = vertical drop height

For this calculation:

V = 5.76 *m/s* (WP final velocity as calculated from Section 6.2.3.5)
V_o = 0.0 *m/s* (WP initially at rest)
g = 9.81 m/s^2 (acceleration due to gravity)

Solving for h:

$$h = (V^2 - V_o^2) / 2g = 1.691\ m$$

A drop height of 1.691 *m* (66.57 *in*) is more than twice any possible drop that the WP might experience whether within the transfer trolley or TEV. Therefore, Requirement 6.2.3.16 is satisfied.

Requirement 6.2.3.17: Section 4.4.3 of Reference 2.2.25 requires that the waste package shall not breach in an event where the drip shield emplacement gantry collides with an emplaced waste package.

Satisfaction of Requirement 6.2.3.17: The analysis (Reference 2.2.54, Table 7-2) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.40, Section 7.1.4) for both cases analyzed, meaning that the effects of the maximum stresses in the OCB due to TEV collision do not cause failure. Since the drip shield emplacement gantry collision is bounded by the TEV collision (Assumptions 3.2.2 and 3.2.4), we can conservatively conclude that the EWA SI ratio for the naval waste package would be less. Therefore, Requirement 6.2.3.17 is satisfied.

Requirement 6.2.3.18: Section 4.4.4 of Reference 2.2.25 requires that the waste package shall not breach in an event where the drip shield gantry drops the drip shield onto the waste package.

Satisfaction of Requirement 6.2.3.18: The event of the drip shield (weighing 5 *MT* (5.5 *tons*) per Reference 2.2.56) dropped onto the waste package is a lot less severe than the largest credible rockfall with a rockbolt weighing 20 *MT* (22 *tons*) (Reference 2.2.26, Section 6.4.5.2.5) onto the waste package, which we can conservatively conclude is a bounding case. The calculation *Nonlithophysal Rock Fall on Waste Packages* (Reference 2.2.41, Table 4, Cases 9 to 12) indicated that the EWA SI ratio in all four rockfall cases involving the rockbolt did not exceed the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.40, Section 7.1.4), indicating that the rockfall scenarios did not result in failure of the waste package. Therefore, Requirement 6.2.3.18 is satisfied.

Requirement 6.2.3.19: Section 4.4.5.1 of Reference 2.2.25 requires that the waste package shall not breach in an event of a rock fall in the non-lithophysal portions of the repository.

Satisfaction of Requirement 6.2.3.19: The largest credible rockfall in the non-lithophysal portions of the repository is a 20 *MT* (22 *tons*) block (Reference 2.2.26, Section 6.4.5.2.5). The calculation (Reference 2.2.41, Table 4) indicated that the EWA SI ratio at any point in the outer shell and lids did not exceed the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.40, Section 7.1.4), indicating that none of the rockfall scenarios resulted in failure of the waste package. Therefore, Requirement 6.2.3.19 is satisfied.

Requirement 6.2.3.20: Section 4.4.5.2 of Reference 2.2.25 requires that the waste package shall not breach in an event of general drift collapse in the lithophysic portions of the repository caused by vibratory ground motion.

Satisfaction of Requirement 6.2.3.20: The analysis (Reference 2.2.44, Table 7-1) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.40, Section 7.1.4), meaning that the effects of the maximum stresses in the OCB due to drift collapse do not cause failure. Therefore, Requirement 6.2.3.20 is satisfied.

Requirement 6.2.3.21: Section 4.4.5.3 of Reference 2.2.25 requires that the waste package shall not breach in an event where the waste package is under a load of fallen rock and then subject to vibratory ground motion, including a scenario where "posts" of invert beams rotating up into the drift strike the waste package due to the failure of the structural steel in the invert.

Satisfaction of Requirement 6.2.3.21: In the event of vibratory ground motion during a load on the WP due to drift collapse, the rubble surrounding the WP is expected to act as a dampener during "fluidization" of the rock due to shaking. The whole system after fluidization would move together in the same direction making it highly unlikely that ground motion after the drift collapse will cause any further damage to the WP. In the case where invert beams strike the WP due to failure of the structural steel in the invert, the analysis (Reference 2.2.53, Figure 7-145) showed an expended toughness fraction (ETF) of 0.85 in the case of the WP hitting the invert beam at an 18º angle, plug offset of 1 *in* (0.254 *m*), and moving at a velocity of 4 *m/s* (13.12 *ft/sec*). An ETF is a measure of damage, and when ETF equals 1.0 failure is defined (Reference 2.2.40, Section 7.1.7 and Appendix A). This means that the WP did not fail in this case. The PCSA group is responsible for determining the probability of a credible seismic event resulting in the WP moving at velocities reaching 4 *m/s* (13.12 *ft/sec*) as well as the probability of a seismic event occurring after a drift collapse. Therefore, Requirement 6.2.3.21 is expected to be satisfied.

6.2.4 Miscellaneous Supporting Calculations and Analyses

6.2.4.1 Shielding

The following dose rate calculations are from *Dose Rate Calculation for the Naval Long Waste Package* (Reference 2.2.31).

6.2.4.1.1 Source Specification

The source used for the naval canister consists of a side source, a bottom source, and a top source. The top source is made up of three components. The side and bottom sources were grouped together in one Monte Carlo N-Particle (MCNP) calculation while the top sources were grouped for use in a second set of MCNP calculations. The results were combined using Excel to represent the entire canister. The source was applied uniformly along the side of the canister. The source data provided will bound the surface radiation levels on the canister and therefore required no axial peaking factor.

The source given at 18-inches from the centerline was applied uniformly over the top of the canister except where the other two sources were present. These other top source components were applied over the six bolt holes and the seal weld on the top of the canister. Figure 4 below shows the top geometry used to apply the sources provided. The gamma source spectrum is listed in Table 2 while the neutron source spectrum is listed in Table 3.

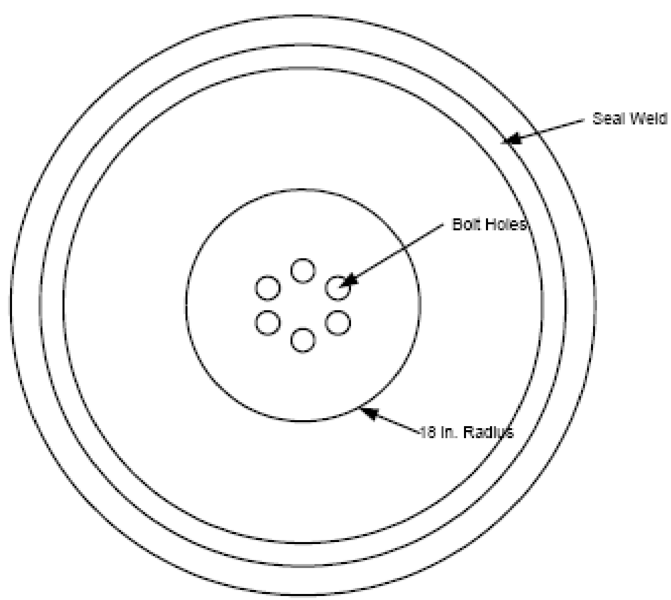

Figure 4. Naval Canister Top Source Distribution Geometry

Source: Reference 2.2.31, Figure 3

Table 2. Naval Canister Gamma Source Spectra

Upper Energy Boundary	Side Surface Over Assembly Mid-Section	Bottom Surface	Top, Above Bolt Holes	Top, 18 inches from Centerline	Top, Above Outer Seal Plate
(MeV)	(photons/cm^2-s)	(photons/cm^2- s)	(photons/cm^2-s)	(photons/cm^2-s)	(photons/cm^2-s)
3.85	2.11E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.35	1.29E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.95	8.67E+03	2.24E+02	1.23E+00	2.91E-02	1.23E+00
2.65	4.09E+04	1.01E+03	5.02E+00	1.08E-01	5.23E+00
2.35	2.33E+06	5.20E+04	1.93E+02	3.21E+00	2.20E+02
2.03	5.04E+05	2.10E+04	1.31E+02	2.77E+00	1.49E+02
1.77	4.31E+06	8.19E+04	2.31E+02	3.65E+00	3.05E+02
1.57	9.45E+05	5.53E+04	1.76E+02	3.00E+00	2.45E+02
1.43	4.23E+07	4.70E+05	5.63E+02	1.77E+00	9.43E+02
1.31	4.50E+07	6.16E+05	7.74E+02	6.86E-01	1.39E+03
1.19	4.21E+07	6.54E+05	9.22E+02	8.81E+00	1.81E+03
1.07	5.66E+07	8.50E+05	1.11E+03	2.01E+01	2.44E+03
0.95	4.30E+07	7.86E+05	1.04E+03	2.51E+01	2.51E+03
0.85	5.95E+08	3.27E+06	1.48E+03	2.28E+01	4.39E+03
0.75	1.76E+08	1.81E+06	1.04E+03	2.83E+01	3.43E+03
0.69	1.54E+09	8.00E+06	1.42E+03	1.03E+02	6.11E+03
0.63	1.07E+09	7.52E+06	1.79E+03	1.20E+02	8.46E+03
0.57	1.98E+09	1.88E+07	4.01E+03	1.60E+02	2.42E+04
0.45	1.93E+09	2.09E+07	3.53E+03	2.96E+01	2.52E+04
0.35	2.15E+09	2.41E+07	4.27E+03	1.00E+03	2.92E+04
0.25	8.78E+08	9.95E+06	9.23E+03	1.02E+04	2.26E+04
0.21	6.03E+08	7.01E+06	1.51E+04	1.75E+04	2.92E+04
0.18	5.26E+08	6.10E+06	1.57E+04	1.91E+04	3.23E+04
0.15	4.03E+08	4.53E+06	1.53E+04	1.92E+04	3.19E+04
0.12	1.89E+08	2.14E+06	1.10E+04	1.43E+04	2.34E+04
0.09	1.93E+07	2.28E+05	3.21E+03	4.24E+03	6.80E+03
0.05	3.57E+04	4.19E+02	4.48E+01	5.72E+01	8.65E+01
Total	**1.23E+10**	**1.18E+08**	**9.23E+04**	**8.62E+04**	**2.57E+05**

Source: Reference 2.2.31, Table 4

Table 3. Naval Canister Neutron Source Spectra

Upper Energy Boundary	Side Surface Over Assembly Mid-Section	Bottom Surface	Top, Above Bolt Holes	Top, 18 inches from Centerline	Top, Above Outer Seal Plate
(MeV)	(neutrons/cm^2-s)	(neutrons/cm^2-s)	(neutrons/cm^2-s)	(neutrons/cm^2-s)	(neutrons/cm^2-s)
21.17	9.96E-02	4.08E+03	3.73E-04	6.01E-05	2.63E-04
12.84	6.15E-01	2.28E-02	1.87E-03	2.89E-04	1.38E-03
10	2.58E+00	8.79E-02	6.40E-03	9.62E-04	4.95E-03
7.79	7.37E+00	2.16E-01	1.32E-02	1.85E-03	1.10E-02
6.07	1.63E+01	4.53E-01	2.47E-02	3.39E-03	2.16E-02
4.72	7.13E+01	2.17E+00	1.19E-01	1.75E-02	1.01E-01
2.86	1.69E+02	8.03E+00	5.56E-01	9.95E-02	4.12E-01
1.74	5.53E+02	7.06E+01	9.96E+00	2.78E+00	5.27E+00
0.82085	7.76E+02	2.51E+02	7.77E+01	2.91E+01	2.95E+01
0.38774	6.36E+02	3.42E+02	1.56E+02	6.71E+01	5.26E+01
0.18316	4.15E+02	2.43E+02	1.35E+02	5.59E+01	4.12E+01
6.738E-02	2.81E+02	1.47E+02	1.12E+02	3.82E+01	2.96E+01
5.530E-03	5.76E+01	3.31E+01	4.40E+01	1.14E+01	7.52E+00
2.260E-05	2.59E+00	2.62E+00	4.27E+00	1.10E+00	7.47E-01
6.250E-07	5.06E-02	1.49E-02	2.72E-02	6.33E-03	4.40E-03
Total	**2.99E+03**	**1.10E+03**	**5.40E+02**	**2.06E+02**	**1.67E+02**

Source: Reference 2.2.31, Table 5

6.2.4.2 Dose Rate Calculation

6.2.4.2.1 Waste Package Dose Rates

All dose rates in this calculation were calculated with the naval long canister inside the WP with all lids secure. Dose rates were calculated on various surfaces inside, on the exterior surface, and a short distance from the WP. In addition to these various dose locations, three scenarios were run to analyze the effects of backscatter on surface dose rates. To create a backscattering effect, a reflector was added to the model. This reflector is a right circular cylinder whose inside surface is located three meters, about 118 *inches*, from each surface of the WP. Figure 5 shows the relationship between the WP and the reflector. The reflector is 30 *cm* (11.8 *in*) thick and is made of air, concrete, or tuff in each of the three cases.

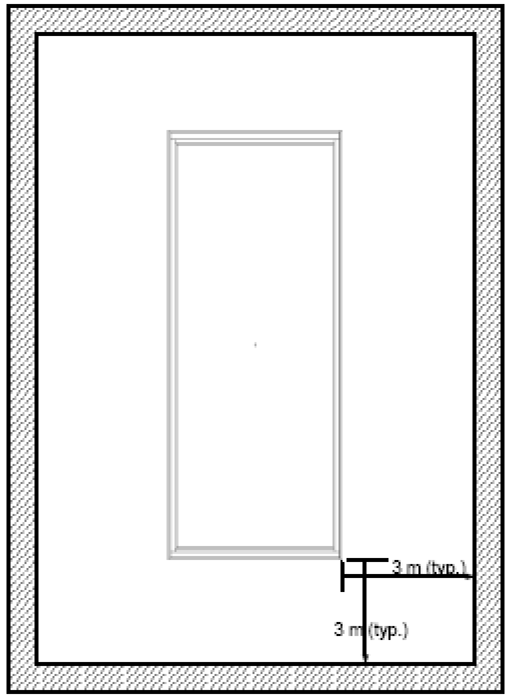

Figure 5. Reflector Geometry

Source: Reference 2.2.31, Figure 4

For dose rates in the radial direction, the WP was divided into six equal length segments (segments 1 – 6) that are each 95.278 *cm* (about 37.5 *inches*) in length. Dose rates were calculated in each of these segments on the outside surface of the canister, the inside surface of the OCB, the outside surface of the OCB and at distances of one and two meters from the WP surface.

In the axial direction, dose rates were calculated at a variety of locations on both the top and bottom of the WP. Dose rates were calculated directly above each bolt hole on the top of the canister (holes 1 – 6), the top of the inner vessel lid, and the top of the OCB lid. Dose rates were also calculated on these surfaces inside an 18-*inch* radius and inside their respective diameters. On the bottom of both the inner barrier and the OCB, dose rates were calculated across the OCB inner diameter (segment 7) in the first case and across the OCB outer diameter (segment 8) in the second.

In both axial directions dose rates were calculated at distances of one and two *meters* from the WP surface. At one *meter*, dose rates were calculated across the OCB outer diameter (segment 8) and the section from the OCB outer diameter to a distance of one *meter* (segment 9). At two *meters*, dose rates were calculated both across the OCB outer diameter (segment 8) and from the OCB outer diameter to a radius of two *meters* from the WP surface (segment 10). Figure 6 below shows the geometric locations of segments one through ten.

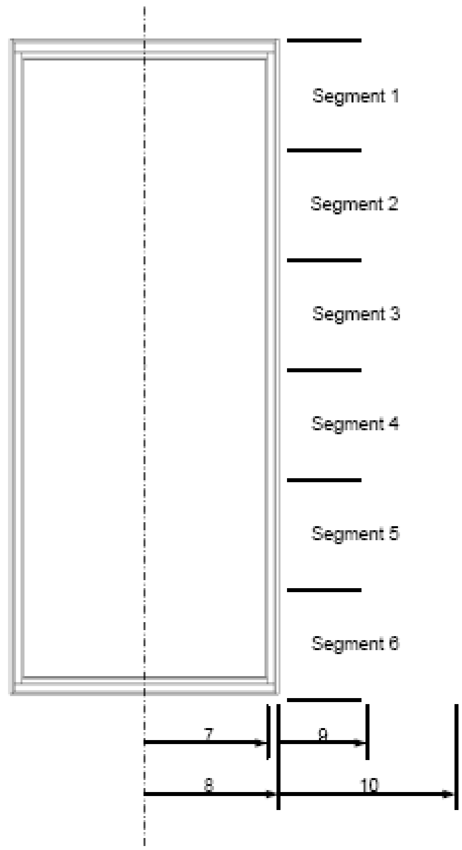

Figure 6. Tally Segmenting Scheme

Source: Reference 2.2.31, Figure 5

Backscattering Analysis

In addition to the cases described above, several cases were run to determine the effect of a reflector on the total surface dose rate. The main focus of this analysis was to find a sufficient thickness of material to get maximum backscatter. These cases were run with a reflector similar to the scenario pictured in Figure 4. The only differences between the two geometries were the material thickness and the distance from the surface of the WP to the inside of the reflector (71 inches in this case as opposed to 3 *meters*, about 118 *inches*, in the previous). The 71-*inch* gap is representative of the conditions found in the emplacement drifts. The materials used were again air, concrete, and tuff. The thicknesses compared for the reflector were 1, 2, 5, 10, 15, 30, 45, and 60 *centimeters*, which is equal to about 0.39, 0.79, 1.97, 3.94, 5.91, 11.81, 17.72, and 23.62 *inches*, respectively. In this analysis the reflector was only in the radial direction and only the side source was used. Six equal segments were created along the length of the WP for tallies and dose rates were calculated on the WP surface in these segments. Each segment is 89.747 *cm* (about 35.3 *inches*) in length and is similar to those pictured in Figure 6.

6.2.4.3 Dose Rates Results and Conclusions

6.2.4.3.1 Radial Dose Rates

The data presented in this section is for the radial surfaces of the naval long canister and WP as well as at distances of one and two meters from the radial surface of the WP. The total dose rate is presented in the tables below for the various scenarios. Tables 4 through 8 present the total dose rates on the surface of the canister, inside surface of the OCB, outside surface of the OCB, and at distances of one and two *meters* from the WP surface. Three geometrically identical cases were run with different materials in the reflector: air, concrete, and tuff. Each case is represented in the tables below. The dose rate and relative error values reported are direct output from MCNP and significant figures have not been applied.

Table 4. Total Dose Rate on the Outside Surface of the Naval Long Canister

Axial Location	No Scatter Material		Concrete		Tuff	
	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error
Segment 1	5.19287E+04	0.0005	5.19214E+04	0.0005	5.19221E+04	0.0005
Segment 2	6.43016E+04	0.0004	6.42981E+04	0.0005	6.43041E+04	0.0005
Segment 3	6.43101E+04	0.0004	6.43056E+04	0.0005	6.43114E+04	0.0005
Segment 4	6.42938E+04	0.0004	6.42938E+04	0.0005	6.42926E+04	0.0005
Segment 5	6.43075E+04	0.0004	6.43038E+04	0.0005	6.43072E+04	0.0005
Segment 6	5.31266E+04	0.0005	5.31231E+04	0.0005	5.31238E+04	0.0005

Source: Reference 2.2.31, Table 7

Table 5. Total Dose Rate on the Inside Surface of the Outer Corrosion Barrier

Axial Location	No Scatter Material		Concrete		Tuff	
	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error
Segment 1	5.87383E+02	0.0020	5.87548E+02	0.0020	5.87448E+02	0.0020
Segment 2	7.11829E+02	0.0018	7.11598E+02	0.0019	7.11818E+02	0.0018
Segment 3	7.12953E+02	0.0018	7.12989E+02	0.0019	7.12978E+02	0.0018
Segment 4	7.11684E+02	0.0018	7.11500E+02	0.0019	7.11565E+02	0.0018
Segment 5	7.12257E+02	0.0018	7.11915E+02	0.0019	7.12115E+02	0.0018
Segment 6	5.99980E+02	0.0020	5.99412E+02	0.0021	5.99822E+02	0.0020

Source: Reference 2.2.31, Table 8

Table 6. Total Dose Rate on the Outside Surface of the Outer Corrosion Barrier

Axial Location	No Scatter Material		Concrete		Tuff	
	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error
Segment 1	8.91027E+01	0.0043	9.12531E+01	0.0043	9.14210E+01	0.0043
Segment 2	1.08917E+02	0.0039	1.11381E+02	0.0040	1.11484E+02	0.0039
Segment 3	1.08991E+02	0.0039	1.11524E+02	0.0039	1.11623E+02	0.0038
Segment 4	1.09075E+02	0.0039	1.11584E+02	0.0039	1.11749E+02	0.0039
Segment 5	1.08780E+02	0.0039	1.10949E+02	0.0039	1.11218E+02	0.0039
Segment 6	9.18829E+01	0.0043	9.40174E+01	0.0043	9.41771E+01	0.0043

Source: Reference 2.2.31, Table 9

Table 7. Total Dose Rate One Meter from Waste Package Outer Surface

Axial Location	No Scatter Material		Concrete		Tuff	
	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error
Segment 1	3.01598E+01	0.0043	3.36510E+01	0.0043	3.39341E+01	0.0043
Segment 2	4.21971E+01	0.0036	4.61878E+01	0.0037	4.65063E+01	0.0037
Segment 3	4.41378E+01	0.0035	4.83100E+01	0.0036	4.85377E+01	0.0036
Segment 4	4.39304E+01	0.0035	4.81383E+01	0.0036	4.83732E+01	0.0036
Segment 5	4.25280E+01	0.0036	4.65629E+01	0.0037	4.67723E+01	0.0036
Segment 6	3.06160E+01	0.0042	3.41890E+01	0.0043	3.43363E+01	0.0042

Source: Reference 2.2.31, Table 10

Table 8. Total Dose Rate Two Meters from Waste Package Outer Surface

Axial Location	No Scatter Material		Concrete		Tuff	
	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error
Segment 1	1.73813E+01	0.0045	2.13443E+01	0.0045	2.16575E+01	0.0045
Segment 2	2.40115E+01	0.0038	2.86026E+01	0.0038	2.88798E+01	0.0038
Segment 3	2.67847E+01	0.0036	3.16854E+01	0.0037	3.20262E+01	0.0036
Segment 4	2.67156E+01	0.0036	3.17544E+01	0.0037	3.19993E+01	0.0036
Segment 5	2.43128E+01	0.0038	2.90487E+01	0.0038	2.92969E+01	0.0038
Segment 6	1.76461E+01	0.0045	2.17242E+01	0.0045	2.19411E+01	0.0045

Source: Reference 2.2.31, Table 11

6.2.4.3.2 Axial Dose Rate

The data presented in this section are for the axial surfaces of the naval long canister and WP as well as at distances of one and two meters from the ends of the WP. The total axial dose rate is presented in Table 9 below for the various scenarios. Table 9 presents the total dose rates on various top and bottom surfaces of the canister and WP as well as at distances of one and two meters from the WP ends. The segments used in Table 9 are described and diagramed in Section 6.2.4.2.1 and Figure 6. Three geometrically identical cases were run with different materials in the "scatter shield"; air, concrete, and tuff. Each case is represented in the table below.

Table 9. Total Dose Rates in the Axial Direction

Axial Location	Segment	No Scatter Material		Concrete		Tuff	
		Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error	Dose Rate (rem/hr)	Relative Error
Inner Barrier Bottom Surface	7	5.39728E+01	0.0084	5.38905E+01	0.0086	5.39480E+01	0.0085
Outer Barrier Bottom Surface	8	8.75128E+00	0.0186	9.77638E+00	0.0183	9.86121E+00	0.0182
1m from Outer Barrier Bottom	8	2.99588E+00	0.0271	5.49305E+00	0.0205	5.76906E+00	0.0203
	9	2.62532E+00	0.0159	5.44784E+00	0.0116	5.61080E+00	0.0114
2m from Outer Barrier Bottom	8	1.64060E+00	0.0357	4.17616E+00	0.0225	4.39494E+00	0.0212
	10	1.49688E+00	0.0127	3.95517E+00	0.0081	4.09984E+00	0.0079
Top of Canister	Hole 1	4.55408E-01	0.0032	4.56913E-01	0.0045	4.56062E-01	0.0042
	Hole 2	4.56723E-01	0.0032	4.56244E-01	0.0045	4.56302E-01	0.0042
	Hole 3	4.53194E-01	0.0032	4.51799E-01	0.0044	4.52419E-01	0.0042
	Hole 4	4.57293E-01	0.0032	4.57852E-01	0.0044	4.57077E-01	0.0042
	Hole 5	4.55277E-01	0.0032	4.53006E-01	0.0045	4.54140E-01	0.0042
	Hole 6	4.57963E-01	0.0032	4.59583E-01	0.0045	4.59222E-01	0.0042
	Canister OD	1.39126E+02	0.0133	1.39427E+02	0.0135	1.39267E+02	0.0134
Inner Barrier Top Lid	Hole 1	3.16314E-02	0.0064	3.23283E-02	0.0120	3.20257E-02	0.0109
	Hole 2	3.16423E-02	0.0065	3.16981E-02	0.0119	3.15728E-02	0.0109
	Hole 3	3.19217E-02	0.0064	3.19600E-02	0.0122	3.20395E-02	0.0111
	Hole 4	3.18024E-02	0.0065	3.22130E-02	0.0122	3.23810E-02	0.0111
	Hole 5	3.16743E-02	0.0065	3.17661E-02	0.0123	3.17607E-02	0.0110
	Hole 6	3.15626E-02	0.0063	3.14815E-02	0.0116	3.13815E-02	0.0104
	Inner Barrier OD	5.02638E+01	0.0089	5.02858E+01	0.0091	5.03167E+01	0.0090
Outer Barrier Top Lid	Hole 1	1.06488E-02	0.0106	1.11408E-02	0.0206	1.11928E-02	0.0184
	Hole 2	1.07040E-02	0.0105	1.09657E-02	0.0200	1.10584E-02	0.0183
	Hole 3	1.05664E-02	0.0105	1.09984E-02	0.0203	1.10032E-02	0.0184
	Hole 4	1.06333E-02	0.0103	1.09867E-02	0.0192	1.10559E-02	0.0173
	Hole 5	1.06293E-02	0.0107	1.10463E-02	0.0200	1.11945E-02	0.0183
	Hole 6	1.04675E-02	0.0102	1.06707E-02	0.0186	1.06388E-02	0.0166
	Outer Barrier OD	7.91579E+00	0.0194	8.83760E+00	0.0190	8.99678E+00	0.0189
1m from Outer Barrier Top	8	2.67479E+00	0.0289	5.23740E+00	0.0216	5.40882E+00	0.0208
	9	2.44215E+00	0.0165	5.23701E+00	0.0120	5.40594E+00	0.0116
2m from Outer Barrier Top	8	1.53058E+00	0.0375	4.14885E+00	0.0231	4.25025E+00	0.0228
	10	1.41311E+00	0.0130	3.82963E+00	0.0081	3.99881E+00	0.0079

Source: Reference 2.2.31, Table 12

6.2.4.3.3 Backscatter Analysis

The focus of the backscattering analysis was to determine a sufficient thickness to provide the maximum amount of backscattering. This was accomplished by running cases with 1, 2, 5, 10, 15, 30, 45, and 60 *cm* of backscattering material. In addition to an initial case run with just air surrounding the WP, cases were run with concrete and tuff at each of these thicknesses. Table 10 below outlines the results of these runs.

Table 10. Naval WP Surface Dose Rates for Various Reflector Thicknesses and Materials

Thickness (cm)	Material	Peak Dose Rate (rem/hr)	Relative Error
0	Air	1.08661E+02	0.0051
1	Concrete	1.09741E+02	0.0050
	Tuff	1.09645E+02	0.0051
2	Concrete	1.10745E+02	0.0050
	Tuff	1.10560E+02	0.0050
5	Concrete	1.12668E+02	0.0050
	Tuff	1.12567E+02	0.0050
10	Concrete	1.13497E+02	0.0050
	Tuff	1.13603E+02	0.0050
15	Concrete	1.13610E+02	0.0050
	Tuff	1.13795E+02	0.0050
30	Concrete	1.13623E+02	0.0050
	Tuff	1.13830E+02	0.0050
45	Concrete	1.13622E+02	0.0050
	Tuff	1.13842E+02	0.0050
60	Concrete	1.13624E+02	0.0050
	Tuff	1.13839E+02	0.0050

Source: Reference 2.2.31, Table 13

6.2.4.4 Dose Rate Conclusions

6.2.4.4.1 Radial Dose Rates

Dose rates were taken on various radial surfaces of the canister and WP with the surfaces of most interest being the contact surface of the WP and those close to the surface (one and two meters from the surface). In all of these cases the area outside the WP and inside the reflector was air. The peak dose rate on the radial surface of the WP was approximately 109.1 *rem/hr* and occurred in segment 4 of the tally geometry. The lowest dose rate found on this surface of the WP was approximately 89.1 *rem/hr* and was located in segment 1 of the geometry. At distances of one and two meters in the radial direction the peak dose rates were 44.1 and 26.8 *rem/hr*, respectively.

The peak dose points on the surface of the WP in the cases using a concrete and tuff reflector were 111.6 *rem/hr* and 111.7 *rem/hr*, respectively, which is a percent difference from the air case of 2.30 and 2.45 percent, respectively. In the case of the concrete reflector there was a percent difference of 9.45 and 18.55 percent at one and two *meters* from the WP surface, respectively, when compared with the air case. In the case of the tuff reflector there was a percent difference of 9.97 and 19.57 percent at one and two *meters* from the WP, respectively, when compared with air. Based on these values a conclusion can be made that the contribution due to scatter are more pronounced as you get closer to the reflector and that tuff is a slightly more conservative scatter material than concrete.

The peak radial surface dose was also found to be more than 10 times greater than the peak dose on either the top or the bottom surface. This shows that the radial dose rate can be used as a bounding condition for the entire WP.

6.2.4.4.2 Axial Dose Rates

Dose rates were calculated at various locations on both canister and WP axial surfaces. In all of these cases the area outside the WP and inside the reflector was air. The most important of these points are the contact surfaces of the WP and a short distance from these surfaces. Calculated as an average over the diameter of the WP with no reflector present, the dose rate on the bottom and top surfaces of the OCB were 8.75 and 7.92 *rem/hr*, respectively. At one and two *meters* from the top surface the dose rates taken over the WP diameter were 2.67 and 1.53 *rem/hr*, respectively. Similarly the dose rates one and two *meters* from the bottom surface of the WP were 3.00 and 1.64 *rem/hr*, respectively.

In the cases using concrete and tuff reflector the dose rates over the bottom surface were 9.78 and 9.86 *rem/hr*, which is a percent difference of 11.71 and 12.68 percent, respectively, from the case with no reflector. Similarly, the dose rates with the concrete and tuff reflectors on the top surface were 8.84 and 9.00 *rem/hr*, which is a percent difference of 11.65 and 13.66 percent, respectively, from the case with no reflector. The percent difference at distances of one and two *meters* for both the top and bottom of the WP were substantially higher than in all of the other cases. This is attributed to scattering from the radial surface into these regions.

As mentioned in the previous section, the radial dose rate is more than ten times higher than either the top or bottom dose rates. When comparing the top and bottom surface dose rates, the bottom is found to be about ten percent higher than the top.

6.2.4.4.3 Backscatter Analysis

The objective of this analysis was to find the optimum or at least the minimum thickness of material to provide the maximum amount of backscatter for use in the first part of this calculation. Based on the data and plots in Section 7.1.3 a thickness of 30 *cm* is sufficient to provide maximum backscattering in the case of our two materials. Therefore, in the main portion of the calculation a reflector thickness of 30 *cm* was chosen to give maximum backscattering.

7. RESULTS AND CONCLUSIONS

This report demonstrates that the design methodology can be applied successfully to the naval waste package configurations and supports the License Application for construction of the repository. General design features were given including design configurations, materials, and guidance for use of codes and standards.

Design features and structural analysis of the naval waste packages were compared to design requirements from the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 2.2.24) and the *Project Design Criteria Document* (Reference 2.2.39). In addition, requirements were derived by the nature of the engineered design solution or imposed by interfaces with postclosure performance assessment. The comparison of naval waste package design features and structural analysis demonstrates requirements are satisfied, or (in a few cases) will be satisfied as final design is completed.

BSC	Calculation/Analysis Change Notice *Complete only applicable items.*	1. QA: QA 2. Page 1 of 1

3. Document Identifier:	4. Rev.:	5. CACN:
000-00C-DNF0-00800-000	00B	001

6. Title:
NAVAL WASTE PACKAGE DESIGN REPORT

7. Reason for Change:
Resolve CR 12202

Condition Description:

In Table 3, Naval Canister Neutron Source Spectra of the Naval Waste Package Design Report - 000-00C-DNF0-00800-000-00B, the bottom surface value for the neutron source spectra of 21.17 MeV is listed as 4.08E+03 and should be 4.08E-03. This error was carried through from reference to the Dose Rate Calculation for the Naval Long Waste Package - 000-00C-DN00-00100-000-00B.

8. Supersedes Change Notice: ☐ Yes If, Yes, CACN No.: ______ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes	☒ No	Results Impacted:	☐ Yes	☒ No
Assumptions Changed:	☐ Yes	☒ No	Design Impacted:	☐ Yes	☒ No

10. Description of Change:

Update Reference 2.2.31as follows:

BSC (Bechtel SAIC Company) 2008. Dose Rate Calculation for the Naval Long Waste Package. 000-00C-DN00-00100-000-00D. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080515.0002.

In Table 3, Naval Canister Neutron Source Spectra of the Naval Waste Package Design Report - 000-00C-DNF0-00800-000-00B, the bottom surface value for the neutron source spectra of 21.17 MeV, which is listed as 4.08E+**03,** is changed to 4.08E-**03.**

11. REVIEWS AND APPROVAL

	Printed Name	Signature	Date
11a. Originator:	Jason Viggato	Jason Viggato	7/24/08
11b. Checker:	Sripathi Nilkar	[signature]	7/24/08
11c. EGS:	Jason Viggato	Jason Viggato	7/24/08
11d. DEM:	Michael Anderson	[signature]	7/24/08
11e. Design Authority:	Robert Slovic	RC Slovic	24 JULY 2008