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ACRONYMS

ASME	American Society of Mechanical Engineers
B&PVC	Boiler and Pressure Vessel
BOD	Basis of Design
DHLW	Defense High-Level Waste
DOE	U.S. Department of Energy
DPC	Dual Purpose Canister
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
HLW	High-Level Waste
IED	Information Exchange Document
IICD	Integrated Interface Control Document
IPWF	Immobilized Plutonium Waste Form
ITS	Important To Safety
ITWI	Important To Waste Isolation
LA	License Application
LaBS	Lanthanide Borosilicate
MCO	Multicanister Overpack
MTHM	Metric Tons of Heavy Metal
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
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
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 TAD waste package configuration. The design methodology is described in the *Waste Package Component Design Methodology Report* (Reference 2.2.30) 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 2.2.22). 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 (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 LA 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 2.2.16), the *Project Design Criteria Document* (PDC) (Reference 2.2.29) and the *Preliminary Preclosure Nuclear Safety Design Bases* (NSDB-LA) (Reference 2.2.65). Additional design requirements are derived from the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17), 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. Further, the Lead Laboratory retains responsibility for demonstrating how and to what extent compliance with the design requirements contributes to barrier capability.

2. REFERENCES

2.1 PROCEDURES/DIRECTIVES

2.1.1 EG-PRO-3DP-G04B-00037, Rev. 10, *Calculations and Analyses*. Las Vegas, Nevada. Bechtel SAIC Company. ACC: ENG.20071018.0001.

2.1.2 BSC (Bechtel SAIC Company) 2007. *Quality Management Directive.* QA-DIR-10, Rev. 002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.200801030.0002.

2.1.3 BSC (Bechtel SAIC Company) 2007. *Configuration Management.* EG-PRO-3DP-G04B-00005 REV 004. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070319.0012.

2.1.4 IT-PRO-0011, Rev. 7, *Software Management*. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20070905.0007.

2.1.5 ORD (Office of Repository Development) 2007. *Repository Project Management Automation Plan*. 000-PLN-MGR0-00200-000-00E. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070326.0019.

2.2 DESIGN INPUTS

2.2.1 10 CFR 63. 2007. *Energy: Disposal of High-Level Radioactive Wastes in a Geologic Repository at Yucca Mountain, Nevada*. Internet Accessible. [DIRS 180319].

2.2.2 ANSI/AWS A5.32/A5.32M-97 (R 2007). 2007. *Specification for Welding Shielding Gases*. Miami, Florida: American Welding Society. TIC: 259771.

2.2.3 ANSI/AWS A2.4-98. 2007. *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. New York, New York: American National Standards Institutes / American Welding Society (ANSI/AWS). TIC: 259774.

2.2.4 ASM (American Society for Metals) 1980. *Properties and Selection: Stainless Steels, Tool Materials and Special-Purpose Metals*. Volume 3 of Metals Handbook. 9th Edition. Benjamin, D., ed. Metals Park, Ohio: American Society for Metals. TIC: 209801. ISBN: 0-87170-009-3.

2.2.5 ASME (American Society of Mechanical Engineers) 2001. *2001 ASME Boiler and Pressure Vessel Code (includes 2002 addenda)*. New York, New York: American Society of Mechanical Engineers. TIC: 251425.

2.2.6 ASME B46.1-2002. 2003. *Surface Texture (Surface Roughness, Waviness and Lay)*. New York, New York: American Society of Mechanical Engineers. TIC: 257359.

2.2.7 ASME NQA-1-2000. 2001. *Quality Assurance Requirements for Nuclear Facility Applications*. New York, New York: American Society of Mechanical Engineers. TIC: 253110. ISBN: 0-7918-2652-X.

2.2.8 ASME Y14.5M-1994 (Reaffirmed 2004). 2004. *Dimensioning and Tolerancing*. New York, New York: American Society of Mechanical Engineers. TIC: 258696. ISBN: 0791822230.

2.2.9 ASME Y14.36M-1996 (Reaffirmed 2002). 2002. *Surface Texture Symbols*. New York, New York: American Society of Mechanical Engineers. TIC: 258843. ISBN: 0791823199.

2.2.10 ASME Y14.38-1999. 1999-2002. *Abbreviations and Acronyms (with Addenda, ASME Y14.38a-2002)*. New York, New York: American Society of Mechanical Engineers. TIC: 258694.

2.2.11 ANSI N14.6-1993. 1993. *American National Standard for Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10000 Pounds (4500 kg) or More*. New York, New York: American National Standards Institute. TIC: 236261.

2.2.12 BSC (Bechtel SAIC Company) 2001. *Waste Package Outer Barrier Stress Due to Thermal Expansion with Various Barrier Gap Sizes*. CAL-EBS-ME-000011 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20011212.0222. [DIRS 152655].

2.2.13 BSC (Bechtel SAIC Company) 2007. *BSC Position on the Use of the ASME Boiler and Pressure Vessel Code for the Yucca Mountain Waste Packages*. 000-30R-WIS0-00200-000-002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070709.0041.

2.2.14 NRC (U.S. Nuclear Regulatory Commission) 1980. *Control of Heavy Loads at Nuclear Power Plants*. NUREG-0612. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 209017. [DIRS 104939].

2.2.15 BSC (Bechtel SAIC Company) 2007. *Waste Package Fabrication Specification*. 000-3SS-DSC0-00100-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070315.0001.

2.2.16 BSC (Bechtel SAIC Company) 2007. *Basis of Design for the TAD Canister-Based Repository Design Concept*. 000-3DR-MGR0-00300-000-001. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071002.0042; ENG.20071026.0033; ENG.20071108.0002;ENG.20071109.0001; ENG.20071120.0023; ENG.20071126.0049; ENG.20071214.0009; ENG.20071213.0005;ENG.20071227.0018; ENG.20080207.0004; ENG.2008.0212.0003.

2.2.17 BSC (Bechtel SAIC Company) 2007. *Provisional Event Sequence Definitions for Waste Packages*. 000-30R-WIS0-00900-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070307.0014.

2.2.18 BSC (Bechtel SAIC Company) 2007. *Probabilistic Characterization of Preclosure Rockfalls in Emplacement Drifts*. 800-00C-MGR0-00300-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070329.0009.

2.2.19 BSC (Bechtel SAIC Company) 2003. *Value Study Report—Waste Package Reevaluation*. 000-3TS-EBS0-00100-000-000. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20030327.0073. [DIRS 163185].

2.2.20 BSC (Bechtel SAIC Company) 2003. *Waste Package Axial Thermal Expansion Calculation*. 000-00C-EBS0-00500-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20030416.0001.

2.2.21 BSC (Bechtel SAIC Company) 2007. *Emplacement Pallet Lift and Degraded Static Analysis*. 000-00C-SSE0-00800-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070813.0017.

2.2.22 BSC (Bechtel SAIC Company) 2007. *Execution Plan for the Thermal-Structural Discipline Workflow for Design, Design Revision, and Prototyping of Waste Packages and Related Components*. Las Vegas, Nevada: Bechtel SAIC Company. 000-30R-MGR0-02100-000-001 ACC: ENG.20070921.0006.

2.2.23 BSC (Bechtel SAIC Company) 2005. *Screening of Features, Events, and Processes in Drip Shield and Waste Package Degradation*. ANL-EBS-PA-000002 REV 05. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20050817.0003; DOC.20050826.0002; DOC.20050929.0007. [DIRS 174995].

2.2.24 BSC (Bechtel SAIC Company) 2007. *Thermal Evaluation of the 5-DHLW/DOE SNF and TAD Waste Packages in the TEV*. 800-00C-DS00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070731.0043.

2.2.25 BSC (Bechtel SAIC Company) 2007. *Naval Long Oblique Impact inside TEV*. 000-00C-DNF0-01200-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070806.0016, ENG.20071024.0004.

2.2.26 BSC (Bechtel SAIC Company) 2007. *IED Waste Package Configuration*. 800-IED-WIS0-02101-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070926.0014.

2.2.27 DOE (U.S. Department of Energy) 2007. *Transportation, Aging and Disposal Canister System Performance Specification REV 0.* WMO-TADCS-000001. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20070614.0007. [DIRS 181403].

2.2.28 BSC (Bechtel SAIC Company) 2007. *Thermal Responses of TAD and 5-DHLW/DOE SNF Waste Packages to a Hypothetical Fire Accident*. 000-00C-WIS0-02900-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070220.0008.

2.2.29 BSC (Bechtel SAIC Company) 2007. Project Design Criteria Document. 000-3DR-MGR0-00100-000-007. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071016.0005;ENG.20071018.0026; ENG.20071108.0001; ENG.20071220.0003 ENG.20080107.0001;ENG.20080107.0002; ENG.20080107.0016; ENG.20080107.0017.

2.2.30 BSC (Bechtel SAIC Company) 2007. *Waste Package Component Design Methodology Report*. 000-30R-WIS0-00100-000-004. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071220.0030.

2.2.31 BSC (Bechtel SAIC Company) 2007. *Nonlithophysal Rock Fall on Waste Packages*. 000-00C-MGR0-01400-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070724.0015.

2.2.32 CRWMS M&O 1997. *Waste Package Materials Selection Analysis*. BBA000000-01717-0200-00020 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980324.0242. [DIRS 100259].

2.2.33 NRC (U.S. Nuclear Regulatory Commission) 2003. *Yucca Mountain Review Plan, Final Report*. NUREG-1804, Rev. 2. Washington, D.C.: U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards. TIC: 254568. [DIRS 163274].

2.2.34 BSC (Bechtel SAIC Company) 2008. *Calculation of Temperatures in a Twelve Waste Package Segment at High Thermal Limits*. 800-00C-WIS0-00700-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.200810129.0007.

2.2.35 BSC (Bechtel SAIC Company) 2008. *Temperatures in an "As-Loaded" and Thermally-Misloaded Drift Segment*. 800-00C-WIS0-00600-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080206.0024.

2.2.36 BSC (Bechtel SAIC Company) 2007. *IED Seismic Data*. 800-IED-MGR0-00701-000 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070216.0003.

2.2.37 BSC (Bechtel SAIC Company) 2007. *IED Waste Package Decay Heat Generation [Sheet 1 of 1]*. 800-IED-WIS0-00701-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071005.0023.

2.2.38 BSC (Bechtel SAIC Company) 2007. *IED Waste Package Decay Heat Generation Design Basis and Thermal Information*. 800-IED-WIS0-00801-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070913.0013.

2.2.39 BSC (Bechtel SAIC Company) 2007. *IED Waste Package Radiation Characteristics [Sheet 1 of 1]*. 800-IED-WIS0-01301-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071120.0005.

2.2.40 DOE (U.S. Department of Energy) 2001. *Yucca Mountain Science and Engineering Report*. DOE/RW-0539. [Washington, D.C.]: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010524.0272. [DIRS 153849].

2.2.41 BSC (Bechtel SAIC Company) 2007. *Naval Long Waste Package Vertical Impact on Emplacement Pallet and Invert*. 000-00C-DNF0-00100-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071017.0001, ENG.20071116.0011.

2.2.42 BSC (Bechtel SAIC Company) 2007. *TEV Collision with an Emplaced 5-DHLW/DOE SNF Short Co-Disposal Waste Package*. 000-00C-MGR0-04100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070904.0033.

2.2.43 BSC (Bechtel SAIC Company) 2007. *Drift Collapse Weight and Thermal Loading of TAD and 5-DHLW/DOE SNF Short Co-Disposal Waste Packages*. 000-00C-MGR0-04400-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071030.0041.

2.2.44 ASTM B 575-99a. 1999. *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and Strip*. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 247534.

2.2.45 BSC (Bechtel SAIC Company) 2007. *Interlocking Drip Shield Configuration*. 000-M00-SSE0-00101-000 REV 00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070409.0001.

2.2.46 BSC (Bechtel SAIC Company) 2001. *Internal Pressurization Due to Fuel Rod Rupture in Waste Packages*. CAL-EBS-ME-000005 REV 01. Las Vegas, Nevada: Bechtel SAIC Company. ACC: MOL.20010629.0076. [DIRS 153755].

2.2.47 BSC (Bechtel SAIC Company) 2006. *21-PWR Waste Package Internal Pressure Estimate*. 000-00C-DSU0-03500-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20061108.0004; ENG.20070402.0003.

2.2.48 BSC (Bechtel SAIC Company) 2007. *TAD Waste Package Configuration*. 000-MW0-DSC0-00101-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070301.0010.

2.2.49 BSC (Bechtel SAIC Company) 2007. *TAD Waste Package Configuration*. 000-MW0-DSC0-00102-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070301.0011.

2.2.50 BSC (Bechtel SAIC Company) 2007. *TAD Waste Package Configuration*. 000-MW0-DSC0-00103-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070301.0012.

2.2.51 BSC (Bechtel SAIC Company) 2007. *IED Waste Package Characteristics - 1999 Design Basis Waste Stream [Sheet 1 of 1]*. 800-IED-WIS0-01401-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071005.0025.

2.2.52 BSC (Bechtel SAIC Company) 2005. *IED Waste Package Weld Characteristics [Sheet 1 of 1]*. 800-IED-WIS0-01001-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050406.0009.

2.2.53 BSC (Bechtel SAIC Company) 2007. *IED Emplacement Drift Configuration and Environment*. 800-IED-MGR0-00501-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070716.0006.

2.2.54 BSC (Bechtel SAIC Company) 2007. *IED Emplacement Drift Invert*. 800-IED-MGR0-00601-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071120.0004.

2.2.55 BSC (Bechtel SAIC Company) 2007. *IED Interlocking Drip Shield*. 800-IED-SSE0-00101-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070913.0011.

2.2.56 Roark, R.J. and Young, W.C. 1975. Formulas for Stress and Strain. 5th Edition. New York, New York: McGraw-Hill. TIC: 240746, ISBN: 0-07-053031-9.

2.2.57 BSC (Bechtel SAIC Company) 2007. *Thermal Evaluation of the CRCF-1 Lower Transfer Room Cells*. 060-00C-DS00-00100-000-00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070913.0011.

2.2.58 BSC (Bechtel SAIC Company) 2007. *TMRB Decision Proposal, Revise TDR-MGR-MD-000037, Postclosure Modeling and Analyses Design Parameters*. TMRB-2006-021. Las Vegas, Nevada: Bechtel SAIC Company. ACC: RPM.20070703.0032. [DIRS 183270].

2.2.59 BSC (Bechtel SAIC Company) 2007. *Postclosure Modeling and Analyses Design Parameters*. TDR-MGR-MD-000037 REV 2. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080108.0002.

2.2.60 Allegheny Technologies 2004. *Nickel-Based Alloy Weld Filler Material and Base Metal Composition Test Program*. 004223, Rev. 0. Volume #1 Final Technical Report Appendices A-C. Albany, Oregon: Allegheny Technologies. ACC: ENG.20040507.0005.

2.2.61 BSC (Bechtel SAIC Company) 2007. *Emplacement and Retrieval Drip Shield Emplacement Gantry Mechanical Equipment Envelope*. 800-MJ0-HE00-00201-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071026.0031.

2.2.62 BSC (Bechtel SAIC Company) 2008. *Drip Shield Gantry Mechanical Equipment Envelope Calculation*. 800-MQC-HEE0-00100-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20080125.0005.

2.2.63 BSC (Bechtel SAIC Company) 2007. *Transport and Emplacement Vehicle Envelope Calculation*. 800-MQC-HE00-00100-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070830.0043.

2.2.64 BSC (Bechtel SAIC Company) 2007. *Emplacement and Retrieval Transport and Emplacement Vehicle Mechanical Equipment Envelope*. 800-MJ0-HE00-00101-000 REV 00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20070918.0041.

2.2.65 BSC (Bechtel SAIC Company) 2007. *Preliminary Preclosure Nuclear Safety Design Bases*. 000-PSA-MGR0-01000-000 REV 002. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071201.0006.

2.2.66 BSC (Bechtel SAIC Company) 2007. *Evaluation of Waste Stream Receipt Scenarios for Repository Loading*. 800-00C-WIS0-00500-000-00B. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20071220.0004.

2.2.67 ASTM A 887-89 (Reapproved 2004). 2004. *Standard Specification for Borated Stainless Steel Plate, Sheet, and Strip for Nuclear Application.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 258746.

2.2.68 Halliday, D.; Resnick, R.; and Merrill, J. 1988. Fundamentals of Physics. 3rd Edition Extended. New York, New York: John Wiley & Sons. TIC: 234765. ISBN: 0-471-81995-6.

2.2.69 DOE (U.S. Department of Energy) 2007. "High-Level Radioactive Waste and U.S. Department of Energy and Naval Spent Nuclear Fuel to the Civilian Radioactive Waste Management System." Volume 1 of *Integrated Interface Control Document.* DOE/RW-0511, Rev. 3. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20070125.0002. [DIRS 178792].

2.2.70 Regulatory Guide 1.193, Rev. 1. 2005. ASME Code Cases Not Approved for Use. Washington, D.C.: U.S. Nuclear Regulatory Commission. Internet Accessible. [DIRS 177622].

2.2.71 BSC (Bechtel SAIC Company) 2006. *Regulatory Guidance Agreement, Regulatory Guide 1.84, Rev. 33 - Design, Fabrication, and Materials Code Case Acceptability, ASME Section III.* REG-CRW-RG-000071 REV 00. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20061012.0020. [DIRS 181679].

2.2.72 Regulatory Guide 1.84, Rev. 33. 2005. *Design, Fabrication, and Materials Code Case Acceptability, ASME Section III.* Washington, D.C.: U.S. Nuclear Regulatory Commission. Internet Accessible. [DIRS 177621].

2.2.73 SNL (Sandia National Laboratories) 2008. *Postclosure Analysis of the Range of Design Thermal Loadings*. ANL-NBS-HS-000057 REV 00. Las Vegas, Nevada: Sandia National Laboratories. ACC: DOC.20080121.0002. [DIRS 179962].

2.3 DESIGN CONSTRAINTS

None.

2.4 DESIGN OUTPUTS

This document provides the basis for the TAD waste package design as embodied in the drawings of these components. The design outputs include the TAD configuration drawings

(References 2.2.48, 2.2.49 and 2.2.50). This document also provides information to support the LA.

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 TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50) are assumed to be the same as the final definitive design. The rationale for this assumption is that the design of the TAD waste package (References 2.2.48, 2.2.49 and 2.2.50) is created for the LA. This assumption is used in Section 6.1.1.3.

3.1.2 The *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17) 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 2.2.16) does not sufficiently describe the credible event sequences for the TAD 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 2.2.17) 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) at a later date (Appendix A, Reference 2.2.65), and satisfaction of design requirements resulting from these event sequences will be addressed by later revisions of the BOD (Reference 2.2.16). This assumption is used in Section 6.2.3.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 In the event sequence where a loaded Transport and Emplacement Vehicle (TEV) is overdriven into an emplaced TAD WP (Reference 2.2.17, Section 4.3.6) the structural response of the TAD 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 2.2.42, 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 TAD WP due to the larger diameter of the 5-DHLW/DOE SNF Short Co-disposed WP (Reference 2.2.56, 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.

3.2.2 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 2.2.17, Section 4.3.8) is less severe than the event sequence where a loaded TEV is overdriven into an emplaced WP (Reference 2.2.17, 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. Furthermore, 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 scenario is less challenging to the OCB than the point contact on the lid initiated by an angled 2-MCO/2-DHLW WP that was analyzed in Reference 2.2.42. This assumption is used in Section 6.2.3.7.

3.2.3 It is assumed that the event sequence where a drip shield emplacement gantry collides with an emplaced waste package (Reference 2.2.17, 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 2.2.64 and 2.2.63 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 2.2.61 and 2.2.62 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 TAD waste package is classified as important to safety (ITS) and important to waste isolation (ITWI) (Reference 2.2.16, Section 11.1.2). 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 2.2.22) is QA: N/A. It is used to augment the *Waste Package Component Design Methodology Report* (Reference 2.2.30).

The *Value Study Report—Waste Package Reevaluation* (Reference 2.2.19) is QA: N/A. It is referenced for historical purposes only.

The *Yucca Mountain Science and Engineering Report* (Reference 2.2.40) 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 2.2.13) is QA: N/A. It is referenced for additional ASME code supporting purposes only.

The Emplacement and Retrieval Drip Shield Emplacement Gantry Mechanical Equipment Envelope (Reference 2.2.61) is QA: N/A. It is used to augment the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17).

The *Preliminary Preclosure Nuclear Safety Design Bases* (NSDB-LA) (Reference 2.2.65) is QA: N/A. It is used for controlling parameters and values related to the TAD WP as dictated by the *BOD* (Reference 2.2.16).

The *Drip Shield Gantry Mechanical Envelope Calculation* (Reference 2.2.62) is QA: N/A. It is used to augment the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17).

The *TMRB Decision Proposal, Revise TDR-MGR-MD-000037, Postclosure Modeling and Analyses Design Parameters* (Reference 2.2.58) is QA: N/A. It is referenced for historical purposes only.

The *Preliminary Preclosure Nuclear Safety Design Bases* (Reference 2.2.65) is QA: N/A. It has been incorporated by reference to the BOD (Reference 2.2.16).

The *Regulatory Guidance Agreement, Regulatory Guide 1.84, Rev. 33 - Design, Fabrication, and Materials Code Case Acceptability, ASME Section III* (Reference 2.2.71) is QA: N/A. It is used to provide guidance on the use of *Regulatory Guide 1.84* (Reference 2.2.72).

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 and plotting calculations in Sections 6.2.3.5. Usage of Microsoft Office in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 2.1.4). Microsoft Office 2003 is listed in the current Level 2 usage Controlled Software Report, as well as the *Repository Project Management Automation Plan* (Reference 2.1.5, 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 plots are 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 2.2.30). 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 2.2.22). 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 2.2.16) and the PDC (Reference 2.2.29). 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 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 design of the TAD waste package is described in Sections 6.1 and 6.2. The general configuration, justification of design features, material selections, and guidance for use of codes and standards are provided. Figure 1 shows an exploded view of the TAD waste package. Figure 2 shows the waste package on an emplacement pallet.

6.1.1 Design of the Waste Package

6.1.1.1 TAD Waste Package Configuration

Commercial spent nuclear fuel arrives at the repository in canisters suitable for long-term disposal or in Dual Purpose Canisters (DPC) and then the fuel is placed in a TAD canister before insertion into the TAD WP. The TAD waste package and naval long waste package are the heaviest and longest of all the current baseline waste package design configurations (an exception is the future design of a TAD Long WP, which is not currently in the scope of this report). The TAD waste package configuration drawings are provided by References 2.2.48, 2.2.49 and 2.2.50.

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.

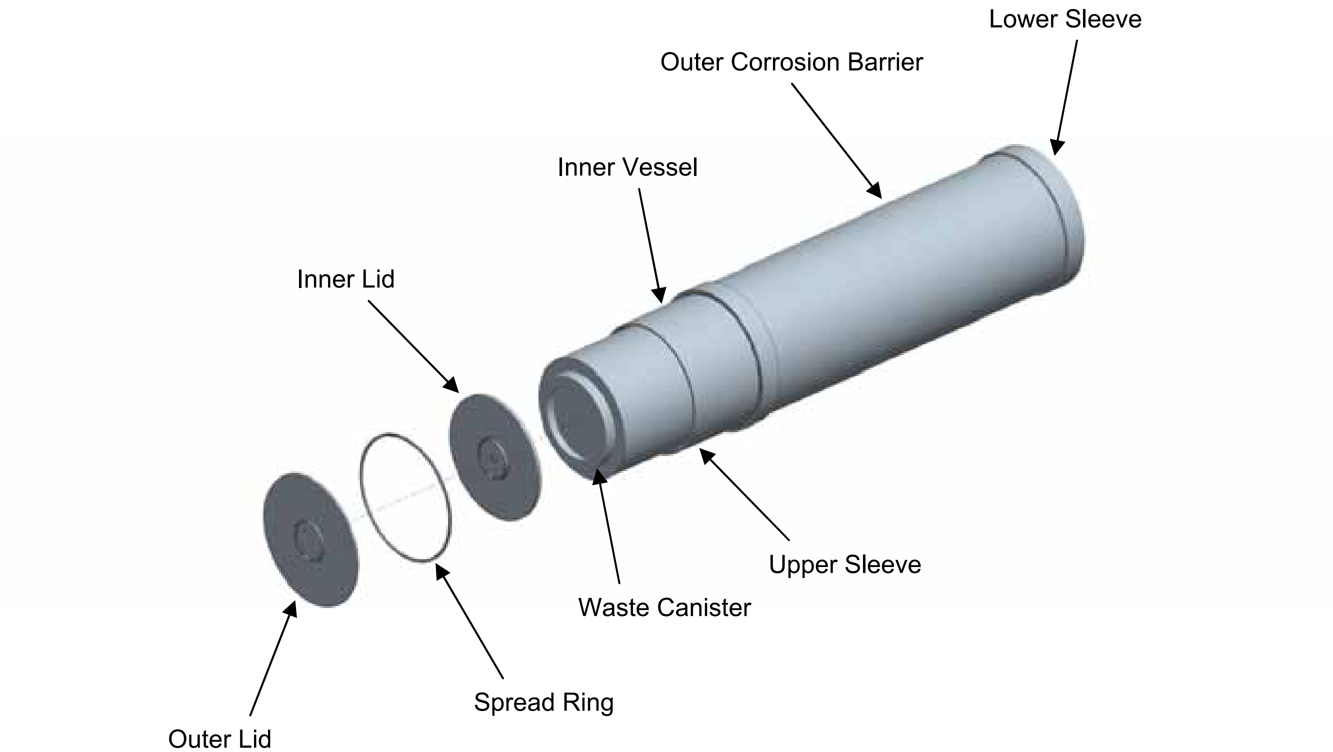

Figure 1.TAD Waste Package

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&PV code-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

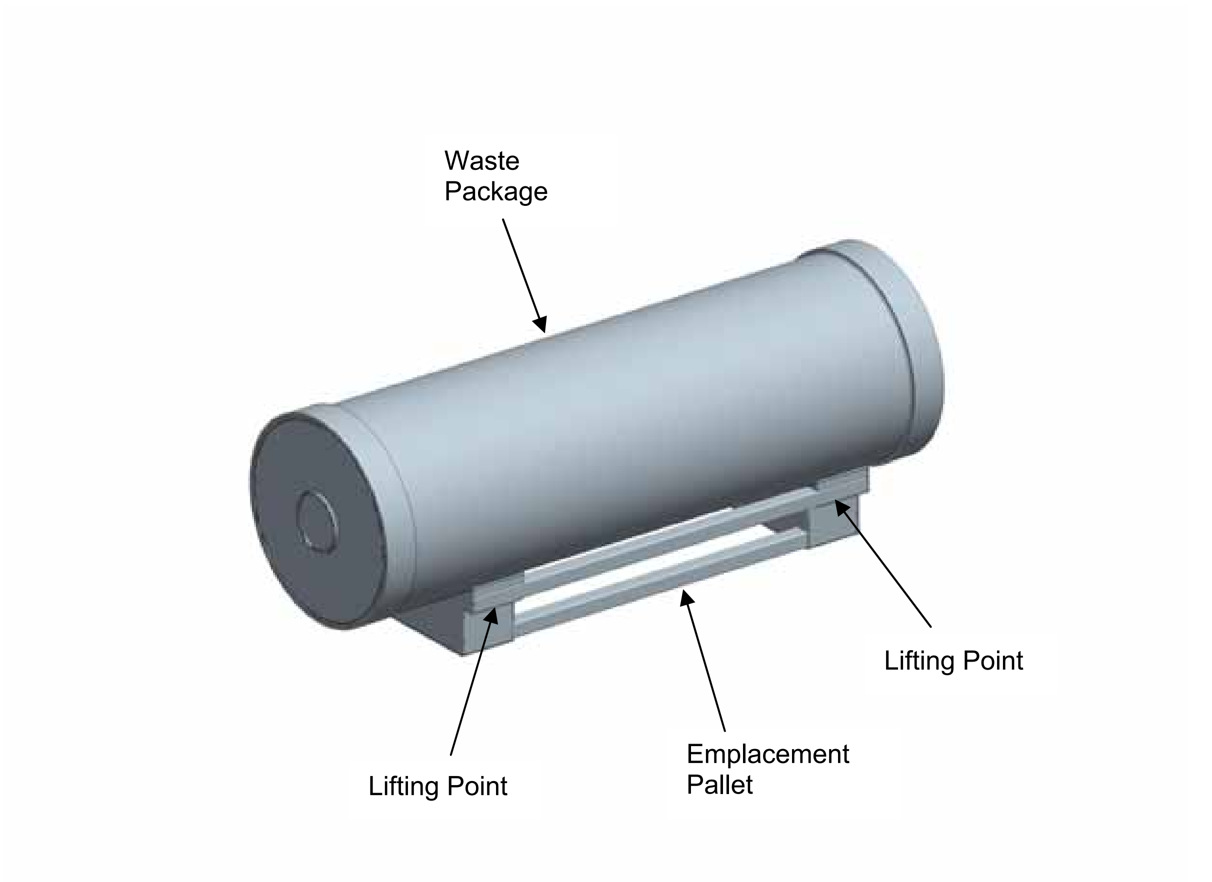

Figure 2. Waste Package on an Emplacement Pallet

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 2.2.19, Attachment III). The outer lid weld is low-plasticity burnished to reduce residual stresses (Reference 2.2.16, Section 11.2.4.6). 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 has a gap in between, both radially and axially. The axial gap is at least 10 *mm* (0.394 *in.*) (Reference 2.2.20, Section 7), and the radial gap will be at least 1 *mm* (0.0394 *in.*) (Reference 2.2.12, 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 length and diameter for the TAD waste package is determined from the overall dimensions of the TAD canisters. The cavity length of the waste packages is approximately 25.4 *mm* (1.0 *in.*) greater than the maximum length of the TAD canister (Reference 2.2.27, Section 3.1.1). The TAD waste package cavity length is 5.410 *m* (213.0 *in.*). The waste package cavity diameter is 1.720 *m* (67.7 in.), allowing 30.5 *mm* (1.2 *in.*) of diameter clearance with the TAD canister dimensions specified in Section 3.1.1 of Reference 2.2.27. Dimensions of the waste package can be found in References 2.2.48, 2.2.49 and 2.2.50 (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 2.2.40, 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 2.2.32, Section 3). The major components are:

- Structural vessel (herein referred to as the Inner Vessel (IV))
- Corrosion-resistant barrier (herein referred to as the Outer Corrosion Barrier (OCB))
- Fill gas
- Canister guide for HLW and DOE SNF canisters

Not every waste package design configuration requires canister guides; it varies according to the waste form each will hold. In the case of the TAD 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), the inner vessel material, than titanium. A structurally strong material Type 316 SS (UNS S31600) was chosen for the inner vessel 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 high 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 inner layer (inner vessel) of the waste package is to structurally 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 TAD canister 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 2.2.30, Tables 1 and 2). The main sources are listed as the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC) (Reference 2.2.5), and the ASM Metals Handbook (Reference 2.2.4). However, Sections 6.1.1.11, 6.1.1.12 and 6.1.1.13 in the same reference also indicates 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* or 68*°F*) material properties are used in the calculations.

6.1.1.6 ASME Code Position

The basis for the selection and application of the ASME 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 2.2.13). 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 2.2.33) provides specific guidance on the appropriateness of using the ASME B&PVC (Reference 2.2.5) 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&PV Code.

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 packages 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 code-compliant design and fabrication of the WPs, BSC has selected to apply Section III, Division I, Subsection NC of the ASME BPVC (Reference 2.2.5). 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) 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 code 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 TAD canister would be repackaged in a new waste package and the original waste package permanently removed from service.

6.2 DESIGN REQUIREMENTS

Design requirements include those requirements that flow to design through the BOD (Reference 2.2.16) and PDC (Reference 2.2.29), 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 2.2.16), *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17) and the PDC (Reference 2.2.29) are described in Sections 6.2.1 through 6.2.3 and are related to use of engineering codes and standards. They require the TAD waste packages to be designed in accordance with practices outlined in the ASME Pressure Vessel Code (Reference 2.2.5). The fabrication requirements are passed on to the vendor via the fabrication specification (Reference 2.2.15). Each design requirement is compared to design features, drawings, and/or calculations for the TAD waste package and then a description of how the design satisfies the requirement is given.

6.2.1 TAD Waste Package Design Criteria

Requirement 6.2.1.1: Section 5.1.1 of the PDC (Reference 2.2.29) requires that structural design of the waste package be in accordance with ANSI N14.6-1993 (Reference 2.2.11), NUREG-0612 (Reference 2.2.14) and *2001 ASME Boiler and Pressure Vessel Code* (Reference 2.2.5), Section II and III, Division I. American Society of Mechanical Engineers (ASME) Section III Code Cases identified in Regulatory Guide 1.193 (Reference 2.2.70) 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 2.2.71) has adopted Regulatory Guide 1.84 (Reference 2.2.72), 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 analyses (e.g. Reference 2.2.25) are taken from Reference 2.2.5. All structural analyses (e.g. Reference 2.2.25) follow the most appropriate method of classifying local primary membrane stress as defined by (Reference 2.2.5, Section III, Division 1, Appendix XIII, XIII-1123(j)) and Reference 2.2.70 is not used. The requirement for ANSI N14.6-1993 (Reference 2.2.11) was intended for the trunnion collar, a component now deleted from the waste package configuration. NUREG-0612 (Reference 2.2.14) 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 2.2.29) will include removal of these requirements. ASME Section III Code Cases identified in Regulatory Guide 1.193 (Reference 2.2.70) are not used. Therefore, Requirement 6.2.1.1 is expected to be satisfied.

Requirement 6.2.1.2: Section 5.1.2 of the PDC (Reference 2.2.29) requires that metallurgical design of the waste package be in accordance with *2001 ASME Boiler and Pressure Vessel Code* (Reference 2.2.5), Section III, Division I, Subsection NC.

Satisfaction of Requirement 6.2.1.2: Material properties (tensile strength, yield strength, maximum allowable stress) that are used in structural analyses (e.g. Reference 2.2.25) are taken from Reference 2.2.5. ASME Section III Code Cases identified in Regulatory Guide 1.193 (Reference 2.2.70) are not used. Therefore, Requirement 6.2.1.2 is satisfied.

Requirement 6.2.1.3: Section 11.2.1.1 of the BOD (Reference 2.2.16) requires that the DOE and commercial waste package system (TAD WP) shall be designed to be capable of isolating commercial SNF, DOE SNF, vitrified DHLW, vitrified commercial HLW, and IPWF at the following annual rates:

1. In the first full year of operation, the repository shall:
    a. Accept and receive 400 *MTHM* commercial SNF and HLW
    b. Accept and receive 66 DOE SNF canisters and 193 DHLW canisters.
2. During years two through four of operations, the repository shall:
    a. Accept and receive at least 3,800 *MTHM* commercial SNF and HLW
    b. Accept and receive at least 257 DOE SNF canisters and 1,143 DHLW canisters.
3. On year five, at the start of full-scale, steady-state operations, the repository shall:
    a. Accept and receive 3,000 *MTHM* commercial SNF and HLW annually
    b. Accept and receive 179 DOE SNF canisters and 763 DHLW canisters annually.

<u>Satisfaction of Requirement 6.2.1.3</u>: Tables 1 and 5 of Reference 2.2.66 use emplacement rates equal to or higher than those required above to represent nominal emplacement rates. This shows that it is possible to handle the amounts of nuclear material required. Therefore, Requirement 6.2.1.3 is satisfied.

Requirement 6.2.1.4: Section 11.2.1.2 of the BOD (Reference 2.2.16) requires that the TAD canisters will be as specified by the *Transportation, Aging, and Disposal Canister System Performance Specification* (Reference 2.2.27).

<u>Satisfaction of Requirement 6.2.1.4</u>: The TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50.) show a cavity height of 213.00 *in.* (5410.2 *mm*) respectively. The inner vessel inside diameter for the TAD waste package is 67.70 *in.* (1719.6 *mm*). These dimensions are in compliance with those shown in Section 3.1.1 of Reference 2.2.27 for the TAD canister. Therefore, Requirement 6.2.1.4 is satisfied.

Requirement 6.2.1.5: Section 11.2.1.3 of the BOD (Reference 2.2.16) requires that the DOE and commercial waste package design shall be capable of operating over a range of thermal conditions and, in conjunction with the Subsurface Facility, shall be capable of allowing a maximum emplacement drift line load (over any seven waste package segment) (linear thermal power) of up to 2.0 kW/m.

The waste package emplacement shall be within an envelope such that the emplacement of waste packages does not exceed the other relevant thermal limits of mid-pillar temperature, drift wall temperature, waste package temperature, and cladding temperature. The calculated Thermal Energy Density of any seven adjacent as-emplaced waste packages shall not exceed 96°C at the mid-pillar calculated using mean host-rock thermal properties and representative saturation levels for wet and dry conditions.

<u>Satisfaction of Requirement 6.2.1.5</u>: Reference 2.2.66 demonstrates that the estimated limiting waste stream can be emplaced at a line-load of 2.0 *kW/m*. Operational requirements are expected to ensure that the 2.0 *kW/m* line-load is not exceeded. TAD waste packages are capable of operating over a range (i.e. meet thermal design criteria) of thermal conditions up to 2.0 *kW/m* (Reference 2.2.34, Section 7.12.2). Reference 2.2.35 (Table 22) gives a peak drift wall temperature of 195.3°*C* for a thermally misloaded drift segment that is expected to bound all other possible seven-package drift segments. This is compliant with the 200°*C* drift wall temperature limit given in Reference 2.2.16, Section 22.2.1.3. Reference 2.2.35 (Table 19) gives a peak mid-pillar temperature of 97.7°*C* for an "as-loaded" estimated limiting seven-package drift segment. Though this result exceeds the 96°*C* mid-pillar temperature limit given in Reference 2.2.59 (Table 1, item # 05-03), it uses only a small part of the 10°*C* margin provided by vaporization and movement of water in the rock indicated by Reference 2.2.73, Section 6.2. A model that fully accounts for hydrological effects is expected to give a mid-pillar temperature that is compliant with the 96°*C* limit. Therefore, Requirement 6.2.1.4 is satisfied.

Requirement 6.2.1.6: Section 11.2.1.5 of the BOD (Reference 2.2.16) requires that the commercial SNF waste packages that provide for the disposal of TAD canisters shall be designed and analyzed recognizing that the TAD canisters will incorporate ASTM A887-89, *Standard Specification for Borated Stainless Steel Plate, Sheet, and Strip for Nuclear Application*

(Reference 2.2.67), Type 304B4 (boron content of 1.1 wt % to 1.2 wt %), Grade A (UNS S30464) into the TAD design as the neutron absorber material. Waste packages containing CSNF shall be designed to manage criticality safety. The neutron absorber plates in commercial waste packages shall be at least 0.433 *inches* (11 *mm* thick) thick and contain between 1.1 to 1.2 wt % borated stainless steel manufactured through powder metallurgy. Multiple plates may be used if corrosion assumptions (250 *nm/year*) are taken into account for all surfaces such that 6 *mm* remains after 10,000 years.

Satisfaction of Requirement 6.2.1.6: The TAD waste package holds the TAD canister only and contains no neutron absorber plates for criticality control. The TAD canister is under development under the direction of the TAD canister subcontractor and issues related to criticality will be addressed by the subcontractor at the time of design. Therefore, Requirement 6.2.1.6 is expected to be satisfied.

Requirement 6.2.1.7: Section 11.2.2.1 of the BOD (Reference 2.2.16) requires that the maximum capacity of the TAD canisters shall be 21 Pressurized Water Reactor (PWR) assemblies or 44 Boiling Water Reactor (BWR) assemblies.

Satisfaction of Requirement 6.2.1.7: The TAD waste package holds one TAD canister. The TAD canister is under development under the direction of the TAD canister subcontractor and this requirement will be addressed by the subcontractor at the time of design. Therefore, Requirement 6.2.1.7 is expected to be satisfied by the final design of the TAD canister.

Requirement 6.2.1.8: Section 11.2.2.2 of the BOD (Reference 2.2.16) requires that the TAD waste package design shall comply with the agreements established under the Integrated Interface Control Document (IICD) (Reference 2.2.69) to ensure compatibility of DOE owned SNF and HLW waste forms with repository surface facility and waste package interfaces, including canister interfaces.

Satisfaction of Requirement 6.2.1.8: The TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50.) show a cavity height of 213.00 *in.* (5410.2 *mm*) respectively. The inner vessel inside diameter for the TAD waste package is 67.70 *in.* (1719.6 *mm*). These dimensions are in compliance with those shown in Figure C-19 of the IICD (Reference 2.2.69) for the naval long waste package (as it has the same dimensions) of the IICD. Therefore, Requirement 6.2.1.8 is satisfied.

Requirement 6.2.1.9: Section 11.2.2.3 of the BOD (Reference 2.2.16) requires that the commercial SNF waste package shall be designed to the TAD canister dimensions in accordance with the *Transportation, Aging and Disposal Canister System Performance Specification* (Reference 2.2.27).

Satisfaction of Requirement 6.2.1.9: The TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50.) show a cavity height of 213.00 *in.* (5410.2 *mm*) respectively. The inner vessel inside diameter for the TAD waste package is 67.70 *in.* (1719.6 *mm*). These dimensions are in compliance with those shown in Section 3.1.1 of Reference 2.2.27 for the TAD canister. Therefore, Requirement 6.2.1.9 is satisfied.

Requirement 6.2.1.10: Section 11.2.2.4 of the BOD (Reference 2.2.16) and Section 5.1.3 of the PDC (Reference 2.2.29) requires that the sealed waste package environment shall provide conditions that maintain waste form characteristics that restrict transport of radionuclides. The waste package shall meet the following temperature criteria for all zirconium clad commercial fuel:

• In Surface facilities, normal conditions - 400°*C*

• For off-normal conditions - 570°*C*

Satisfaction of Requirement 6.2.1.10: Thermal evaluation of the TAD waste package in the CRCF is reported in Reference 2.2.57. Cladding temperature remained below 400 *C* for waste package thermal powers below 23 *kW* for normal conditions (Reference 2.2.57, Table 51), and below 570 *C* for waste package thermal powers up to 30 *kW* for off-normal conditions (Reference 2.2.57, Table 95). Therefore, Requirement 6.2.1.10 is satisfied.

Requirement 6.2.1.11: Section 11.2.2.5 of the BOD (Reference 2.2.16) requires that the commercial waste package design shall be capable of allowing the disposing of the waste forms with a maximum thermal power of up to 18.0 kW.

The waste package emplacement shall be within an envelope such that the emplacement of waste packages does not exceed the other relevant thermal limits of mid-pillar temperature, drift wall temperature, waste package temperature, and cladding temperature. The calculated Thermal Energy Density of any seven adjacent as-emplaced waste packages shall not exceed 96°C at the mid-pillar calculated using mean host-rock thermal properties and representative saturation levels for wet and dry conditions.

Satisfaction of Requirement 6.2.1.11: TAD waste packages are capable of operating over a range of thermal conditions up to 18 *kW* (Reference 2.2.34, Section 7.12.2). Reference 2.2.35 (Table 22) gives a peak drift wall temperature of 195.3°*C* for a thermally misloaded drift segment that is expected to bound all other possible seven-package drift segments. This is compliant with the 200°*C* drift wall temperature limit given in Reference 2.2.16, Section 22.2.1.3. Reference 2.2.35 (Table 19) gives a peak mid-pillar temperature of 97.7°*C* for an "as-loaded" estimated limiting seven-package drift segment. Though this result exceeds the 96°*C* mid-pillar temperature limit given in Reference 2.2.59 (Table 1, item # 05-03), it uses only a small part of the 10°*C* margin provided by vaporization and movement of water in the rock indicated by Reference 2.2.73, Section 6.2. A model that fully accounts for hydrological effects is expected to give a mid-pillar temperature that is compliant with the 96°*C* limit. Therefore, Requirement 6.2.1.4 is satisfied.

Requirement 6.2.1.12: Section 11.2.2.6 of the BOD (Reference 2.2.16) requires that the TAD 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.

Satisfaction of Requirement 6.2.1.12: 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 2.2.21) showed acceptable stress levels under lifting with in-drift temperatures and reduced material thickness due to corrosion. Therefore, Requirement 6.2.1.12 is satisfied.

Requirement 6.2.1.13: Section 11.2.2.9 of the BOD (Reference 2.2.16) 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.*

Satisfaction of Requirement 6.2.1.13: The *Waste Package Fabrication Specification* (Reference 2.2.15, 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 2.2.15) 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 6.2.1.13 is satisfied.

Requirement 6.2.1.14: Section 11.2.2.10 of the BOD (Reference 2.2.16) requires that the TAD waste package inner vessel shall have one lid and be made of stainless steel Type 316 (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 TAD waste packages. For post closure mechanical calculations and analysis, a corrosion allowance of at least 2 *mm* 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 2.2.44) 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%

Satisfaction of Requirement 6.2.1.14: The TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50) 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. The *Postclosure Modeling and Analyses Design Parameters* report (Reference 2.2.59) restricts the range of alloying constituents in Alloy 22 from that shown in the applicable material specification (Reference 2.2.44). This was part of a larger group of restrictions on design as approved by the Technical Management Review Board (Reference 2.2.58), 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 2.1.3), supplemented by the guidance in the discipline-specific execution plan (Reference 2.2.22). It should be noted that the restrictions are at the upper 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 2.2.44) often does not meet the minimum material properties required by the material specification (Reference 2.2.60, Section 5.7.1). Therefore, the material properties of Reference 2.2.60 are of a higher standard and the restrictions listed in a) through d) are unlikely to have any practical consequences to waste package design or fabrication. Therefore, Requirement 6.2.1.14 is expected to be satisfied.

Requirement 6.2.1.15: Section 11.2.2.11 of the BOD (Reference 2.2.16) requires that the waste packages shall be designed to accommodate canisters designed to support their own weight and that of their contents for multiple vertical lifts and horizontal translations while suspended from above via their lifting features.

Satisfaction of Requirement 6.2.1.15: The TAD waste package holds one TAD canister and recognizes that it accommodates a TAD canister that is designed to support its own weight. The TAD canister is under development under the direction of the TAD canister subcontractor and this requirement will be addressed by the subcontractor at the time of design. Therefore, Requirement 6.2.1.15 is expected to be satisfied by the final design of the TAD canister.

Requirement 6.2.1.16: Section 11.2.2.18 of the BOD (Reference 2.2.16) requires that the Cladding temperature for DOE SNF of commercial origin placed in disposable multi-element canisters shall not exceed:

1. 350°C for zirconium alloy-clad assemblies (to prevent damage from creep or hydride reorientation).
2. 400°C for stainless steel-clad assemblies.

Commercial waste packages shall be designed so that CSNF cladding shall not exceed a maximum temperature of 350*°C* upon emplacement (to prevent damage from creep or hydride reorientation). For off-normal and accident conditions, the maximum cladding temperature shall not exceed 570*°C*.

Satisfaction of Requirement 6.2.1.16: Table 24 of Reference 2.2.35 shows a maximum temperature at the TAD WP core of 394*°C* (741*°F*), which occurs during preclosure with a 30 day loss of ventilation off-normal event which is well below the 570*°C* (1058*°F*) limit. Table 24 of the same reference shows a maximum core temperature of 312°*C* (594°*F*) during normal operation. Table 24 of Reference 2.2.35 gives a maximum TAD core temperature of 237°*C* (459°*F*) during postclosure. Both preclosure normal operating and postclosure TAD core temperatures are well below the 350°*C* (662°*F*) cladding limit. Therefore, Requirement 6.2.1.16 is satisfied.

Requirement 6.2.1.17: Section 11.2.2.22 of the BOD (Reference 2.2.16) requires that each waste package configuration shall be loaded with one of the following combinations (short loading is allowed):

(a) 2 HLW glass canisters and 2 N Reactor MCOs,
(b) 5 HLW glass canisters (including up to 1 LaBS glass canister) and 1 DSNF canister,
(c) 1 24 *in*. DSNF canister and 4 HLW canisters (center location empty),
(d) Or a single CSNF TAD canister

Satisfaction of Requirement 6.2.1.17: The TAD waste package holds one TAD canister. The TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50.) show a cavity height of 213.00 *in.* (5410.2 *mm*) respectively. The inner vessel inside diameter for the TAD waste package is 67.70 *in.* (1719.6 *mm*). These dimensions are in compliance with those shown in Section 3.1.1 of Reference 2.2.27 for the TAD canister (Note - this design report is limited to the TAD WP design). Therefore, Requirement 6.2.1.17 (d) is satisfied.

Requirement 6.2.1.18: Section 11.2.2.24 of the BOD (Reference 2.2.16) 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 6.2.1.18: The thermal calculation (Reference 2.2.34, Section 7.12.2) showed that the waste package surface temperature stayed well below 300°*C* for the first 500 years and below 200°*C* for the next 9,500 years in cases analyzed. Therefore, Requirement 6.2.1.18 is satisfied. However, the fundamental responsibility for demonstrating postclosure thermal performance is the responsibility of the Lead Laboratory.

Requirement 6.2.1.19: Section 11.2.3.1.1 of the BOD (Reference 2.2.16) and Section A.7.1 of the NSDB-LA (Reference 2.2.65) require that the waste package in each waste handling building 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 6.2.1.19: Satisfaction of all the TAD waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17) are addressed in Section 6.2.3. The Preclosure Safety Analyses (PCSA) group is responsible for determining the TAD waste package mean frequency of failure for all credible event sequences. Requirement 6.2.1.19 is expected to be satisfied upon completion of the final design.

Requirement 6.2.1.20: Section 11.2.3.1.4 of the BOD (Reference 2.2.16) and Section A.7.2 of the NSDB-LA (Reference 2.2.65) require that the TAD 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 6.2.1.20: Satisfaction of all the TAD waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17) are addressed in Section 6.2.3. The PCSA group is responsible for determining the TAD waste package mean frequency of failure for all credible event sequences. Requirement 6.2.1.20 is expected to be satisfied upon PCSA's review and the completion of the final design.

Requirement 6.2.1.21: Section 11.2.3.1.6 of the BOD (Reference 2.2.16) and Section A.7.3 of the NSDB-LA (Reference 2.2.65) require that a 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.

Satisfaction of Requirement 6.2.1.21: Satisfaction of all the TAD waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17) are addressed in Section 6.2.3. The PCSA group is responsible for determining the TAD waste package mean frequency of failure for all credible event sequences. Requirement 6.2.1.21 is expected to be satisfied upon PCSA's review and the completion of the final design.

Requirement 6.2.1.22: Section 11.2.3.1.11 of the BOD (Reference 2.2.16) 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 6.2.1.22: 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. Requirement 6.2.1.22 is expected to be satisfied upon the completion of the final design.

Requirement 6.2.1.23: Sections 11.2.3.1.12 and 29.2.1.3 of the BOD (Reference 2.2.16) requires that the TAD 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 6.2.1.23: This requirement is part of the Waste Package Closure System which falls under the responsibility of the Mechanical Handling Closure and Loadout Group. Requirement 6.2.1.23 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.1.24: Section 11.2.3.2.2 of the BOD (Reference 2.2.16) and Section A.7.4 of the NSDB-LA (Reference 2.2.65) require that mean frequency of a waste package breach outside of a facility nuclear confinement Heating Ventilation and Air Conditioning (HVAC) area shall be less than 1E-04 over the preclosure period.

Satisfaction of Requirement 6.2.1.24: Satisfaction of all the TAD waste package design requirements based on credible preclosure event sequences as defined in the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17) are addressed in Section 6.2.3. The PCSA group is responsible for determining the TAD waste package mean frequency of failure for all credible event sequences. Requirement 6.2.1.24 is expected to be satisfied upon PCSA's review and the completion of the final design.

Requirement 6.2.1.25: Section 11.2.4.3 of the BOD (Reference 2.2.16) 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 2.2.26)
- *IED Waste Package Characteristics - 1999 Design Basis Waste Stream [Sheet 1 of 1]*, 800-IED-WIS0-01401-000 (Reference 2.2.51)
- *IED Waste Package Decay Heat Generation [Sheet 1 of 1]*, 800-IED-WIS0-00701-000 (Reference 2.2.37)
- *IED Waste Package Decay Heat Generation Design Basis and Thermal Information*, 800-IED-WIS0-00801-000 (Reference 2.2.38)
- *IED Seismic Data*, 800-IED-MGR0-00701-000 (Reference 2.2.36)
- *IED Waste Package Radiation Characteristics [Sheet 1 of 1]*, 800-IED-WIS0-01301-000 (Reference 2.2.39)
- *IED Waste Package Weld Characteristics [Sheet 1 of 1]*, 800-IED-WIS0-01001-000 (Reference 2.2.52)
- *IED Emplacement Drift Configuration and Environment,* 800-IED-MGR0-00501-000 (Reference 2.2.53)
- *IED Emplacement Drift Invert,* 800-IED-MGR0-00601-000 (Reference 2.2.54)
- *IED Interlocking Drip Shield,* 800-IED-SSE0-00101-000 (Reference 2.2.55).

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 TAD 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 6.2.1.25: All characteristics and interfaces of the waste packages are maintained in all the above mentioned IEDs (References 2.2.26, 2.2.51, 2.2.37, 2.2.38, 2.2.36, 2.2.39, 2.2.52, 2.2.53, 2.2.54, 2.2.55). The Emplacement Drift Configuration and Environment IED (Reference 2.2.53) contains the subsurface temperature and humidity data as provided by the Lead Laboratory. The Waste Package Configuration IED (Reference 2.2.26) contains the waste package component masses, quantities, dimensions, materials and weld volumes as provided by the BSC Engineering. The Waste Package Radiation Characteristics IED (Reference 2.2.39) 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 2.2.37 and 2.2.38) contain the design waste package decay heat data as provided by the Lead Laboratory. Therefore, Requirement 6.2.1.25 is satisfied.

Requirement 6.2.1.26: Section 11.2.4.4 of the BOD (Reference 2.2.16) 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 6.2.1.26: The TAD waste package configuration drawings (References 2.2.48, 2.2.49 and 2.2.50) 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 6.2.1.26 is satisfied.

Requirement 6.2.1.27: Section 11.2.4.5 of the BOD (Reference 2.2.16) 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 6.2.1.27: Since the internal design of the TAD canister is unknown a naval canister is used as a reasonable surrogate. The maximum calculated WP internal pressure is 1.01 *MPa* (146 *psi*) at an elevated temperature of 400*°C* (752*°F*) (Reference 2.2.47, Table 1). This value is considerably less than the maximum allowable internal pressure of 1.22 *MPa* (177 *psi*) at 400*°C* (752*°F*) for the TAD WP (Reference 2.2.46, Table 6-1). Therefore, Requirement 6.2.1.27 is satisfied.

Requirement 6.2.1.28: Section 11.2.4.6 of the BOD (Reference 2.2.16) 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 *in.* 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 6.2.1.28: 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. Requirement 6.2.1.28 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.1.29: Section 11.2.4.7 of the BOD (Reference 2.2.16) 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 6.2.1.29: Requirements "a" and "b" are controlled via the *Waste Package Fabrication Specification* (Reference 2.2.15, Section 5.6). The thermal calculation (Reference 2.2.34, Section 7.12.2) showed that the waste package surface temperature stayed well below 300°*C* for the first 500 years and below 200°*C* for the next 9,500 years in cases analyzed, which satisfies requirement "c" (Note: postclosure performance is the responsibility of the Lead Laboratory). Requirement 6.2.1.29 is expected to be satisfied upon the Mechanical Handling review and the completion of the final design.

Requirement 6.2.1.30: Section 11.2.4.8 of the BOD (Reference 2.2.16) requires that the TAD 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 6.2.1.30: Mechanical Handling is responsible for this requirement as defined in the BOD (Reference 2.2.16, Section 13.2.3.1.37). Requirement 6.2.1.30 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.1.31: Section 11.2.4.9 of the BOD (Reference 2.2.16) requires that the waste package surface finish shall be specified to be at least 125 *µinch* roughness as defined in ASME B46.1-2002 (Reference 2.2.6).

Satisfaction of Requirement 6.2.1.31: The *Waste Package Fabrication Specification* (Reference 2.2.15, 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 6.2.1.31 is satisfied.

Requirement 6.2.1.32: Section 11.2.4.10 of the BOD (Reference 2.2.16) requires that the median probability of defects for the manufacture, handling, and emplacement of the 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.

Satisfaction of Requirement 6.2.1.32: The pertinent fabrication requirements are controlled via the *Waste Package Fabrication Specification* (Reference 2.2.15, Sections 3 and 5). The Science document (Reference 2.2.23, Section 6.2.15) concludes that the implementation of those fabrication requirements achieve this reliability. Performance of the waste package in the postclosure will be demonstrated by the lead laboratory. Requirement 6.2.1.32 is expected to be satisfied upon Lead Lab's review and the completion of the final design.

Requirement 6.2.1.33: Section 11.2.4.11 of the BOD (Reference 2.2.16) 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 6.2.1.33: All fabrication, handling and transport related requirements are controlled by the fabrication specification (Reference 2.2.15). Mechanical Handling is responsible for compliance to the remainder of this requirement which is defined in the BOD (Reference 2.2.16, Section 13.2.3.1.35). Requirement 6.2.1.33 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.1.34: Section 11.2.4.12 of the BOD (Reference 2.2.16) requires that 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 6.2.1.34: 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. Requirement 6.2.1.34 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.1.35: Section 11.2.4.13 of the BOD (Reference 2.2.16) requires that 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 6.2.1.35: 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. Requirement 6.2.1.35 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.1.36: Section 11.2.4.14 of the BOD (Reference 2.2.16) requires that the waste package containing the TAD canister with 21-PWR fuel assemblies shall represent the worst-case dose rate (80 *GWd/MTU* burnup, 5% U-235 enrichment and 5 years decay).

Satisfaction of Requirement 6.2.1.36: This is a requirement that must be met at the commercial facility where the TAD canister is loaded. Requirement 6.2.1.36 is expected to be satisfied.

Requirement 6.2.1.37: Section 8.2.1.23 of the BOD (Reference 2.2.16) 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 6.2.1.37: Table 7-2 of Reference 2.2.21 shows that the maximum tensile stresses for 21*ºC* (70*ºF*) and 250*ºC* (482*ºF*) are located in the OCB of the WP with values of 56.8 *MPa*, which are significantly less than the 257 *MPa* limit. Therefore, Requirement 6.2.1.37 is satisfied.

6.2.2 Waste Package Fabrication Criteria

Requirement 6.2.2.1: Section 5.2 of the PDC (Reference 2.2.29) states that waste packages shall be fabricated in accordance with the following:

ANSI/AWS A2.4-98 (Reference 2.2.3) provides the standard symbols for the welding, brazing, and nondestructive examination of nuclear components.

ANSI/AWS A5.32/A5.32M-97 (Reference 2.2.2) provides the specifications of welding shielding gases used in the welding processes of nuclear components.

ANSI N14.6-1993 (Reference 2.2.11) provides definitions for special lifting devices for shipping containers weighing 10,000 pounds or more.

ASME 2001 (Reference 2.2.5), Section II, provides the properties for the materials used in the design and fabrication of Class NF nuclear components.

ASME 2001 (Reference 2.2.5), Section III, Subsection NCA, provides the general requirements for the design and fabrication of nuclear power plant components.

ASME 2001 (Reference 2.2.5), Section III, Division 1, Subsection NB, NC, and NF.

ASME 2001 (Reference 2.2.5), Section V, provides the requirements for the nondestructive examination of nuclear components.

ASME 2001 (Reference 2.2.5), Section IX, provides welding and brazing qualifications for the welding of nuclear components.

ASME B46.1-2002 (Reference 2.2.6) provides surface texture (surface roughness, waviness, and lay) requirements for fabrication of nuclear components.

ASME Y14.36M-1996 (Reference 2.2.9) provides the requirements for surface texture symbols used in the designing of nuclear components.

ASME Y14.38-1999 (Reference 2.2.10) provides the requirements for abbreviations and acronyms used in the designing of nuclear components.

ASME Y14.5M-1994 (Reference 2.2.8) provides the requirements for dimensioning and tolerancing of drawing.

ASME Section III Code Cases that shall not be used are those listed in Regulatory Guide 1.193 (Reference 2.2.70).

Cleaning, packaging, shipping, receiving, storage, and handling of waste packages shall be in accordance with ASME NQA-1-2000, Subparts 2.1 and 2.2 (Reference 2.2.7). 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 2.2.15 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 fabrication specification (Reference 2.2.15) but updates are expected as the specification is a living document and the standards refer to common definitions. All structural analyses (e.g. Reference 2.2.25) follow the most appropriate method of classifying local primary membrane stress as defined by (Reference 2.2.5, Section III, Division 1, Appendix XIII, XIII-1123(j)) and Reference 2.2.70 is not used. The requirement for ANSI N14.6-1993 (Reference 2.2.11) was intended for the trunnion collar, a component now deleted from the waste package configuration. Updates to the PDC (Reference 2.2.29) will include removal of this requirement. ASME Section III Code Cases identified in Regulatory Guide 1.193 (Reference 2.2.70) are not used. Therefore, Requirement 6.2.2.1 is expected to be satisfied as final design is completed.

Requirement 6.2.2.2: Table 1, Number 03-12 of Reference 2.2.58 requires that the waste package outer corrosion barrier cylinder shall be fabricated from no more than 3 sections with longitudinal welds offset. The waste package will be inspected and evaluated per applicable criteria, e.g., Parameter 03-18, at the fabricator location and upon receipt at the repository location.

Satisfaction of Requirement 6.2.2.2: Figure 3 shows one possible approach to the waste package fabrication process. Therefore, Requirement 6.2.2.2 is expected to be satisfied as final design is completed.

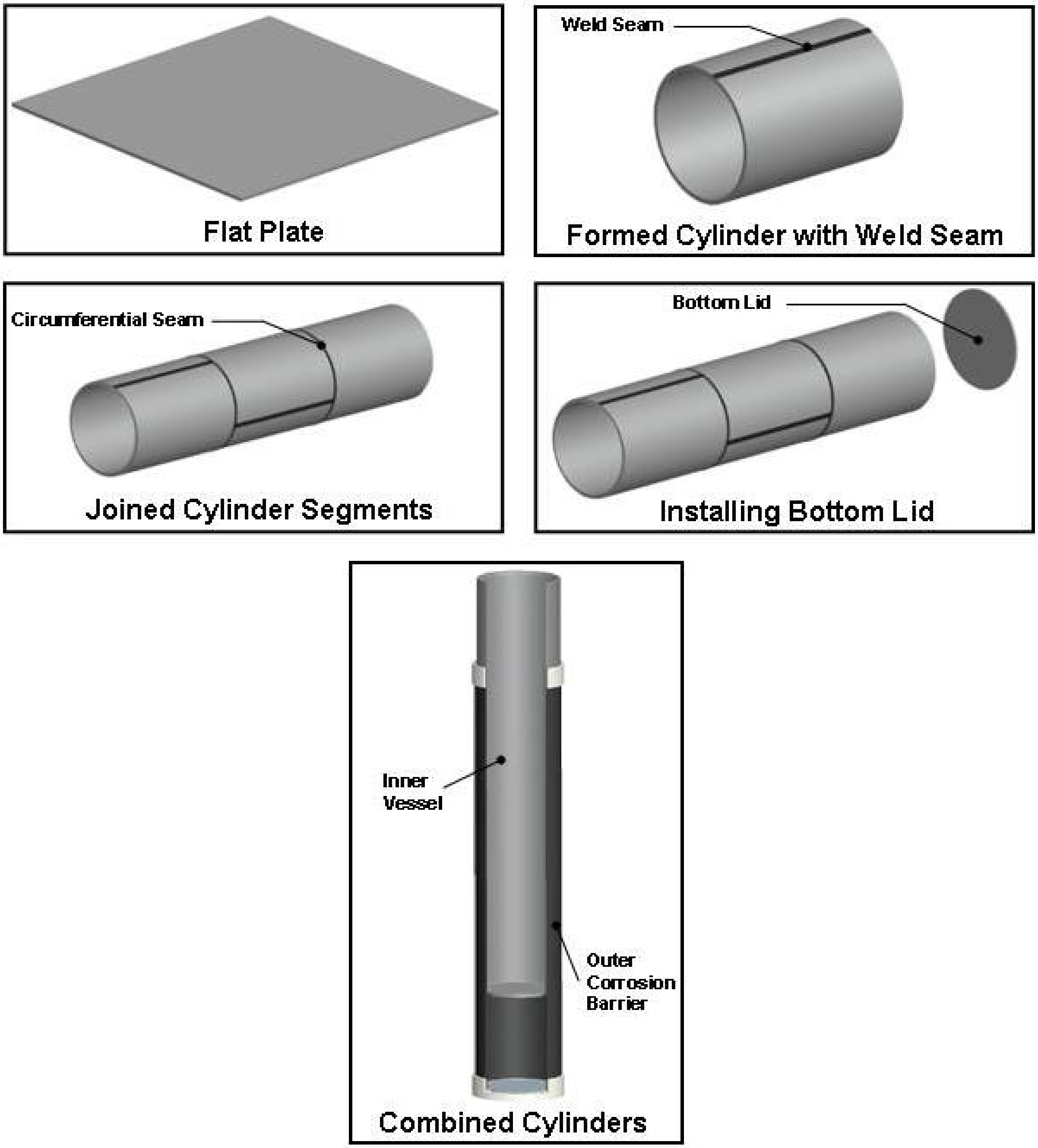

Figure 3. Fabrication of Waste Packages

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 2.2.17). The requirements in this study are used as a supplement since the latest revision of the BOD (Reference 2.2.16) does not sufficiently describe the credible event sequences for the TAD waste package (Assumptions 3.1.2 and 3.1.3).

Requirement 6.2.3.1: Section 4.1.2 of Reference 2.2.17 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 2.2.16, Section 13.2.3.1.21). Requirement 6.2.3.1 is expected to be satisfied upon Mechanical Handling's review and the completion of the final design.

Requirement 6.2.3.2: Section 4.1.6 of Reference 2.2.17 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 limit is within durations allowed by Licensing specifications.

Satisfaction of Requirement 6.2.3.2: Thermal evaluation of the TAD waste package in the CRCF is reported in Reference 2.2.57. Table 95 of Reference 2.2.57 shows that for the total loss of ventilation scenarios all temperatures remain far below the limits of cladding and waste package surface temperature. Therefore, Requirement 6.2.1.5 is satisfied.

Requirement 6.2.3.3: Section 4.1.7 of Reference 2.2.17 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 limit is prevented. Licensing specifications for the duration of the off-normal cladding temperatures must be determined.

Satisfaction of Requirement 6.2.3.3: Credible fires are expected to be only a few minutes with only a small part of the waste package exposed to flame. 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* (852 *F*) in 30 minutes and that clad remains below 570 *C* (1058 *F*) (Reference 2.2.28, Figure 2). Fires in any room where the waste package transfer trolley is located are expected to be far less severe, both in duration and severity. Licensing specifications for the duration of the off-normal cladding temperatures must be determined through further PCSA analyses. Therefore, Requirement 6.2.3.3 is satisfied.

Requirement 6.2.3.4: Section 4.3.1 of Reference 2.2.17 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 2.2.25, Table 7-3 and Reference 2.2.41, Table 7-11) showed that the element wall-averaged (EWA) stress intensity (SI) stayed below the project tiered second condition acceptance criterion of 0.77 (Reference 2.2.30, 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 2.2.17 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 2.2.25, Table 7-3) lists the ratios of EWA SI to true tensile strength. Using the analyzed velocities and resulting EWA SI ratios for runs 2B, 4, and 5, we can determine (using the polynomial equation generated in Excel per Figure 4 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 2.2.30, 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*). Requirement 6.2.3.5 is expected to be satisfied upon PCSA's review and the completion of the final design.

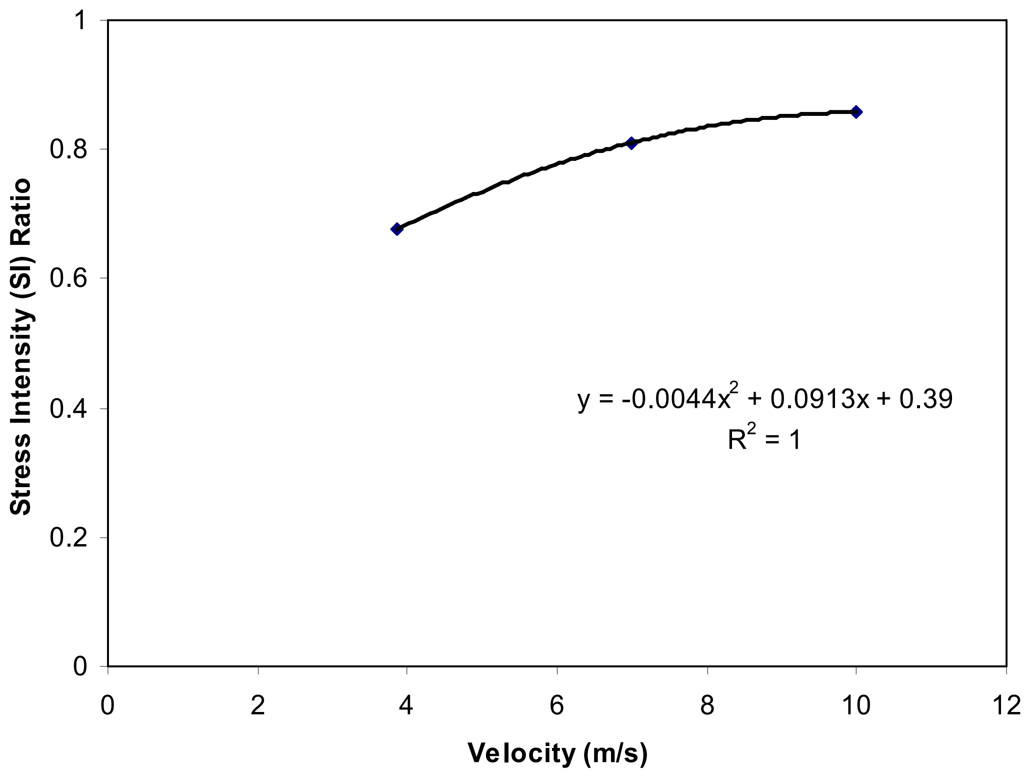

Figure 4. SI Ratio versus Velocity Trend

Requirement 6.2.3.6: Section 4.3.6 of Reference 2.2.17 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: Analysis of this event sequence (Reference 2.2.42, Table 7-2) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.30, Section 7.1.4) for both cases analyzed, meaning that the effects of the maximum stresses in the OCB due to a TEV collision do not cause failure. Using Assumption 3.2.1, we can conservatively conclude that the EWA SI ratio for the TAD waste package would be less. Therefore, Requirement 6.2.3.6 is satisfied.

Requirement 6.2.3.7: Section 4.3.8 of Reference 2.2.17 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 TEV collision with an emplaced WP analysis (Reference 2.2.42, Table 7-2) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.30, Section 7.1.4) for both cases analyzed, meaning that the effects of the maximum stresses in the OCB due to a TEV collision do not cause failure. Since the dragging of the emplaced waste package is bounded by the TEV collision (Assumptions 3.2.1 and 3.2.2), we can conservatively conclude that the EWA SI ratio for the OCB of a TAD waste package would remain below failure criteria levels (Reference 2.2.30, Section 7.1.4). Therefore, Requirement 6.2.3.7 is satisfied.

Requirement 6.2.3.8: Section 4.3.11 of Reference 2.2.17 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 2.2.24, Table 36) showed that the TAD waste package temperature inside the TEV remained around 198 *C* (388 *F*) without ventilation, using a heat load of 18 *kW* and 50 *C* (122 *F*) ambient temperature and 490 *C* (914 *F*) cladding temperature (Reference 2.2.24, Table 36) for a 30 *kW* TAD WP. The WP temperature is below the 300 *C* (572 *F*) TAD waste package temperature limit (Reference 2.2.16, Section 11.2.2.24) and the cladding is well below the 570 *C* off-normal cladding temperature limit (see Requirement 6.2.1.10). Further licensing specifications for the duration of the off-normal cladding temperatures must be determined through PCSA analyses. Therefore, Requirement 6.2.3.8 is satisfied.

Requirement 6.2.3.9: Section 4.3.12 of Reference 2.2.17 requires that the WP will 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 limit is prevented. Licensing specifications for the duration of the off-normal cladding temperatures must be determined.

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 2.2.28), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.24, Table 36) showed that the TAD WP temperature inside the TEV remained around 198 *C* (388 *F*) without ventilation, using a heat load of 18 *kW* and 50 *C* (122 *F*) ambient temperature. This is below the 300 *C* (572 *F*) TAD WP temperature limit (Reference 2.2.16, Section 11.2.2.24). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.16, Section 11.2.2.24) 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. Licensing specifications for the duration of the off-normal cladding temperatures must be determined through further PCSA analyses. Therefore, Requirement 6.2.3.9 is expected to be satisfied.

Requirement 6.2.3.10: Section 4.3.13 of Reference 2.2.17 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 limit is prevented. Licensing specifications for the duration of the off-normal cladding temperatures must be determined.

Satisfaction of Requirement 6.2.3.10: The steady-state analysis (Reference 2.2.24, Table 40) showed that the TAD waste package temperature inside the TEV remained around 197 *C* (387 *F*) without ventilation, using a heat load of 18 *kW*, 46.7 *C* (116 *F*) maximum ambient outdoor temperature and direct solar energy. This is below the 300 *C* (572 *F*) TAD waste package temperature limit (Reference 2.2.16, Section 11.2.2.24). Reference 2.2.24, Table 43, also shows the cladding temperature remained around 341 *C* (646 *F*), well below the 570 *C* (1058 *F*) off-normal temperature limit. Further licensing specifications for the duration of the off-normal cladding temperatures must be determined through PCSA analyses. Therefore, Requirement 6.2.3.10 is satisfied.

Requirement 6.2.3.11: Section 4.3.14 of Reference 2.2.17 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 limit 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 2.2.28), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.24, Table 36) showed that the TAD WP temperature inside the TEV remained around 198 *C* (388 *F*) without ventilation, using a heat load of 18 *kW* and 50 *C* (122 *F*) ambient temperature. This is below the 300 *C* (572 *F*) TAD WP temperature limit (Reference 2.2.16, Section 11.2.2.24). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.16, Section 11.2.2.24) 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. Therefore, Requirement 6.2.3.11 is expected to be satisfied.

Requirement 6.2.3.12: Section 4.3.15 of Reference 2.2.17 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. Licensing specifications for the duration of the off-normal cladding temperatures must be determined.

Satisfaction of Requirement 6.2.3.12: The steady-state analysis of this event sequence (Reference 2.2.24, Table 43) showed that the TAD waste package temperature inside the TEV remained around 175 *C* (347 *F*) without ventilation, using a heat load of 18 *kW* and 22 *C* (72 *F*) cold drift wall temperature. This is below the 300 *C* (572 *F*) TAD waste package temperature limit (Reference 2.2.16, Section 11.2.2.24). Reference 2.2.24, Table 43, also shows the cladding temperature remained around 341 *C* (646 *F*), well below the 570 *C* (1058 *F*) off-normal temperature limit (see Requirement 6.2.1.10). Further licensing specifications for the duration of the off-normal cladding temperatures must be determined through PCSA analyses. Therefore, Requirement 6.2.3.12 is satisfied.

Requirement 6.2.3.13: Section 4.3.16 of Reference 2.2.17 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 limit 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 2.2.28), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.24, Table 36) showed that the TAD WP temperature inside the TEV remained around 198 *C* (388 *F*) without ventilation, using a heat load of 18 *kW* and 50 *C* (122 *F*) ambient temperature. This is below the 300 *C* (572 *F*) TAD WP temperature limit (Reference 2.2.16, Section 11.2.2.24). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.16, Section 11.2.2.24) 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. Therefore, Requirement 6.2.3.13 is expected to be satisfied.

Requirement 6.2.3.14: Section 4.3.17 of Reference 2.2.17 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 limit is prevented. Licensing specifications for the duration of the off-normal cladding temperatures must be determined.

Satisfaction of Requirement 6.2.3.14: The steady-state analysis of this event sequence (Reference 2.2.24, Table 43) showed that the TAD waste package temperature inside the TEV remained around 175 *C* (347 *F*) without ventilation, using a heat load of 18 *kW* and 22 *C* (72 *F*) cold drift wall temperature. This is below the 300 *C* (572 *F*) TAD waste package temperature limit (Reference 2.2.16, Section 11.2.2.24). Reference 2.2.24, Table 43, also shows the cladding temperature remained around 341 *C* (646 *F*), well below the 570 *C* (1058 *F*) off-normal temperature limit (see Requirement 6.2.1.10). Since 341 *C* (646 *F*) is below the normal cladding limit 350 *C* (662 *F*) (Requirement 6.2.1.16) duration is not an issue and there is no loss of margin as Reference 2.2.17, Section 4.3.14 states. Further licensing specifications for the duration of the off-normal cladding temperatures must be determined through PCSA analyses. Therefore, Requirement 6.2.3.14 is satisfied.

Requirement 6.2.3.15: Section 4.3.18 of Reference 2.2.17 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 limit 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 2.2.28), or the rate of increase is about 18 *C*/min (33 *F/min*). The steady-state analysis (Reference 2.2.24, Table 36) showed that the TAD WP temperature inside the TEV remained around 198 *C* (388 *F*) without ventilation, using a heat load of 18 *kW* and 50 *C* (122 *F*) ambient temperature. This is below the 300 *C* (572 *F*) TAD WP temperature limit (Reference 2.2.16, Section 11.2.2.24). A severe fire may cause the WP temperature to exceed the limit of 300 *C* (572 *F*) (Reference 2.2.16, Section 11.2.2.24) 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. Therefore, Requirement 6.2.3.15 is expected to be satisfied.

Requirement 6.2.3.16: Section 4.4.2 of Reference 2.2.17 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 either the waste package transfer trolley or the TEV.

Satisfaction of Requirement 6.2.3.16: Using data from the analysis (Reference 2.2.25, Table 7-3) we calculated in Section 6.2.3.5 the impact velocity in which the WP reaches the project tiered second condition acceptance criterion EWA SI ratio of 0.77 (Reference 2.2.30, Section 7.1.4). Using Newton's equation of motion (Reference 2.2.68, 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* (18.9 *ft/sec*) (WP final velocity as calculated from Section 6.2.3.5)
V_o = 0.0 *m/s* (WP initially at rest)

$g = 9.81\ m/s^2$ ($32.2\ ft/s^2$) (acceleration due to gravity)

Solving for *h*:

$$h = (V^2 - V_o^2) / 2g = 1.691\ m\ (66.57\ in.)$$

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 2.2.17 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 2.2.42, Table 7-2) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.30, 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 3.2.1 and 3.2.3), we can conservatively conclude that the EWA SI ratio calculated for the OCB of a TAD waste package would remain below failure criteria levels (Reference 2.2.30, Section 7.1.4). Therefore, Requirement 6.2.3.17 is satisfied.

Requirement 6.2.3.18: Section 4.4.4 of Reference 2.2.17 requires that the waste package shall not breach in an event where the drip shield gantry drops a drip shield onto an emplaced waste package.

Satisfaction of Requirement 6.2.3.18: The event of a drip shield (weighing 5 *MT* (5.5 *tons*) per Reference 2.2.45) dropped onto a waste package is a lot less severe than the largest credible rockfall with a rockbolt weighing 20 *MT* (22 *tons*) (Reference 2.2.18, 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 2.2.31, Table 4, Cases 9 to 12) indicated that the EWA SI ratio of the OCB in all four rockfall cases involving the rockbolt did not exceed the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.30, 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 2.2.17 requires that the waste package shall not breach in an event of a very large block 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 2.2.18, Section 6.4.5.2.5). The calculation (Reference 2.2.31, Table 4) indicated that the EWA SI ratio at any point in the OCB did not exceed the project tiered first condition acceptance criterion of 0.7 (Reference 2.2.30, 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 2.2.17 requires that the waste package shall not breach in an event of general drift collapse caused by vibratory ground motion in the lithophysal portions of the repository.

Satisfaction of Requirement 6.2.3.20: The analysis (Reference 2.2.43) showed that the EWA SI ratio stayed below the project tiered first condition acceptance criteria of 0.7 (Reference 2.2.30, 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 2.2.17 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 case where invert beams strike the WP due to failure of the structural steel in the invert, the analysis (Reference 2.2.41, Figure 7-145) showed a mean expended toughness fraction (ETF) of 0.85 in the worst orientation case of the OCB with mean material toughness index (I_T) hitting the invert beam at an 18º angle, at 1 *in.* (0.0254 *m*) offset from the inner vessel top plug, and moving at a velocity of 4 *m/s* (13.12 *ft/sec*). The I_T is a measure of strength and the ETF is a measure of damage, and when ETF equals 1.0 failure is defined (Reference 2.2.30, Section 7.1.7 and Appendix I). This means that the WP did not fail in this case. 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 and the WP and rubble will also move in concert with the rest of the mountain. 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. Requirement 6.2.3.21 is expected to be satisfied.

7. RESULTS AND CONCLUSIONS

This report demonstrates that the design methodology can be applied successfully to the TAD waste package configuration and supports the License Application (LA) 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 TAD waste package were compared to design requirements from the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 2.2.16), the *Project Design Criteria Document* (Reference 2.2.29) and the *Provisional Event Sequence Definitions for Waste Packages* (Reference 2.2.17). In addition, requirements were derived by the nature of the engineered design solution or imposed by interfaces with postclosure performance assessment. The comparison of TAD waste package design features against thermal and structural analyses demonstrates requirements are satisfied, or (in a few cases) will be satisfied as final design is completed.