BSC

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Complete only applicable items.

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Drip Shield and Waste Package Emplacement Pallet Design Report

6. Group

Thermal/Structural Analysis

7. Document Status Designation

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8. Notes/Comments

Because of a shortage of personnel who are qualified to check emplacement pallet design analyses, the EGS for this document was approved to check this design report (Interoffice Memorandum No. 0726071451).

No need for formal review by Lead Laboratory, per email from Neil Brown on May 29th, 2007 to Michael Anderson.

Attachments	Total Number of Pages
None	N/A

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
00A	This design analysis supersedes and revises the previous document ANL-XCS-ME-000001 REV 00 to report the results of the finite element analyses and evaluations for the latest drip shield and emplacement pallet designs. All pages are affected. Change bars are not used because the changes are extensive.	45	45	Zekai Ceylan D.G. McKenzie IV	Hongyan Marr	N/A [EGS signature not required when 00A was issued]	M.J. Anderson 2/25/04
ECN-1	Change status to committed as results are not expected to change	1	1	T. Schmitt	M. Mullin	M.J. Anderson	M.J. Anderson 8/12/05
00B	Major revision to reflect change in scope of design report. Deleted seismic, rockfall, and dead load analysis since these responsibilities have been transferred to the Lead Lab. Changed Titanium Grade 24 to Grade 29 to be consistent with the current design. Updated references and formatted to new procedures. All pages are affected.	26	26	D.C. Mecham [signature] 8-9-07	J.C. Viggato [signature] 8/9/07	M.J. Anderson [signature] 8/9/07	M.J. Anderson [signature] 8/9/07

DISCLAIMER

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1. PURPOSE

A design methodology has been developed for the drip shield and emplacement pallet 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 drip shield and emplacement pallet configurations. The design methodology is described in the *Waste Package Component Design Methodology Report* (Reference 2.2.32) as augmented by the *Execution Plan for the Thermal-Structural Discipline Workflow for Design, Design Revisions, and Prototyping of Waste Packages and Related Components* (Reference 2.2.30). This demonstrates that the design methodology can be applied successfully to the drip shield and emplacement pallet configurations and supports the License Application for construction of the repository. This report summarizes design features that show the designs are in compliance with applicable design requirements. Design requirements are contained in the *Basis of Design for the TAD Canister-Based Repository Design Concept* (BOD)(Reference 2.2.19) and the *Project Design Criteria Document* (PDC)(Reference 2.2.21). Additional design constraints are derived from the engineered design solution and *Postclosure Modeling and Analyses Design Parameters* (Reference 2.2.28) which lists design features that affect postclosure performance and will be incorporated in future revisions of the BOD.

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 constraints 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. (Section 1.3 of Reference 2.2.28).

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2.3 DESIGN CONSTRAINTS

None

2.4 DESIGN OUTPUTS

This document provides the basis for the drip shield and emplacement pallet designs as embodied in the drawings of these components. Because of the iterative nature of the design process, the drip shield drawings (References 2.2.23, 2.2.25, 2.2.26) and emplacement pallet drawings (References 2.2.13, 2.2.14, 2.2.15, and 2.2.16) are both inputs to and outputs of this design report . This document also provides information to support the License Application.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 Emplacement Pallet Dimensions and Materials

The dimensions, masses, materials and load paths used in the development of this design report, corresponding to the Emplacement Pallet drawings (References 2.2.14 and 2.2.15) are assumed to be the same as the final definitive design. The rationale for this assumption is that the design of the Emplacement Pallet (References 2.2.14 and 2.2.15) is created for the License Application (LA). This assumption is used in Reference 2.2.23, which is used in Section 6.1 and will require verification for the License Application (LA). This assumption is being tracked in CalcTrac.

3.1.2 Short Emplacement Pallet Dimensions and Materials

The dimensions, masses, materials and load paths used in the development of this design report, corresponding to the Emplacement Pallet-Short drawings (References 2.2.13 and 2.2.16) are assumed to be the same as the final definitive design. The rationale for this assumption is that the design of the Short Emplacement Pallet is created for the License Application (LA). This assumption is used in Reference 2.2.23, which is used in Section 6.1 and will require verification for the License Application (LA). This assumption is being tracked in CalcTrac.

3.1.3 Drip Shield Dimensions and Materials

The dimensions, masses, materials and load paths used in the development of this design report, corresponding to the Drip Shield drawings (References 2.2.23 to 2.2.26) are assumed to be the same as the final definitive design. The rationale for this assumption is that the design of the Drip Shield is created for the License Application (LA). This assumption is used in Reference 2.2.23, which is used in Section 6.1 and will require verification for the License Application (LA). This assumption is being tracked in CalcTrac.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Emplacement Pallet Lift Acceleration

The acceleration used for the emplacement pallet lift is 1.0 m/s^2 (total upward acceleration being 10.81 m/s^2 including gravity). The rationale for this assumption is that operational constraints are expected to prevent excessive acceleration during lifting, and 1.0 m/s^2 is a reasonably bounding value for lifting operations. This assumption was used in Reference 2.2.23, which is used in Section 6.1.2.1.

3.2.2 Corrosion Rate for Alloy 22

The general corrosion rate used for Alloy 22 material is 2.56 mm per 10,000 years (Reference 2.2.20). This value is the 99.99th percentile rate of corrosion of Alloy 22. Stainless steel has a corrosion rate of 1.5 mm for 10,000 years (Reference 2.2.20). Note that 2mm minimum corrosion constraint is imposed by Reference 2.2.28, Table 1, 08-03d and 08-03e. Since the emplacement pallet is composed of components made from Alloy 22 and 316 SS, the higher corrosion rate of 2.56 mm is used. The rationale for this assumption is that it provides the calculation with a conservatively bounded result of degradation with regards to material thickness. Therefore this assumption does not require verification. This assumption was used in Reference 2.2.23, which is used in Section 6.1.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

The drip shield is classified as ITWI and the emplacement pallet is classified as ITS and ITWI (see Reference 2.2.19, section 8.1.2). Therefore, the final version of this document is designated QA:QA. This document was developed in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1).

4.2 USE OF SOFTWARE

No software was used in developing this report.

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 2.2.32). Common design work practices and design changes are controlled within the design group through the *Execution Plan for the Thermal-Structural Discipline Workflow for Design, Design Revision, and Prototyping of Waste Packages and Related Components* (Reference 2.2.30). Design methodology can be viewed simply as gathering all the design input information; making reasonable assumptions; selecting analyses methods and computational tools; and showing that design criteria are satisfied.

Inputs to the design come from project requirements, interfaces with other organizations, and specific technical information. Top level requirements originate from the U.S. Department of Energy (DOE) and include regulations such as 10 CFR Part 63 [Reference 2.2.1]. These requirements flow to design through two documents, the BOD (Reference 2.2.19) and the PDC (Reference 2.2.21). 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 Drawings and Interface Definition Documents (e.g. Reference 2.2.20). 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.

5. LIST OF ATTACHMENTS

None.

6. BODY OF CALCULATION

6.1 DESIGN DESCRIPTION

The designs of the drip shield and emplacement pallet are described in Sections 6.1 and 6.2. The general configurations, justification of design features, material selections, and guidance for use of codes and standards are provided. The dimensions, masses, materials and load paths used in the development of this design report are assumed to be the same as the final definitive design and must be verified (see Assumptions 3.1.1, 3.1.2, and 3.1.3). Material thicknesses include allowance for specified corrosion rates (see Assumption 3.2.2). Figure 1 shows the arrangement of the emplacement pallet, waste package, and drip shield in a cross section of an emplacement drift (see Reference 2.2.22).

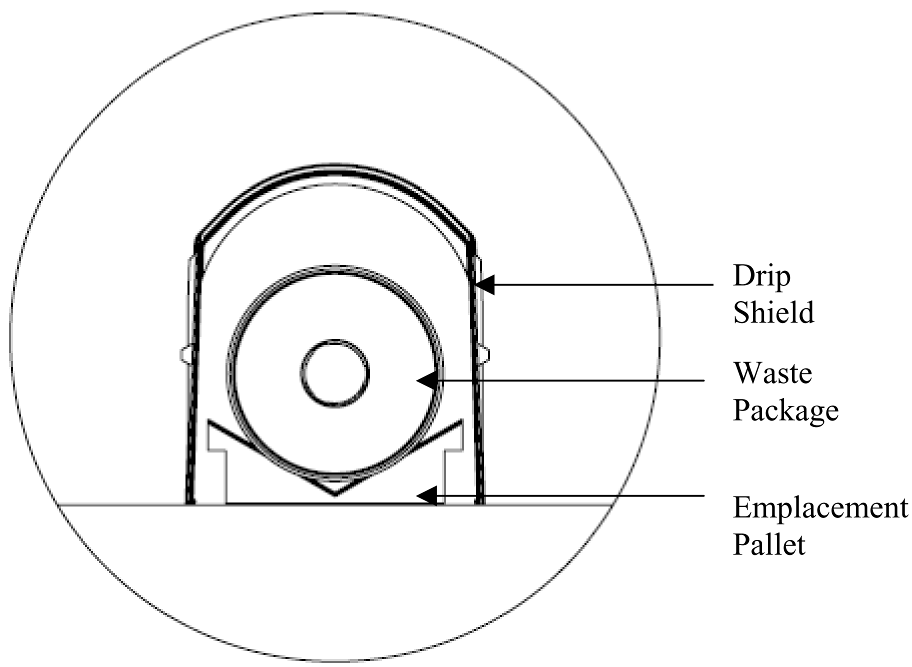

Figure 1. Drift Cross Section showing Emplacement Pallet, Waste Package, Drip Shield Arrangement

6.1.1 Design of the Drip Shield

6.1.1.1 General Configuration of the Drip Shield

The drip shield is installed at the end of the preclosure period to protect the waste packages from water intrusion and from rockfalls during postclosure (Reference 2.2.21, Section 4.2.13.5.5). Several alternatives for protecting the waste packages were investigated in the *Value Study Report—Drip Shield Reevaluation* (Reference 2.2.31). The *Interlocking Drip Shield Configuration* drawings (000-M00-SSE0-00101-000, 000-M00-SSE0-00102-000, and 000-M00-SSE0-00103-000) are available in References 2.2.23, 2.2.25, and 2.2.26. The standard nomenclature for major components that comprise the drip shield is shown in Table 1.

Table 1. Standard Nomenclature for Drip Shield Components

Preferred Terminology	Acceptable for Clarity or Brevity	Description
DS Top Plate	DS Plate 1	The plate that covers the top of the DS (Ti-7)
DS Sidewall	DS Plate 2	The vertical plate on either side of the DS (Ti-7)
Internal Support Plate	N/A	Support plate located at the DS corner, located below the top plate (Ti-7)
External Support Plate	N/A	Support plate located at the DS corner, located on the outer surface of the sidewall (Ti-7)
Drip Shield Connector Plate	Connector Plate	Plates designed to connect one drip shield to another (Ti-7)
Water Diversion Ring	DSC Connector Guide	Structural connector rings located below the connector plates (Ti-7)
Bulkhead	N/A	The structural support member located under the top plate that spans from one sidewall to the other (Ti-29)
Longitudinal Stiffener	Bulkhead Longitudinal Stiffener	The structural support member located under the top plate that runs in longitudinal (axial) direction (Ti-29)
Support Beam	N/A	High-strength vertical beam located on the outer surface of the sidewall (Ti-29)
Base	Base Plate	Base plate mechanically attached to the bottom of the sidewalls, which are made of Alloy 22

NOTE: DS = drip shield; Alloy 22 = Alloy SB-575 N06022; Ti-7 = Titanium-Grade 7; Ti-29=Titanium-Grade 29. A detailed description of the materials listed can be found in Reference 2.2.6, Section II, Part B

6.1.1.2 Justification of Drip Shield Design Features

The drip shield is fabricated from Ti-7 plates for the diversion of dripping water, Ti-29 for the structural support, and Alloy 22 for the base plates to prevent direct contact between the titanium and the steel members in the invert. The Alloy 22 base plates help prevent any potential galvanic coupling, serving as a barrier between the titanium and the invert steel beams. The drip shield top plates and the sidewalls are exposed to direct contact with dripping water or rockfalls from the emplacement drift. The geometry of these plates is configured such that dripping water is diverted around the waste package and onto the emplacement drift invert. The interlocking feature of the drip shield includes water diversion rings and support beam connectors to divert dripping water at the seams between the drip shield segments and around the waste packages to the emplacement drift invert. In case of rockfalls and subsequent static loads from fallen rocks, the load is transferred from the top plates to the structural support members. Since the bulkheads and the longitudinal stiffeners are placed directly under the top plate, the vertical load is partially carried by these members. The internal forces and bending moments due to external forces are subsequently transferred to the internal and external support plates and then to the support beams, sidewalls, and finally to the emplacement drift invert.

All of the titanium components are fabricated by welding and then stress-relieved. However, Alloy 22 base plates are mechanically attached to the titanium sidewalls since the two materials cannot be reliably welded together. The requirements for materials, fabrication, welding, and heat treatment are specified in *Yucca Mountain Project Engineering Specification for Prototype Drip Shield* (Reference 2.2.27).

All drip shields are uniformly sized so that one design can be used to enclose all waste package types. The drip shield segments are designed to accommodate an interlocking feature to prevent separation between the contiguous segments (Figure 2). This feature consists of an overlapping section with connector guides between the drip shield segments. The minimum lift height required to interlock the drip shield segments is at least 40 inches (1.016 m) (Reference 2.2.12) for clearance between the two drip shield segments.

The drip shield base plates rest on the transverse support beams of the drift invert and on the inside of the runway beams.

Dimensions for the drip shield are provided on the configuration drawings (References 2.2.12, 2.2.23, 2.2.25, and 2.2.26). An isometric view of the drip shield is provided in Figure 2.

Figure 2. Interlocking Drip Shield Isometric View

6.1.1.3 Drip Shield Material Selection

There are a few factors governing the selection of materials for drip shields. The main function of the drip shields is to divert the water that drips from the drift walls around the waste packages and to the drift invert, prolonging the longevity and structural integrity of the waste packages. An important consideration is the corrosion resistance of the drip shield during the regulatory period. Because of its resistance to general and localized corrosion, Ti-7 is the chosen material for diversion of dripping water.

The design requirements for the drip shield include structural strength as well as corrosion resistance. Structural strength is required so that the drip shield can protect the waste package against damage by rockfalls resulting from drift degradation. The drip shields must also withstand the static loads from backfill (if used, see sections 2.2.1.6 and 8.1.1 of Reference 2.2.19) and fallen rocks and prevent any damage to the waste package. The selection of Ti-29 as the drip shield structural material is based on the high strength requirement for such mechanical load conditions.

6.1.1.4 Codes and Standards for the Drip Shield

There are presently no codes or standards directly applicable to the design of the drip shield. If codes and standards relevant to the drip shield design are developed, they will be added in future revisions of this design report and the PDC. For guidance, the requirements of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC) (Reference 2.2.6) and ANSI/AISC N690 (Reference 2.2.2) will be used.

6.1.1.5 Data and Parameters for Drip Shield Materials

The sources of material properties are listed in the *Waste Package Component Design Methodology Report* (Reference 2.2.32, Table 2). The main sources are listed as the ASME B&PVC (Reference 2.2.6), and the ASM Metals Handbook (Reference 2.2.5). However, Section 5.2.8.10 in the same reference also indicates that when the temperature-dependent material properties are not available from these sources, vendor data are used in the calculations.

6.1.2 Design of the Emplacement Pallet

6.1.2.1 General Configuration of the Emplacement Pallet

The emplacement pallet is the structure that supports the waste package. It serves to support and protect the waste package during lifting and emplacement activities (See Assumption 3.2.1). It provides structural support and isolation from the invert during preclosure and postclosure periods of the repository. The *Emplacement Pallet Configuration* and *Emplacement Pallet-Short Configuration* drawings (000-M00-TEP0-00101-00A, 000-M00-TEP0-00102-00A, 000-M00-SSE0-00201-000, and 000-M00-SSE0-00202-000) are available in References 2.2.13, 2.2.14, 2.2.15, and 2.2.16. There are two configurations for the emplacement pallet; the normal sized emplacement pallet and the short sized emplacement pallet. The short size is used for the 5-DHLW/DOE SNF Short Waste Package (5-defense high-level radioactive waste/U.S. Department of Energy spent nuclear fuel). When referring to the emplacement pallet, both sizes of pallets are discussed at the same time, unless specifically stated otherwise. There are a few major sub-assemblies that comprise the waste package emplacement pallet. The standard nomenclature for major components that comprise the emplacement pallet is shown in Table 2.

Table 2. Standard Nomenclature for Waste Package Emplacemet Pallet Components

Preferred Terminology	Acceptable for Clarity or Brevity	Description
Waste Package Support	Alloy 22 Piers	Alloy 22 structures that cradle the waste package during handling, emplacement, preclosure and postclosure. Also provides lifting points for handling the emplacement pallet loaded with the waste package during handling, emplacement, and retrieval.
Stainless Steel Tubes	Longitudinal Stiffeners/Tubes	Stainless steel tubes that keep the waste package supports aligned during handling, emplacement, retrieval.

NOTE: Alloy 22 = Alloy SB-575 N06022. Stainless Steel = SA-240, Type 316. A detailed description of the materials listed can be found in Reference 2.2.6, Section II, Parts A and B.

Dimensions for the emplacement pallets are given in the configuration drawings (in References 2.2.13, 2.2.14, 2.2.15, and 2.2.16). Isometric views with and without a waste package are provided in Figures 3 and 4.

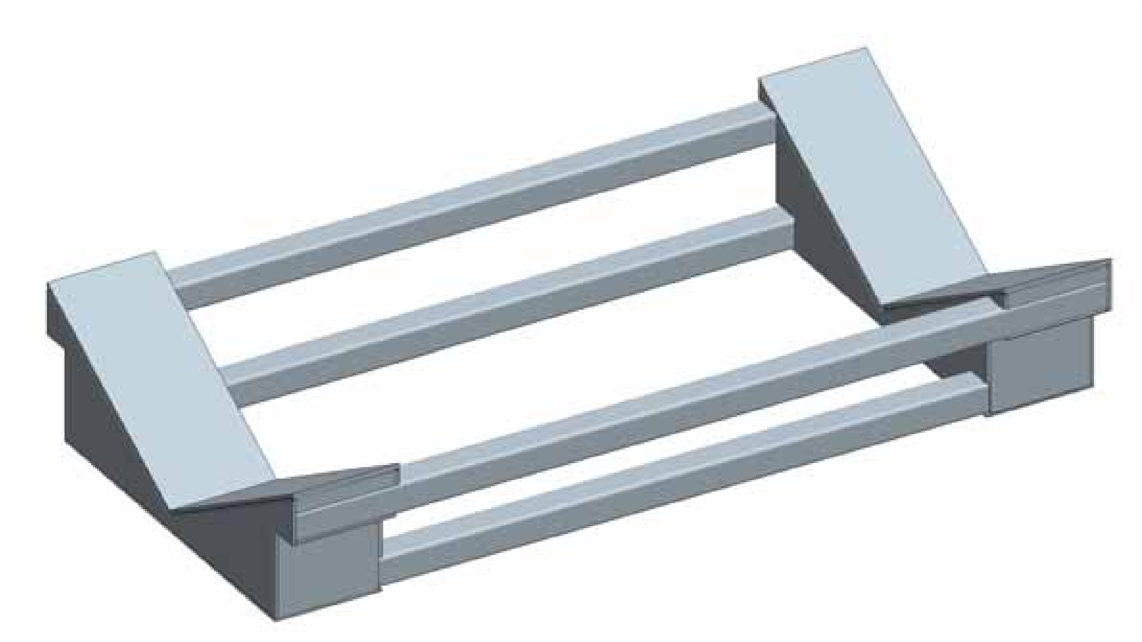

Figure 3. Emplacement Pallet Isometric View

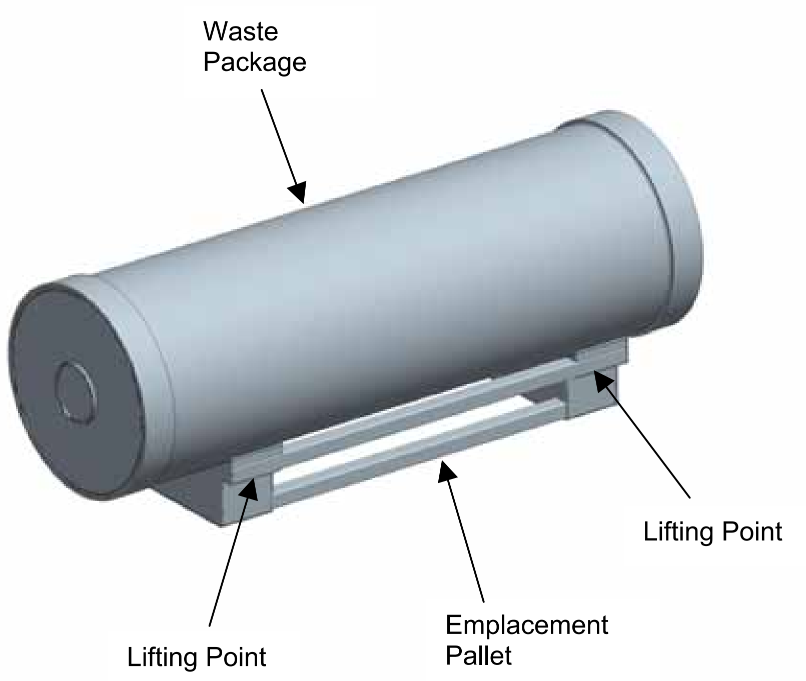

Figure 4. Emplacement Pallet Loaded with Waste Package

6.1.2.2 Justification of Emplacement Pallet Design Features

The waste package emplacement pallet supports the waste package during handling, emplacement, preclosure, and early postclosure periods (Figure 3). The waste package is transported into the emplacement drift after being loaded onto the emplacement pallet (Figure 4). The loaded waste package emplacement pallet is lifted from the bottom of the Alloy 22 plates located below the square tubes on the side of each waste package support. Figure 4 is provided only for illustration of the waste package after being emplaced on the pallet. It should be noted that this figure does not represent the current closure-weld configuration, which is outside the scope of this report. The waste package is in contact with the pallet, between the two sleeves. The emplacement pallet prevents the waste package from coming into contact with the invert of the drift and therefore helps prevent direct exposure to invert moisture or materials that may induce corrosion of the waste package.

As described earlier, two sizes of the waste package emplacement pallet are used. One is designed to accommodate all waste packages except for 5-DHLW/DOE SNF Codisposal Short waste package (References 2.2.14 and 2.2.15). A second, short emplacement pallet design is specifically developed for the 5-DHLW/DOE SNF Codisposal Short waste package since this waste package is substantially shorter than the rest of the waste package designs (Reference 2.2.13 and 2.2.16). The emplacement pallets are fabricated from Alloy 22 plates that are welded together to form the waste package supports. Two waste package supports are connected by square stainless steel tubes to form the emplacement pallet. Each waste package support includes a V-shaped cradle to accommodate all waste package diameters. The emplacement pallet is shorter than the waste package; therefore, the waste package is supported on the outer corrosion barrier between the upper & lower WP sleeves. The waste package is not mechanically attached to the emplacement pallet. The ends of the waste package extend further than the ends of the emplacement pallet, which allows the waste packages to be placed end-to-end without interference from the emplacement pallets.

The waste packages are required to be retrievable during the preclosure period. Therefore, the waste package emplacement pallet must remain in a condition that can be lifted by the Transport and Emplacement Vehicle (TEV) during this period.

6.1.2.3 Emplacement Pallet Material Selection

Long-term corrosion resistance is required for the emplacement pallet design so that it can perform its structural support function with high reliability for the regulatory period. The waste package support material (Alloy 22) provides the long-term corrosion resistance and the means for an identical material contact with the waste package outer corrosion barrier. The emplacement pallet will also be stress relieved to remove stresses from welding and fabrication to ensure minimized corrosion. The connecting stainless steel tubes provide structural strength and also long-term resistance to external loads on the emplacement pallet assembly.

6.1.2.4 Codes and Standards for the Emplacement Pallet

Structural design of the emplacement pallet follows the most appropriate criteria from the *2001 ASME Boiler and Pressure Vessel Code* (Reference 2.2.6), which are the rules for construction of component supports of Class 2 Vessels designed to NC-3200. For normal operations, the design evaluation is based on Plate-Type Supports per ASME B&PVC (Reference 2.2.6) Table NF-3131(a)-1, Note (1) and Article NF-3142. This is an elastic analysis based on maximum shear stress theory (stress intensity, SI), with allowable limits contained in NF-3220. Finite element analyses are performed and the results are compared to these allowable limits.

For off normal operations, there are no imposed emplacement pallet design stress limits or failure criteria. For anticipated event sequences where an emplacement pallet can be included (e.g. waste package on emplacement pallet drop or rock fall on emplaced waste package), a design evaluation is not required for the emplacement pallet structural response. During the analysis of event sequences the emplacement pallet can be included as a passive component in the evaluation of the WP outer corrosion barrier's ability to meet its requirements and failure criteria, without imposing performance requirements on the emplacement pallet itself.

For manufacturing, fabrication, and non-destructive examination purposes, the requirements of ASME B&PVC (Reference 2.2.6) and the *Waste Package Emplacement Pallet Fabrication Specification* (Reference 2.2.18) will be used.

6.1.2.5 Data and Parameters for Emplacement Pallet Materials

The sources of material properties are listed in the *Waste Package Component Design Methodology Report* (Reference 2.2.32, Table 2). The main sources are listed as the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (B&PVC)

(Reference 2.2.6), and ASM Metals Handbook (Reference 2.2.5). However, Section 5.2.8 in reference 2.2.32 (as noted in Section 5.1.2 of the PDC) also indicates vendor data for Alloy 22 (Haynes International) is to be used where applicable.

6.2 DESIGN REQUIREMENTS

Design requirements include those requirements that flow to design through the BOD (Reference 2.2.19) and PDC (Reference 2.2.21), 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 2.2.19) and PDC (Reference 2.2.1) are described in Sections 6.2.1 through 6.2.4 and are related to use of engineering codes and standards. They require the emplacement pallet to be designed in accordance with practices outlined in the ASME Pressure Vessel Code (Reference 2.2.6). No specific code or standard is specified for design of the drip shield. Numerous codes and standards are cited for fabrication of both the emplacement pallet and the drip shield. The fabrication requirements are passed on to the vendor via specifications (see for example, References 2.2.18 and 2.2.27). Sections 6.2.5 and 6.2.6 discuss the requirements derived from the design solution and postclosure performance assessment, respectively.

Each design requirement is compared to design features, drawings, and/or calculations for the emplacement pallet and drip shield and then a description of how the design satisfies the requirement is given.

6.2.1 Emplacement Pallet Design Criteria

Requirement 6.2.1.1: Section 5.4 of the PDC (Reference 2.2.21) requires that structural design of the emplacement pallet be in accordance with *2001 ASME Boiler and Pressure Vessel Code* (Reference 2.2.6), Section II and III, Division I. Section 5.4 of the PDC also contains the following Note: *2001 ASME Boiler and Pressure Vessel Code* (Reference 2.2.6, Section II and Section III, Division 1) provides the properties and general requirements, respectively, for materials used in the design and fabrication of nuclear components. ASME 2001 (Reference 2.2.6), Section II, does not contain an exhaustive list of material properties, and it may be necessary to obtain values from other sources as appropriate. Possible additional sources of material properties are identified in the Waste Package Component Design Methodology Report (Reference 2.2.32, Sections 4.2.2.3 and 4.2.3.1).

<u>Satisfaction of Requirement 6.2.1.1</u>: Key parameters (including material density, Poisson's Ratio, and Modulus of Elasticity) that are used in the structural analysis (Reference 2.2.23, Section 6) are taken from (Reference 2.2.6). The structural analysis (Reference 2.2.23) follows the most appropriate component support rules from ASME Section III, Article NF-3220 for supports of class 2 vessels designed to NC-3200. The design evaluation, for Plate-Type Supports using linearly elastic analysis based on maximum shear stress theory (stress intensity, SI), with allowable limits contained in NF-3220. Therefore Requirement 6.2.1.1 is satisfied.

Requirement 6.2.1.2: Sections 11.2.2.6 and 12.2.2.4 of the BOD (Reference 2.2.19) require that the waste packages be retrievable during the preclosure period. Therefore, the waste package emplacement pallet must remain in a condition that can be lifted by the TEV during this period.

Satisfaction of Requirement 6.2.1.2: The structural analysis (Reference 2.2.23) considered in-drift temperatures and reduced material thickness due to corrosion. Results showed acceptable stress levels under lifting. Therefore Requirement 6.2.1.2 is satisfied.

Requirement 6.2.1.3: Section 8.2.3.1.5 of the BOD (Reference 2.2.19) requires emplacement pallet be designed for loading conditions associated with a DBGM-2 seismic event and to demonstrate sufficient seismic design margin to ensure a "no failure" safety function is maintained for loading conditions associated with a BDBGM seismic event.

Satisfaction of Requirement 6.2.1.3: The emplacement pallet may deform due to seismic events but the "no failure" safety function is maintained because the waste package is designed to withstand seismic events. Hence, Requirement 6.2.1.3 is expected to be satisfied.

6.2.2 Emplacement Pallet Fabrication Criteria

Requirement 6.2.2.1: Section 5.5 of the PDC (Reference 2.2.21) states that emplacement pallets shall be fabricated in accordance with the following:

ANSI/AWS A2.4-98 (Reference 2.2.4) provides the standard symbols for the welding, brazing, and nondestructive examination of nuclear components.
ANSI/AWS A5.32/A5.32M-97 (Reference 2.2.3) provides the specifications of welding shielding gases used in the welding processes of nuclear components.
ASME 2001 (Reference 2.2.6), Section II, provides the properties for the materials used in the design and fabrication of Class NF nuclear components.
ASME 2001 (Reference 2.2.6), Section III, Division I, Subsection NF, provides the general requirements for the design and fabrication of supports for Class 2 nuclear components.
ASME 2001 (Reference 2.2.6), Section V, provides the requirements for the nondestructive examination of nuclear components.
ASME 2001 (Reference 2.2.6), Section IX, provides welding and brazing qualifications for the welding of nuclear components.
ASME 2001 (Reference 2.2.6), Section III, Division 1, Subsection NF (including 2002 Addenda) or, as negotiated, the ASME Code version in effect at the time of procurement.
ASME B46.1-2002 (Reference 2.2.7) provides surface texture (surface roughness, waviness, and lay) requirements for fabrication of nuclear components.
ASME Y14.36M (Reference 2.2.10) provides the requirements for surface texture symbols used in the designing of nuclear components.
ASME Y14.38-1999 (Reference 2.2.11) provides the requirements for abbreviations and acronyms used in the designing of nuclear components.
ASME Y14.5M-1994 (Reference 2.2.9) provides the requirements for dimensioning and tolerancing of drawing.

Cleaning, packaging, shipping, receiving, storage, and handling of emplacement pallets shall be in accordance with ASME NQA-1-2000, Subparts 2.1 and 2.2 (Reference 2.2.8). These 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 4, 5, 6, 7, 8, 9 and 10 of Reference 2.2.18 impose the specific, applicable sections from codes and standards for the Emplacement Pallet Design, Materials, Fabrication, and Examination and Testing. ASME Y14.36M-1996 (Surface Texture Symbols) and ASME Y14.38-1999 (Abbreviations and Acronyms) are not listed in the current version of the pallet specification (Reference 2.2.18) but updates are expected as the specification is a living document and the standards refer to common definitions. Similarly, Reference 2.2.18 cites the 1995 version of ASME B46.1 (Surface Texture (Surface Roughness, Waviness and Lay)) but the 2002 version will be listed as the specification is updated. Therefore Requirement 6.2.2.1 is expected to be satisfied as final design is completed.

6.2.3 Drip Shield Design Criteria

Requirement 6.2.3.1: Section 5.6 of the PDC (Reference 2.2.21) states that no codes or standards have been identified at this time for structural design of the drip shield. This requirement is intended as a placeholder that may be used to impose design codes and standards as final detailed design is completed. As codes and standards are established for use in drip shield design, they will be added in future revisions of this design report.

Satisfaction of Requirement 6.2.3.1: Although codes and standards have not been specified for use in the drip shield design, guidance from codes and standards has been used in the design. Key parameters (including material density, Poisson's Ratio, and Modulus of Elasticity) that are used in the structural analysis being performed by SNL the YMP Lead Laboratory are taken from (Reference 2.2.6). Where appropriate, additional vendor data has been used. The structural analysis method for determining failure stress is outlined in Reference 2.2.32, and is consistent with ANSI/AISC N690 (Reference 2.2.2). Hence, it is expected that if Requirement 6.2.3.1 is established, it will be satisfied.

6.2.4 Drip Shield Fabrication Criteria

Requirement 6.2.4.1: Section 5.7 of the PDC (Reference 2.2.21) states that drip shields shall be fabricated in accordance with the following:

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

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

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

ASME 2001 (Reference 2.2.6), Section III, Subsection NCA, provides the rules and general requirements for the construction of Division 1 components, including the requirements for affixing a code stamp.

ASME 2001 (Reference 2.2.6), Section III, Division I, Subsection NF, provides the general requirements for the design and fabrication of supports for Class 2 nuclear components.

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

ASME 2001 (Reference 2.2.6), Section IX, provides welding and brazing qualifications for the welding of nuclear components.
ASME 2001 (Reference 2.2.6), Section III, Division 1, Subsection NF (including 2002 Addenda) or, as negotiated, the ASME Code version in effect at the time of procurement.
ASME B46.1-2002 (Reference 2.2.7) provides surface texture (surface roughness, waviness, and lay) requirements for fabrication of nuclear components.
ASME Y14.36M (Reference 2.2.10) provides the requirements for surface texture symbols used in the designing of nuclear components.
ASME Y14.38-1999 (Reference 2.2.11) provides the requirements for abbreviations and acronyms used in the designing of nuclear components.
ASME Y14.5M-1994 (Reference 2.2.9) provides the requirements for dimensioning and tolerancing used in the designing of nuclear components.

Cleaning, packaging, shipping, receiving, storage, and handling of drip shields shall be in accordance with ASME NQA-1-2000, Subparts 2.1 and 2.2 (Reference 2.2.8). These 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 6.2.4.1: The specific applicable requirements from codes and standards are implemented by specifications such as the *Yucca Mountain Project Engineering Specification for Prototype Drip Shield* (Reference 2.2.27). Sections 2, 3, 4, 5, 6, 7, 8, and 9 of Reference 2.2.27 impose the specific, applicable sections from codes and standards for the Drip Shield Design, Materials, Fabrication, and Examination and Testing. NOTE: The references in this requirement to ASME Y14.38-1999 (Abbreviations and Acronyms) and Section II, Class NF are not listed in the specification (Reference 2.2.27) but updates are expected as the specification is a living document and the standards only provide common definitions and the second material properties. Therefore, Requirement 6.2.4.1 is expected to be satisfied as final design is completed.

6.2.5 Pallet Requirements Derived from the Design Solution

The waste package emplacement pallet is the design component that provides structural support and isolation between the invert and the waste package during preclosure and postclosure periods of the repository. The pallet is designed to support the waste package and protect it during lifting and emplacement activities. These design features derive the following fundamental requirements:

Requirement 6.2.5.1: The waste package emplacement pallet shall support the waste package during the preclosure period and retain its form sufficiently to allow horizontal lifting of the waste package by the pallet after exposure to the applicable loads under normal operating conditions.

Satisfaction of Requirement 6.2.5.1: The two normal condition loads for the emplacement pallet are the horizontal lifting of the pallet loaded with the waste package and the pallet under the waste package static load as emplaced in the drift. The calculation results for the emplacement pallet horizontal lifting show that the maximum stress intensity (the difference between the first and the third principal stresses) in the pallet due to horizontal lifting is 274 MPa at 250 °C (Reference 2.2.23, Section 7.6). The corresponding Alloy 22 (UNS N06022) design stress intensity at 250 °C is 300 MPa (Reference 2.2.23, Table 7-1). Since the maximum stress intensity is less than the design stress intensity there will be some change in the pallet's form when lifting at 250 °C, but the emplacement pallet will retain its form sufficiently enough to allow subsequent waste package lifts under normal operating conditions.. Hence, for horizontal lifting and static loads of the waste package on the pallet, the requirement stated above is met.

Requirement 6.2.5.2: Configuration of the waste package emplacement pallet shall facilitate emplacement of the waste packages at short distances from each other (line loading of drift).

Satisfaction of Requirement 6.2.5.2: Figure 4 and Reference 2.2.23, Section 6.4, show that the pallet is designed to be lifted on the sides by the TEV. Additionally, the emplacement pallets (References 2.2.13, 2.2.14, 2.2.15, and 2.2.16) are designed to be shorter than the waste packages they support. The combination of these two features removes any physical limit for the minimum spacing between waste packages due to the emplacement pallet design. Therefore Requirement 6.2.5.2 is satisfied.

6.2.6 Requirements Derived from Postclosure Modeling and Analysis Design Parameters

The *Postclosure Modeling and Analysis Design Parameters* (Reference 2.2.28) report lists key design parameters that are used in repository performance assessment. These key parameters become derived requirements that include geometric orientation, material selection, surface contact, contact stress, corrosion allowance, fabrication specifications, QA requirements, and subjection to off-normal events. The responsibility to show these requirements are satisfied is broken into two parts. The responsibility to do so for the preclosure period belongs to Bechtel SAIC Company, and the responsibility to do so for the postclosure period belongs to SNL the YMP Lead Laboratory. This section describes how these requirements are satisfied during the preclosure period.

Requirement 6.2.6.1: The emplacement pallet shall support the waste package in the horizontal position. (Derived from Reference 2.2.28, Table 1, Item 08-02)

Satisfaction of Requirement 6.2.6.1: The emplacement pallet is configured to support the waste package in the horizontal position (Reference 2.2.22). Therefore Requirement 6.2.6.1 is satisfied.

Requirement 6.2.6.2: The emplacement pallet shall be fabricated of Alloy 22 plates and square stainless steel tubes. (Derived from Reference 2.2.28, Table 1, Item 08-03b)

Satisfaction of Requirement 6.2.6.2: The emplacement pallet materials are Alloy 22 and stainless steel as required. Therefore Requirement 6.2.6.2 is satisfied.

Requirement 6.2.6.3: The contacts between the waste package and emplacement pallet shall be Alloy 22. (Derived from Reference 2.2.28, Table 1, Item 08-03c and 08-04)

Satisfaction of Requirement 6.2.6.3: The emplacement pallet configuration drawings (References 2.2.13, 2.2.14, 2.2.15, and 2.2.16) and Figure 3 show that each waste package support includes a V-shaped cradle, fabricated from Alloy 22 (UNS N06022) plates, to accommodate all waste package diameters. This design feature provides Alloy 22 (UNS N06022) contact surface for the waste package. Therefore Requirement 6.2.6.3 is satisfied.

Requirement 6.2.6.4: The drip shield base contacting the invert shall be Alloy 22. (Derived from Reference 2.2.28, Table 1, Item 07-07)

Satisfaction of Requirement 6.2.6.4: The drip shield base is made from Alloy 22. Therefore Requirement 6.2.6.4 is satisfied.

Requirement 6.2.6.5: Mechanical loading shall result in tensile stresses of less than 257 MPa in the alloy 22 components of the waste package and the pallet. (Derived from Reference 2.2.28, Table 1, Items 02-09 and 08-05)

Satisfaction of Requirement 6.2.6.5: Reference 2.2.23, Section 7 shows the tensile stresses in the alloy 22 components of the waste package and the pallet are 32.4 MPa and 55.1 MPa, respectively. Both are below 257 MPa. Therefore Requirement 6.2.6.5 is satisfied.

Requirement 6.2.6.6: Corrosion allowance for stainless steel surfaces shall be a minimum of 2 mm (Derived from Reference 2.2.28, Table 1, Item 08-03e)

Satisfaction of Requirement 6.2.6.6: The stainless steel thickness is 9.5 mm (Reference 2.2.17), sufficient to permit 2 mm corrosion. After repository closure, there is no lift of the emplacement pallet, so this allowance is not relevant to engineering design. Use of this allowance may be made by the Lead Laboratory for post closure analysis. Therefore Requirement 6.2.6.6 is satisfied.

Requirement 6.2.6.7: Corrosion allowance for Alloy 22 surfaces shall be a minimum of 2mm (Derived from Reference 2.2.28, Table 1, Item 08-03d)

Satisfaction of Requirement 6.2.6.7: The structural calculations are based on dimensions, which are reduced by more than 2 mm on each surface from the minimum dimensions specified (Reference 2.2.23, Section 6.3). Therefore Requirement 6.2.6.7 is satisfied.

Requirement 6.2.6.8: The drip shield shall be constructed of Titanium Grade 7, with a minimum thickness of 15 mm. The drip shield structural material shall be manufactured of Titanium Grade 29 and be of sufficient thickness to meet the structural requirements after accounting for corrosion allowance of 1mm on each side. (Derived from Reference 2.2.28, Table 1, Items 07-03 and 07-04)

Satisfaction of Requirement 6.2.6.8: The drip shield materials are *Titanium Grade 7 and Titanium Grade 29.* Thicknesses are 15 mm for both the side walls and top cover of the drip shield. Structural analysis of the drip shield structural components including 1 mm of corrosion allowance to confirm sufficient thickness is work being performed by SNL the YMP Lead Laboratory. Confirmation of Requirement 6.2.6.8 will be provided by the YMP Lead Laboratory.

Requirement 6.2.6.9: Mechanical properties at 150° C shall be used for postclosure analysis. (Derived from Reference 2.2.28, Table 1, Items 07-03 and 08-03f)

Satisfaction of Requirement 6.2.6.9: The structural calculations for the emplacement pallet during postclosure are based on material properties at 150°C (Reference 2.2.23, Section 6.4). YMP Lead Laboratory structural analyses of the drip shield during postclosure will be performed using material properties at 150°C. Therefore Requirement 6.2.6.9 is satisfied.

Requirement 6.2.6.10: The drip shield will interlock and overlap in a manner that prevents a liquid drip path from above the drip shield to the waste package. (Derived from Reference 2.2.28, Table 1, Item 07-02)

Satisfaction of Requirement 6.2.6.10: The geometry of the drip shield is such that the dripping water is diverted around the waste package and onto the emplacement drift invert (see Figure 2 and Reference 2.2.22). Therefore Requirement 6.2.6.10 is satisfied.

Requirement 6.2.6.11: The drip shield to drip shield interface shall not preclude the exchange of atmosphere between the volumes above and below the drip shields through that interface. (Derived from Reference 2.2.28, Table 1, Item 07-06).

Satisfaction of Requirement 6.2.6.11: The drip shield to drip shield interface is simply overlapping contact with no seal that could preclude the movement of air (See Figure 2 and References 2.2.23, 2.2.25, and 2.2.26). Therefore Requirement 6.2.6.11 is satisfied.

Requirement 6.2.6.12: Specifications for drip shield fabrication and handling shall include the following:

> The drip shield shall be fabricated in a controlled manner that results in minimal material defects. Drip shield manufacturing activities will be performed in accordance with written procedures including heat treatment, operations will be controlled, and inspections will be done to confirm proper results. To reduce possibility of improper weld material, the Grade 29 structure assembly shall be physically separate from the Grade 7 plate attachment until assembled. (Derived from Reference 2.2.28, Table 1, Item 07-09)
>
> The drip shield fabrication welds shall be nondestructively examined by visual (VT), liquid penetrant (PT), and ultrasonic testing (UT), for flaws. (Derived from Reference 2.2.28, Table 1, Item 07-10)
>
> The welding techniques for the fabrication welds shall be constrained to MSMA (manual shielded metal arc), GMAW (gas metal arc welding) except for short-circuiting mode, and GTAW (gas tungsten arc welding). Welding flaws will be repaired in accordance with written procedures that have been accepted by the design organization prior to their usage. (Derived from Reference 2.2.28, Table 1, Item 07-11)
>
> All drip shield welding materials shall be verified immediately prior to usage to prevent incorrect material usage. For Ti-7 to Ti-7 welds, ER-Ti-7 weld filler material shall be used. For Ti-29 to Ti-29 welds, ER-Ti-29 shall be used. For Ti-7 to Ti-29 welds ER-Ti-28 weld filler shall be used. The weld filler material identifiers are taken from ASME-SFA-5.16 the *Specification for Titanium and Titanium Alloy Welding Electrodes and Rods* (Reference 2.2.6, Section II, Part C, SFA-5.16). (Derived from Reference 2.2.28, Table 1, Item 07-12)

> After fabrication the drip shield assembly and lifting feature assemblies shall be stress-relieved; after completion of all required work except for the final machining. The drip shield assembly and lifting feature assemblies shall be furnace heated for stress relief at 1100° Fahrenheit +/- 50° Fahrenheit for a minimum of 2 hours. To prevent pickup of hydrogen, a slightly oxidizing atmosphere shall be used; air-cooling is allowed. (Derived from Reference 2.2.28, Table 1, Item 07-13)

Satisfaction of Requirement 6.2.6.12: The *Yucca Mountain Project Engineering Specification for Prototype Drip Shield* Yucca Mountain Project Engineering Specification (Reference 2.2.27) sections 2, 3, 4, 5, 6, 7, 8, and 9 impose the specific, applicable sections from codes and standards for the Drip Shield Design, Materials, Fabrication, and Examination and Testing. Air-cooling is expected to provide the "slightly oxidizing atmosphere" mentioned in this requirement. There is not specific wording that drip shield welding materials be verified immediately prior to usage. Protection against incorrect material usage is provided by requiring welders to possess only one wire tip at a time (Section 5.5.1.2 of Reference 2.2.27), established hold points for the first weld (Appendix C of Reference 2.2.27); and requiring weld maps to include traceability to all materials (Section 5.4.2.1of Reference 2.2.27). Therefore Requirement 6.2.6.12 is satisfied.

Requirement 6.2.6.13: To account for volume increase of corrosion products the drip shield shall not be constrained laterally or longitudinally, or rigidly mounted to the invert. Drip shield connectors will be designed to allow thermal expansion with no effect on drip shield performance to 200°C. (Derived from Reference 2.2.28, Table 1, Item 07-15)

Satisfaction of Requirement 6.2.6.13: The drip shield sits on the invert (Reference 2.2.22), but is not fastened to it and there are no constraints on the sides or ends of the assembled drip shield. Segments of the drip shield will be installed flush with each other (Reference 2.2.26, Note 2), but there is no design feature to limit movement of the free ends of drip shields at the ends of emplacement drifts, thus accommodating thermal expansion or volume increase of corrosion products. Therefore Requirement 6.2.6.13 is satisfied.

NOTE: Postclosure analysis by SNL the YMP Lead Laboratory provides the description of drip shield and emplacement pallet response to rock fall and seismic events.

7. RESULTS AND CONCLUSIONS

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

Design features and structural analysis of the drip shield and emplacement pallet were compared to design requirements from the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 2.2.19) and the *Project Design Criteria Document* (Reference 2.2.21). In addition, requirements were derived by the nature of the engineered design solution or imposed by interfaces with postclosure performance assessment. The comparison of drip shield and emplacement pallet design features and structural analysis demonstrates all requirements are satisfied, or (in a few cases) will be satisfied as final design is completed.

NOTE: Postclosure analysis by SNL the YMP Lead Laboratory provides the description of drip shield and emplacement pallet response to rock fall and seismic events.