OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
ANALYSIS/MODEL COVER SHEET
Complete Only Applicable Items

1. QA: QA

2. [X] Analysis — Check all that apply

Type of Analysis	[X] Engineering [ ] Performance Assessment [ ] Scientific
Intended Use of Analysis	[ ] Input to Calculation [ ] Input to another Analysis or Model [X] Input to Technical Document [ ] Input to other Technical Products

Describe use:

Design description of the naval SNF waste package

3. [ ] Model — Check all that apply

Type of Model	[ ] Conceptual Model [ ] Abstraction Model [ ] Mathematical Model [ ] System Model [ ] Process Model
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TABLES

ACRONYMS

AMR	Analysis and Model Report
ANS	American Nuclear Society
ANSI	American National Standards Institute, Inc.
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
CRWMS	Civilian Radioactive Waste Management System
DOE	U.S. Department Of Energy
FEA	finite element analysis
ICD	Interface Control Document
k_{eff}	effective neutron multiplication factor
LA	License Application
LWR	light water reactor
M&O	Management and Operating Contractor
MT	metric tons
MTHM	metric tons heavy metal
N/A	not applicable
NG	nuclear grade
NNPP	Naval Nuclear Propulsion Program
NRC	U.S. Nuclear Regulatory Commission
OCRWM	Office of Civilian Radioactive Waste Management
PWR	pressurized water reactor
SDD	System Description Document
SNF	spent nuclear fuel
SR	Site Recommendation
TBD	to be determined
TBV	to be verified
TCR	Technical Change Request
TPDP	Technical Product Development Plan
TSPA	Total System Performance Assessment
WP	waste package
WPD	Waste Package Department
WPO	Waste Package Operations

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1. PURPOSE

The purpose of this analysis is to demonstrate the design of the naval spent nuclear fuel (SNF) waste package (WP) using the Waste Package Department's (WPD) design methodologies and processes described in the *Waste Package Design Methodology Report* (CRWMS M&O [Civilian Radioactive Waste Management System Management and Operating Contractor] 2000b). The calculations that support the design of the naval SNF WP will be discussed; however, only a sub-set of such analyses will be presented and shall be limited to those identified in the *Waste Package Design Sensitivity Report* (CRWMS M&O 2000c).

The objective of this analysis is to describe the naval SNF WP design method and to show that the design of the naval SNF WP complies with the *Naval Spent Nuclear Fuel Disposal Container System Description Document* (CRWMS M&O 1999a) and Interface Control Document (ICD) criteria for Site Recommendation. Additional criteria for the design of the naval SNF WP have been outlined in Section 6.2 of the *Waste Package Design Sensitivity Report* (CRWMS M&O 2000c).

The scope of this analysis is restricted to the design of the naval long WP containing one naval long SNF canister. This WP is representative of the WPs that will contain both naval short SNF and naval long SNF canisters. The following items are included in the scope of this analysis:

- Providing a general description of the applicable design criteria
- Describing the design methodology to be used
- Presenting the design of the naval SNF waste package
- Showing compliance with all applicable design criteria.

The intended use of this analysis is to support Site Recommendation reports and assist in the development of WPD drawings. Activities described in this analysis were conducted in accordance with the technical product development plan (TPDP) *Design Analysis for the Naval SNF Waste Package* (CRWMS M&O 2000a).

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2. QUALITY ASSURANCE

The development of this analysis is conducted under activity evaluation *Waste Package Design Methodology and AMRs – 1101 2125 M1* (CRWMS M&O 1999b). The results of that evaluation were that the activity is quality affecting in accordance with CRWMS M&O procedure QAP-2-0, *Conduct of Activities*, and is subject to the *Quality Assurance Requirements and Description* (DOE [U.S. Department of Energy] 2000) requirements. The Quality Assurance program applies to this analysis. The naval SNF long disposal container was classified, in accordance with QAP-2-3, *Classification of Permanent Items,* as Quality Level 1 in *Classification of the MGR Naval Spent Nuclear Fuel Disposal Container System* (CRWMS M&O 1999f). This analysis applies to the waste packages identified in *Naval Spent Nuclear Fuel Disposal Container System Description Document* (CRWMS M&O 1999a, Appendix B) as components of the overall system classified as Quality Level 1.

The control of this document is accomplished in accordance with AP-6.1Q, *Controlled Documents*, which provides for electronic source file verification. In process work is controlled through the checking process, which is governed by AP-3.10Q, *Analyses and Models*. The transmittal of the final product is conducted over the established YMP (Yucca Mountain Project) electronic infrastructure (e.g., e-mail, network servers). The fidelity of these systems is provided by other organizations and procedures. These controls meet the intent of AP-SV.1Q, *Control of the Electronic Management of Data.*

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3. COMPUTER SOFTWARE AND MODEL USAGE

No computer software or models were used in the production of this analysis.

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4. INPUTS

This design analysis provides a compilation of results from other technical documents. No calculations or numerical evaluations have been performed. The data shown in Table 1 are obtained from codes within CRWMS M&O (1999a). A statement on the appropriateness of U.S. Navy inputs appears in Section 4.1.2. The inputs are appropriate for use in this analysis.

The naval waste package that is the subject of this analysis consists of the naval long SNF canister, the shells (inner and outer) that comprise the disposal container, and the lids that close the disposal container. Results of technical documents that support criteria compliance are presented in Sections 6.3 and 6.4.

4.1 DATA AND PARAMETERS

The number of digits in the values cited herein may be the result of a calculation or may reflect input from other sources; consequently, the number of digits should not be interpreted as an indication of accuracy.

4.1.1 Material Specifications

The materials selected for the inner shell and the outer shell of the naval SNF disposal container are the American Society of Mechanical Engineers (ASME) alloys SA-240 S31600 and SB-575 N06022 (Alloy 22), respectively. The chemical compositions of these materials are presented in Table 1. Table 2 presents the temperature dependence for the tensile strength of SA-240 S31600.

Table 1. Chemical Compositions for the Materials of the Naval SNF Disposal Container.

Element	Material	
	Outer Shell SB-575 N06022[a] (Weight Percent)	**Inner Shell SA-240 S31600[b] (Weight Percent)**
Molybdenum	12.5-14.5	2.00-3.00
Chromium	20.0-22.5	16.00-18.00
Iron	2.0-6.0	Remainder
Tungsten	2.5-3.5	-
Cobalt	2.5 max	-
Carbon	0.015 max	0.08 max
Silicon	0.08 max	0.75 max
Manganese	0.50 max	2.00 max
Vanadium	0.35 max	-
Phosphorus	0.02 max	0.045 max
Sulfur	0.02 max	0.030 max
Nickel	Remainder	10.00-14.00
Nitrogen	-	0.10 max

SOURCES: [a] ASTM (American Society for Testing and Materials) B 575-97, *Standard Specification for Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-*

Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Plate, Sheet, and strip. p. 2.

[b] ASTM A 240/A 240M-95a, *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and strip for Pressure Vessels*. p. 2.

NOTE: The material specification ASTM B 575 N06022 is identical to ASME SB-575 N06022. The material specification ASTM A 240 S31600 is identical to ASME SA-240 S31600.

Table 2. Temperature Dependence for the Tensile Strength of SA-240 S31600

Temperature (°F)	-20 to 100	200	300	400	700	750	800	850	900	950	1000
Temperature (°C)	-29 to 38	93	149	204	371	399	427	454	482	510	538
Tensile Strength (ksi)	75.0	75.0	73.4	71.8	71.8	71.4	70.9	69.7	68.5	66.5	64.4
Tensile Strength (MPa)	517	517	506	495	495	492	489	481	472	459	444

SOURCE: ASME 1995, Section III, Table U.

4.1.2 Statement of the Quality of U.S. Navy Inputs

The Naval Nuclear Propulsion Program's (NNPP) quality assurance program has been reviewed and accepted by OCRWM. A statement addressing the quality of all NNPP activities related to OCRWM acceptance and eventual disposal of naval SNF in a geologic repository can be found in an enclosure submitted as part of a letter from the NNPP to the NRC, dated October 29, 1999 (Mowbray 1999). The YMSCO and OCRWM (including the Office of Quality Assurance) concurred with the enclosure prior to its submittal to the NRC. This enclosure appears as an addendum to the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998). The enclosure/addendum is classified. However, Section 1.4 of the addendum has been cleared for release; it reads:

> The NNPP has an extensive Quality Assurance Program ... that has been developed and used over the history of the NNPP. In 1998, OCRWM completed a review of the NNPP Quality Assurance Program and found the program acceptable for all NNPP activities related to OCRWM acceptance and eventual disposal of naval SNF in a geologic repository. NNPP programs described in this addendum conform to the NNPP Quality Assurance Program as will activities related to packaging and disposal of naval SNF.

In accordance with subsection 3.3 of AP-3.15Q, *Managing Technical Product Inputs*, a document can be considered a controlled source if, under an OCRWM-approved quality assurance program, it is: a) developed, reviewed, approved, and released, and b) maintained as current through processes that result in revising the controlled source when the information contained therein changes. The addendum to the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998) meets the above criteria.

4.1.3 Naval Canister Parameters

Thermal, structural, and shielding information for the naval SNF canister was provided by the U.S. Department of the Navy's NNPP transmittal dated August 6, 1999 (Naples 1999). Some basic thermal and structural parameters of the naval SNF canisters are tabulated in Tables 3 and 4 for the reader's benefit.

Table 3. Thermal Parameters of the Naval SNF Canisters

Parameter	Value
Design basis heat generation rate at time of emplacement	8,010 Watts
Average lumped thermal conductivity (long canister)	3.3 W/m-K
Weighted average lumped density	4,005 kg/m^3
Emissivity of canister	0.6
Average uranium loading per canister	0.22 metric tons

SOURCE: Naples 1999, Enclosure 1.

Table 4. Structural Parameters of the Naval SNF Canisters

Parameter	Value
Canister length (long)	5,350 mm (210.63 in.)
Canister diameter	1,679.4 mm (66.12 in.)
Bounding loaded canister weight	49.0 tons
Location of center of mass of a loaded long canister (measured from the bottom external surface)	Between 103 in. and 123 in.
Canister material	316L stainless steel

SOURCE: Naples 1999, Enclosure 3.

4.2 CRITERIA

The criteria governing the design of the naval SNF WP consist of one System Description Document (SDD), *Naval Spent Nuclear Fuel Disposal Container System Description Document*, (CRWMS M&O 1999a), and three ICDs. The ICDs are as follows:

- *U.S. Department of Energy* (DOE) *Spent Nuclear Fuel to the Monitored Geologic Repository for Mechanical and Envelope Interfaces* (DOE 1999a)
- *Interface Control Document For the Waste Packages/Disposal Containers and the Surface Repository Facilities and Systems For Mechanical, Envelope, and Functional Interfaces Between Surface Facilities Operations and Waste Package Operations* (CRWMS M&O 1998a)
- *Interface Control Document For Waste Packages and the Mined Geologic Disposal System Repository Subsurface Facilities and Systems For Mechanical, and Envelope Interfaces Between Engineered Barrier System Operations and Waste Package Operations* (CRWMS M&O 1998b).

4.2.1 System Description Criteria

The following SDD criteria apply to the design and development of all naval waste packages. The SDD provides a list of performance criteria for the naval SNF WP that is consistent with higher level documents and will result in the WP meeting higher level requirements. This section of the document will reiterate those criteria. Certain criteria not addressed in this document are enumerated in Table 5. Each criterion in this section also contains traceability, as applicable, to the criterion listed in the *Naval Spent Nuclear Fuel Disposal Container System Description Document* (CRWMS M&O 1999a).

Table 5. Omitted Criteria and Basis for Omission

SDD Section	Summary	Basis for Omission
1.2.5	Operational Criteria	No criteria are identified.
1.3	Subsystem Design Criteria	No criteria are identified.

4.2.1.1 Functional Criteria

The waste package must meet a number of functional criteria as outlined in the *Naval Spent Nuclear Fuel Disposal Container System Description Document* (CRWMS M&O 1999a). The functional criteria are listed in Table 6.

Table 6. Functional Criteria for the Naval SNF Waste Package

SDD	Functional Criterion
1.1.1	The waste package contains canistered, naval SNF within its boundary until it is breached.
1.1.2	The waste package restricts the transport of radionuclides to the outside of the waste package's boundary after it is breached.
1.1.3	The waste package provides criticality control during and after loading.
1.1.4	The waste package accommodates the thermal loading strategy for the repository.
1.1.5	The waste package provides identification of individual disposal containers and their contents.
1.1.6	The waste package provides safety for personnel, equipment, and the environment.
1.1.7	The waste package prevents adverse reactions involving the naval SNF during handling operations.
1.1.8	The disposal container/waste package withstands loading, handling, sealing, transfer, emplacement, and retrieval loads.
1.1.9	The waste package withstands the emplacement drift environment for the regulatory period of the repository.
1.1.10	The waste package provides conditions needed to maintain the physical and chemical stability of the naval SNF.
1.1.11	The waste package minimizes the mobilization of radionuclides.
1.1.12	The waste package conducts heat transfer between the naval SNF and the environment external to the waste package.
1.1.13	The disposal container/waste package accommodates handling, sealing, loading, emplacement, and retrieval operations.
1.1.14	The disposal container/waste package outer surface facilitates decontamination.

SOURCE: CRWMS M&O 1999a, Section 1.1.

4.2.1.2 System Performance Criteria

Table 7 summarizes the SDD criteria for the naval SNF WP, as established in CRWMS M&O (1999a). The column with the heading "SDD" indicates the SDD criterion identifiers. The column with the heading "Brief Description" describes the SDD criterion. The column heading "Comments" provides additional information on the SDD criterion and its compliance. The column with the heading "SR/LA" [Site Recommendation/License Application] describes which criteria will be addressed for SR and which will be addressed for LA (see CRWMS M&O 2000c). A N/A appearing in the column "SR/LA" indicates that the criterion will not be addressed by the WPD. The column denoted as "Section" indicates the applicable section of this analysis where criterion compliance is addressed.

Table 7. Naval Waste Package SDD Criteria

SDD	Brief Description	Comments	SR/LA	Section
1.2.1.1	The disposal container/waste package shall be designed such that the expected annual dose to the average member of the critical group shall not exceed 25 mrem total effective dose equivalent at any time during the first 10,000 years after permanent closure.	To be addressed by Performance Assessment in the TSPA.	N/A	6.3.1.1
1.2.1.2	The disposal container shall accommodate short (185.63 in.) and long (210.63 in.) naval SNF canisters made of 316L stainless steel (SS).	4715-mm short canister 5350-mm long canister Shown in sketch.	SR	6.3.1.2
1.2.1.3	The disposal container shall consist of an inner cylinder that is 5-cm (2-in.) thick stainless steel alloy 316L, and an outer cylinder that is 2-cm ($^3/_4$-in.) thick Alloy 22 material.	The outer cylinder will be 2.5-cm thick. Shown in sketch.	SR	6.3.1.3
1.2.1.4	The waste package shall have a minimum heat rejection flux of (TBD).	Thermal criterion	SR	6.3.1.4
1.2.1.5	The disposal container/waste package shall prevent the breach of the naval SNF canister during normal handling operations.	Normal operating loads are substantially less than design basis events loads.	LA	N/A
1.2.1.6	The disposal container/waste package shall be designed to support/allow retrieval up to 300 years after the start of emplacement operations.	Structural criterion	SR	6.3.1.5
1.2.1.7	The disposal container/waste package, excluding the labels, shall have an external surface finish Roughness Average of 250 μin (6.36 μm) or less.		LA	N/A
1.2.1.8	The disposal container/waste package shall have all external surfaces accessible for visual inspection and decontamination.	Shown in sketch.	SR	6.3.1.6
1.2.1.9	The disposal container/waste package shall have a label or other means of identification with a unique package identifier and contents information.		LA	N/A
1.2.1.10	All labels applied to the disposal container shall not impair the integrity of the waste package.	CRWMS M&O 2000c list the SR/LA status as N/A.	LA	N/A
1.2.1.11	All information contained on all labels applied to the disposal container/waste package shall be legible or read by remote means until permanent closure of the repository.		LA	N/A

Table 7. (Continued)

SDD	Brief Description	Comments	SR/LA	Section
1.2.1.12	Lifting features of the disposal container/waste package shall be designed for three times the maximum weight of the waste package without generating a combined shear stress or maximum tensile stress in excess of the corresponding minimum tensile yield strength of the materials.	Structural criterion	SR	6.3.1.7
1.2.1.13	The lifting features of the disposal container/waste package shall be designed for five times the weight of the waste package without exceeding the ultimate tensile strength of the materials.	Structural criterion	SR	6.3.1.8
1.2.1.14	The disposal container shall withstand the worst case handling environments encountered during loading, sealing, and transfer operations.		LA	N/A
1.2.1.15	The waste package shall withstand the worst case handling environments encountered during transfer, emplacement, and retrieval operations.		SR	6.3.1.7 6.3.1.8
1.2.1.16	The waste package shall be designed to achieve a reliability of (TBD) during the first 10,000 years after emplacement.	To be addressed by Performance Assessment in the TSPA.	N/A	6.3.1.9
1.2.1.17	The disposal container/waste package shall be constructed of non-combustible and heat resistant materials.		SR	6.3.1.10
1.2.1.18	Disposal container/waste package materials shall exclude the use of explosive or pyrophoric materials.		SR	6.3.1.11
1.2.1.19	Disposal container/waste package materials shall exclude the use of free liquids.		SR	6.3.1.12
Safety Criteria				
1.2.2.1.1	During the preclosure period, while in a horizontal orientation, the waste package shall be designed to withstand a 13-MT rock falling 3.1 m onto the side of the waste package without breaching.	Structural criterion Performed on the 21-PWR WP.	SR	6.3.2.1
1.2.2.1.2	During the preclosure period, while in a vertical orientation, the disposal container shall be designed to withstand a 2.3-MT object falling 2 m onto the end of the waste package without breaching.		LA	N/A
1.2.2.1.3	During the preclosure period, the disposal container/waste package, shall be designed to withstand (while in a vertical orientation) a drop from a height of 2 m onto a flat, unyielding surface.	Structural criterion	SR	6.3.2.3
1.2.2.1.4	During the preclosure period, the waste package, shall be designed to withstand (while in a horizontal orientation) a drop from a height of 2.4 m onto a flat, unyielding surface without breaching.	Structural criterion	SR	6.3.2.4
1.2.2.1.5	During the preclosure period, the waste package shall be designed to withstand (while in a horizontal orientation) the greater stress resulting from a drop of 1.9 m onto a steel support in an emplacement drift, or a drop of 2.4 m onto a concrete pier, without breaching by puncture.	Structural criterion Performed on the 44-BWR WP.	SR	6.3.2.2

Table 7. (Continued)

SDD	Brief Description	Comments	SR/LA	Section
1.2.2.1.6	During the preclosure period, the waste package shall be designed to withstand a tip over from a vertical position with slap down onto a flat, unyielding surface without breaching.	Structural criterion Performed on the 21-PWR WP.	SR	6.3.2.5
1.2.2.1.7	The waste package shall be designed to withstand a Frequency Category 2 Design Basis Earthquake. Both vibratory ground motion and fault displacement must be considered.	Structural criterion	SR/LA	6.3.2.6
1.2.2.1.8	During the preclosure period, the waste package shall be designed to withstand the impact of a 0.5-kg missile (a 1-cm diameter, 5-cm long valve stem) travelling at 5.7 m/s, without breaching.	Structural criterion	SR	6.3.2.7
1.2.2.1.9	During the preclosure period, the waste package shall be designed to withstand, without breaching, the maximum impact resulting from a transporter runaway, derailment, and impact, taking credit as appropriate for interfacing systems that prevent derailment and impact with the walls of the repository drifts or mitigate the impact on the waste package.	63 km/h maximum speed	LA	N/A
1.2.2.1.10	During the preclosure period, waste package shall be designed to withstand, without breaching, the maximum internal pressure of (TBD) at an ambient temperature less than or equal to (TBD) as generated by (TBD).	Structural criterion	SR	6.3.2.8
1.2.2.1.11	The waste package shall be designed to withstand the hypothetical fire criteria defined in 10 CFR 71, Section 73(c)(4).	CRWMS M&O 2000c list this criterion as SR/LA.	LA	N/A
1.2.2.1.12	During the preclosure period, the waste package shall be designed such that nuclear criticality shall not be possible. The effective neutron multiplication factor (k_{eff}) must be sufficiently below unity.	Demonstration of compliance with this criterion is beyond the scope of this document. CRWMS M&O 2000c list the SR/LA status as SR.	N/A	6.3.2.9
1.2.2.1.13	During the postclosure period, the naval SNF waste package shall be designed such that nuclear criticality shall not be credible for intact naval spent fuel. The calculated effective neutron multiplication factor (k_{eff}) must be shown to have at least a 5 percent margin to criticality.	Demonstration of compliance with this criterion is beyond the scope of this document.	N/A	6.3.2.10
System Environment Criteria				
1.2.3.1	The waste package shall meet all performance requirements during and after exposure to the emplacement drift environments.		LA	N/A
System Interfacing Criteria				
1.2.4.1	Comply w/ SRF to WPO interface control document.	B00000000-01717-8100-00021 (CRWMS M&O 1998a)	LA	N/A
1.2.4.2	Comply w/ EBSO to WPO interface control document.	B00000000-01717-8100-00009 (CRWMS M&O 1998b)	LA	N/A
1.2.4.3	Disposal container design shall reduce the dose rate at all external surfaces of a waste package to (TBD).	Shielding criterion	SR	6.3.3.1
1.2.4.4	The waste package shall be designed to have a maximum thermal output of 11.8 kW.	Thermal criterion	SR	6.3.3.2

Table 7. (Continued)

SDD	Brief Description	Comments	SR/LA	Section
1.2.4.5	The quantity of waste forms disposed of in this suite of disposal containers shall total approximately 65 MTHM.	Waste stream criterion	SR	6.3.3.3
1.2.4.6	The disposal container shall be designed for loading and sealing in a vertical orientation.	Shown in sketch.	SR	6.3.3.4
1.2.4.7	The disposal container/waste package shall be designed to be handled while in the horizontal orientation, the vertical orientation, and when the disposal container/waste package is transitioning between the horizontal and vertical position.	Structural criterion	SR	6.3.3.5
1.2.4.8	The disposal container/waste package shall be designed to support required welding times.		LA	N/A
Codes and Standards Criteria				
1.2.6.1	1995 ASME Boiler and Pressure Vessel Code (Section III, Division 1, Subsection NG-1995)	Structural criterion	SR	6.3.4.1
1.2.6.2	1995 ASME Boiler and Pressure Vessel Code (Section III, Division 1, Subsection NB-1995)	Structural criterion	SR	6.3.4.2
1.2.6.3	Nuclear Criticality Control of Special Actinide Elements (ANSI/ANS-8.15-1981)	Compliance with this criterion is beyond the scope of this document.	LA	N/A
1.2.6.4	Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors (ANSI/ANS-8.1-1998)	Compliance with this criterion is beyond the scope of this document.	LA	N/A
1.2.6.5	Criteria for Nuclear Safety Controls in Operations with Shielding and Confinement (ANSI/ANS-8.10-1983)	Compliance with this criterion is beyond the scope of this document.	LA	N/A
1.2.6.6	Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors (ANSI/ANS-8.17-1984)	Compliance with this criterion is beyond the scope of this document.	LA	N/A

SOURCE: CRWMS M&O 1999a, Section 1.2

NOTES: ANSI-American National Standards Institute, Inc.
ANS–American Nuclear Society
BWR-boiling water reactor
CFR-Code of Federal Regulations
EBSO-Engineered Barrier System Organization
LWR–light water reactor
MT–metric tons
LA-License Application
MTHM-metric tons heavy metal
PWR-pressurized water reactor
SRF-Surface Facility
TBD–to be determined
TSPA–Total System Performance Assessment
WPO–Waste Package Operations
N/A-Not Applicable
SR-Site Recommendation

4.2.2 Interface Control Criteria

Two of the ICDs (CRWMS M&O 1998a and CRWMS M&O 1998b) that govern the development of all naval waste packages are explicitly listed in naval SDD criteria 1.2.4.1 and 1.2.4.2. The third ICD (DOE 1999a) specifies dimensions, materials, and handling requirements for a superseded disposal container design. However, naval SDD criteria 1.2.1.2, 1.2.1.3, and 1.2.1.5 sufficiently cover the requirements addressed in DOE (1999a).

4.2.3 Other Considerations

An important consideration in the long-term integrity of the waste package is resistance to corrosion. Stress corrosion cracking occurs in susceptible metals experiencing tensile stresses in corrosive environments. Tensile stresses occur in the weld bead during cooling and are a result of the welding process. With the exception of the final closure welds, all the welds used to fabricate the waste package will be solution annealed at the manufacturer. This annealing will ensure a reduced tensile stress that prevents stress corrosion cracking and supports evaluations of corrosion rates by testing. Treatment of the final closure welds is addressed in Section 6.4.

Additional criteria for the waste packages identified in CRWMS M&O (2000c) are presented in Table 8.

Table 8. Additional Waste Package Criteria

Criterion	Brief Description	Comments	SR/LA	Section
1	This criterion imposes a manufacturing residual stress in the outer shell material below 20 percent of the yield strength for a depth of (TBD-235) (CRWMS M&O 2000c, Table 4) from the outer surface	21-PWR is selected to show compliance with this criterion.	SR	6.4
2	This criterion imposes a limit for the static loads. They must be below 20 percent of the yield strength in the outer shell material at the interface with the emplacement pallet	21-PWR is selected to show compliance with this criterion.	SR	6.3.1.5
3	This criterion imposes a limit for the seismic loads. They must be below the yield strength in the outer shell material.	It is a limitation of this document that the preclosure seismic criterion is not addressed.	SR/LA	N/A

SOURCE: CRWMS M&O 2000c, Section 6.2.

4.3 CODES AND STANDARDS

The codes and standards applicable to the design of the naval waste package have been identified in CRWMS M&O (1999a, Section 1.2.6). The applicable codes and standards are enumerated in Table 7 and discussed in Section 6.3.4.

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5. ASSUMPTIONS

In this analysis, the assumptions inherent in the work are divided into two categories.

The first category consists of the process and methodology assumptions that are necessitated either by the computational tool or by the particular application to the range of problems at hand. While a particular process or tool may be used to analyze a broad range of physical phenomena, the application of the same to processing and disposal of waste forms at the repository requires assumptions appropriate to the particular calculation. This category of assumptions is addressed in the *Waste Package Design Methodology Report* (CRWMS M&O 2000b, Section 5.1).

The second category of assumptions consists of those that are specific to a particular analysis or calculation. An example of this is a set of assumptions necessary to perform a drop calculation for a particular waste package. Those assumptions used in calculations that support this WP will be presented in this section.

5.1 SOURCE TERM

5.1.1 General Assumption

5.1.1.1 Photon and Neutron Currents

The photon and neutron currents at two-year decay time are assumed to evaluate an upper limit for the dose rates on the WP external surfaces. The rationale for this methodological assumption is that the source terms at two-year decay time generate conservative (higher) dose rates compared to source terms at a five-year decay time. Furthermore, the U.S. Navy provided the source terms as decay fractions by energy group relative to two-year decay times. This assumption is used in Section 6.3.3.1.

5.2 STRUCTURAL

5.2.1 General Assumptions

The following assumptions apply to the structural calculations. A list of the specific structural calculations that detail the given assumption is provided in parenthesis.

5.2.1.1 Temperature Dependent Material Properties

Some of the temperature-dependent material properties are not available for SB-575 N06022 (Alloy 22), SA-240 316 NG (316 NG SS), and SA-240 S31603 (316L SS). Therefore, room-temperature (20 °C) material properties are assumed for all materials. The impact of using room-temperature material properties is anticipated to be small. The rationale for this assumption is that the mechanical properties of said materials do not change significantly at the temperatures experienced during handling and lifting operations. This assumption applies to Sections 6.3.1.5, 6.3.1.7, 6.3.1.8, 6.3.2.3, 6.3.2.4, and 6.3.3.5 of this document (CRWMS M&O 2000e, CRWMS M&O 2000f, CRWMS M&O 2000g, CRWMS M&O 2000o, and CRWMS M&O 2000l).

5.2.1.2 Poisson's Ratio for Alloy 22

The Poisson's ratio of Alloy 625 is assumed for Alloy 22. The impact of this assumption is anticipated to be negligible. The rationale for this assumption is that the chemical compositions of Alloy 22 and Alloy 625 are similar. This assumption applies to Sections 6.3.1.5, 6.3.1.7, 6.3.1.8, 6.3.2.3, 6.3.2.4, and 6.3.3.5 of this document (CRWMS M&O 2000e, CRWMS M&O 2000f, CRWMS M&O 2000g, CRWMS M&O 2000o, and CRWMS M&O 2000l).

5.2.1.3 Poisson's Ratio of 316L

The Poisson's ratio of 316L SS is not available in literature. Therefore, the Poisson's ratio of 316 SS is assumed for the 316L SS used within the naval canister. The impact of this assumption is anticipated to be negligible. The rationale for this assumption is the similar chemical composition of these two stainless steels. This assumption applies to Sections 6.3.1.5, 6.3.2.3, and 6.3.2.8 of this document (CRWMS M&O 2000e, CRWMS M&O 2000f, and CRWMS M&O 2000g).

5.2.1.4 Solid Connection Between the Inner and Outer Shells

The inner and outer shells are assumed to have solid connections at the adjacent surfaces. The rationale for this assumption is that the design of the WP (at the time these calculations were performed) specifies the assembly of the inner and outer shells by shrink fit, or weld clad to one another. NOTE: A recent design change specifies the inner and outer shell be assembled using a slip fit technique that will allow up to a four-millimeter gap (radial) between the shells. This design change is not expected to affect the compliance of the naval SNF waste package with applicable criteria. The structural calculations had already been completed or were in process when the design change took effect. This assumption applies to Sections 6.3.1.5, 6.3.1.7, 6.3.1.8, 6.3.2.3, and 6.3.3.5 of this document (CRWMS M&O 2000e, CRWMS M&O 2000f, CRWMS M&O 2000g, and CRWMS M&O 2000l).

5.2.2 Supporting Assumptions for the Vertical Drop Calculation

The following assumptions were only given in *Vertical Drop of the Naval SNF Long Waste Package on Unyielding Surface* (CRWMS M&O 2000e). This calculation supports satisfaction of Naval SDD criterion 1.2.2.1.3.

5.2.2.1 Uniform Mass Density for Naval SNF Canister

The exact geometry of the naval SNF canister is simplified in such a way that its total mass, 44,452 kg, is distributed within the cylinder of circular cross section and uniform mass density. This assumption slightly increases the bending moment acting on the weld joining the lower inner shell lid and the inner shell. The rationale for this conservative assumption is to provide the set of bounding results, while simplifying the finite element representation. This assumption applies to Section 6.3.2.3 of this document.

5.2.2.2 Contact Stiffness for the Vertical Drop Calculation

The magnitude of the contact stiffnesses between the WP and the unyielding surface, the closure lid and the inner-lid lifting feature, and the outer lid and the closure-lid lifting feature are assumed to be 6×10^{10} N/m. The assumption for contact stiffness produces a different magnitude for each structural calculation. A statement of the assumption and its rationale for use are presented in the *Waste Package Design Methodology Report* (CRWMS M&O 2000b, Section 5.1) without mention of specific magnitudes. For this reason, the magnitude of the contact stiffness is mentioned here. This assumption applies to Section 6.3.2.3 of this document.

5.2.3 Supporting Assumption for the Outer Shell Stress Calculation

The following assumption was only given in *Tensile Stresses Developing in an Outer Shell of a Waste Package Mounted on an Emplacement Pallet* (CRWMS M&O 2000f). This calculation supports satisfaction of Naval SDD criterion 1.2.1.6, and the additional structural criterion 2 presented in Table 8.

5.2.3.1 Contact Stiffness for the Outer Shell Stress Calculation

The magnitude of the contact stiffness between the WP and the emplacement pallet is assumed to be 1×10^{8} N/m. The assumption for contact stiffness produces a different magnitude for each structural calculation. A statement of the assumption and its rationale for use are presented in the *Waste Package Design Methodology Report* (CRWMS M&O 2000b, Section 5.1) without mention of specific magnitudes. For this reason, the magnitude of the contact stiffness is mentioned here. This assumption applies to Sections 6.3.1.5 of this document

5.2.4 Supporting Assumption for the Internal Pressurization Calculation

The following assumption was given in *Internal Pressurization Due to Fuel Rod Rupture in Waste Packages* (CRWMS M&O 2000q). This calculation supports satisfaction of Naval SDD criterion 1.2.2.1.10.

5.2.4.1 Analysis of a 21-PWR WP Assumed to Bound the Naval SNF WP

The internal pressure of the 21-PWR WP is assumed for the naval SNF WP design. The rationale for this assumption is that the 21-PWR has a smaller diameter than the naval SNF waste package, and, due to the confidential nature of the fuel, there is no knowledge of the internals of the naval SNF canister. This assumption is used in Section 6.3.2.8 of the document.

5.2.5 Supporting Assumptions for the Horizontal Drop Onto an Unyielding Surface

5.2.5.1 Rate Dependent Material Properties

Some of the rate-dependent material properties were not available for the materials used. Therefore, the material properties obtained under the static loading conditions were assumed for all materials. In general, this is a conservative assumption. In this case, the impact of using material properties obtained under the static loading conditions was anticipated to be small. The rationale for this assumption is that the mechanical properties of subject materials do not significantly change at the peak strain rates in the course of the 2.4 m horizontal drop. This assumption is used in Section 6.3.2.4 of the document.

5.2.5.2 Large Elastic Modulus Used for the Unyielding Surface

The target surface was conservatively assumed to be essentially unyielding by using a large elastic modulus for the target surface compared to the waste package. The rationale for this assumption is that a bounding set of results is desired in terms of stresses and it is known that the use of an essentially unyielding surface ensures slightly higher stresses in the WP. This assumption is used in Section 6.3.2.4 of the document.

5.2.5.3 Simplified Geometry for the Naval SNF WP

The exact geometry of the Naval SNF canister is simplified for the purpose of this calculation in such a way that its total mass, 44,452 kg (see Section 5.3), is assumed to be distributed within a cylinder of circular cross section and uniform mass density. This assumption slightly increases the bending moment acting on the weld joining the lower inner shell lid and the inner shell. The rationale for this conservative assumption is to provide the set of bounding results, while simplifying the finite element representation (FER). This assumption is used in Section 6.3.2.4 of the document.

5.3 THERMAL

5.3.1 Supporting Assumptions for the Thermal Calculation

The following assumptions were given in *Thermal Analysis of the Naval SNF Waste Package* (CRWMS M&O 2000m). This calculation supports satisfaction of Naval SDD criterion 1.2.1.4.

5.3.1.1 Properties of Helium at One Atmosphere

The properties of helium at a pressure of one atmosphere is assumed to be representative of the conditions that it will experience in the WP. The rationale for this assumption is the fact that a one-atmosphere fill pressure at ambient temperature is representative of industry standard for storage casks. The highest pressure to which storage casks are filled is approximately 1.5 atmosphere; also, most industry vendors use substantially lower pressure in their designs (Knoll and Gilbert 1987). Even though the internal pressure of the WP will increase due to the temperature rise, the thermal conductivity of most gases is pressure-independent, provided the mass density remains constant. Thus, using the thermal conductivity at one atmosphere is reasonable. This assumption applies to Section 6.3.1.4.

5.3.1.2 Half Cross Section Representation

The calculation represented half the WP cross section. The rationale for this assumption is the following. The geometry of the cross section is symmetrical about the cutting planes of the representation. Therefore, the heat conduction paths will also be symmetrical, resulting in no heat conduction across the cutting planes. The radiative heat transfer across these cutting planes is assumed negligible relative to the radiative heat transfer in the rest of the cross section. This assumption applies to Section 6.3.1.4.

5.3.1.3 Decay Heat Output of Naval SNF Canister

The decay heat output of the naval SNF canister beyond 250 years after reactor shutdown is assumed to remain constant at the 250-year value. The U.S. Navy has not provided values of SNF heat output beyond 250 years. The rationale for this assumption is to ensure the naval SNF WP provides appropriate thermal heat flux values for the surface of the naval SNF canister under conditions that bound all expected. This assumption applies to Section 6.3.1.4.

5.3.1.4 Centered Configuration of Components

The naval SNF canister is assumed centered within the WP. The rationale for this assumption is to simplify the model and create the most thermally limiting configuration of components, ensuring that the model will give the highest possible temperatures within the WP. This assumption applies to Section 6.3.1.4.

5.3.1.5 Emissivity of 316L

The emissivity of stainless steel 316L is assumed to be 0.60. The rationale for this assumption is consistency with the range of emissivity for this material (0.57-0.66). This assumption applies to Section 6.3.1.4.

5.3.1.6 Boundary Conditions for Thermal Calculation

The boundary temperature history for a naval SNF WP is assumed to be bounded by the boundary temperature history for the design basis 21-PWR WP. The rationale for this assumption is that the 21-PWR WP has a smaller diameter and a higher heat generation rate (11.8 kW), providing conservative temperatures within the WP. This assumption applies to Section 6.3.1.4.

5.3.1.7 Homogenous Volumetric Heat Generation

The entire internal volume of the naval canister is assumed to generate heat. This allows the use of smeared properties within the naval canister. The rationale for this assumption is that the internals of the canister are unknown to the WPD and it allows for the uniform heating of the waste package surface. This assumption applies to Section 6.3.1.4.

5.4 SHIELDING

5.4.1 Supporting Assumption for the Shielding Calculation

The assumption used in the shielding calculations referenced in this analysis is described in the *Calculation of the Surface Dose Rates for the Single-CRM Naval SNF Waste Package* (CRWMS M&O 2000d). This calculation supports satisfaction of Naval SDD criterion 1.2.4.3.

5.4.1.1 Material Properties for 316 NG

The properties of stainless steel 316L are assumed for the SS 316 NG in the inner shell of the WP. The properties of SS 316 NG were not available. The rationale for this assumption is that the two materials have similar chemical compositions and the same density, which results in nearly identical radiation attenuation properties. This assumption applies to Section 6.3.3.1.

5.5 CRITICALITY STATEMENT

Due to the confidential nature of naval reactor fuel, no criticality calculations will be performed by the WPD. The U.S. Navy has provided an addendum to the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998), which outlines the criticality methodology used by the NNPP. Any assumptions concerning criticality are beyond the scope of this document.

6. ANALYSIS/MODEL

This section will demonstrate that the naval disposal container/waste package design satisfies the system criteria presented in Section 4.2. However, the reader is reminded that only the Naval SNF Disposal Container SDD criteria selected for Site Recommendation will be addressed. The remaining SDD criteria will be addressed, as a part of the licensing process, after Site Recommendation.

There are criteria that impose the size and materials for the naval disposal container. For those criteria, an examination of the sketches that show the design of the naval disposal container is necessary. Designing a fully compliant WP within project criteria requires elaborate analytical methods. The analytical methods used by the WPD for the design of the naval SNF long waste package is described in *Waste Package Design Methodology Report* (CRWMS M&O 2000b). The results of the structural, thermal, and shielding calculations are presented in Section 6.3.

This section contains no discussion of alternate methods, as there are no alternate methods that are considered applicable. This analysis does not provide estimates of any of the factors for the Post-closure Safety Case or Potentially Disruptive Events, and is, therefore, assigned Level 3 importance.

6.1 STATEMENT ON NAVAL SNF CRITICALITY CRITERIA COMPLIANCE

The U.S. Navy has provided an addendum to the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998), which outlines the naval methodology and compliance with SDD criteria 1.2.2.1.12 and 1.2.2.1.13. This addendum was submitted to the U.S. Nuclear Regulatory Commission (NRC) for review, as an enclosure, in a letter from the NNPP to the NRC on October 29, 1999 (Mowbray 1999).

No criticality calculations for the naval SNF long waste package will be performed by WPD. Naval Reactors will perform all criticality analyses related to naval NSF. Compliance with naval SDD criteria 1.2.2.1.12 and 1.2.2.1.13 are outside the scope of this analysis.

6.2 NAVAL SPENT NUCLEAR FUEL WASTE PACKAGE DESIGN

The naval SNF long WP provides long-term confinement of the naval long canister. It is designed to withstand loading, transfer, emplacement, and retrieval loads and long term exposure to the repository environment. The design of the naval SNF long WP is shown in the isometric view located in Attachment I and illustrated in Figure 1. For Site Recommendation, this is the only design for which the application of the design methodology and processes will be demonstrated. The Sketch SK-0194, presented in Attachment II, shows the design of the naval SNF long WP for the disposal of one naval long canister.

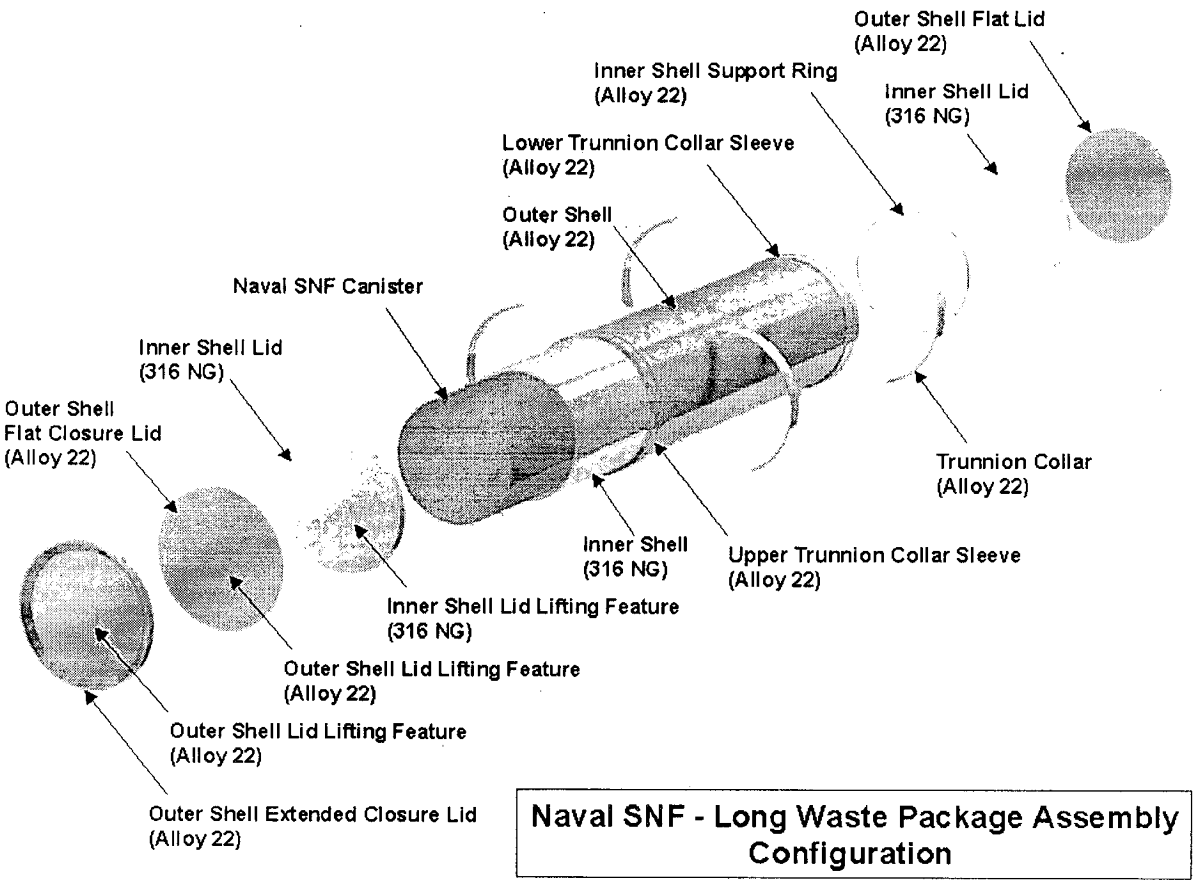

Figure 1. Isometric View of the Naval Long SNF Waste Package

The naval SNF waste package is essentially a right-circular cylinder comprised of two separate layers. Each layer is a cylindrical shell and henceforth will be called the inner shell and the outer shell. The inner shell is of 50-mm-thick 316 NG stainless steel, SA-240 S31600, which is rolled to a 1.819-m outside diameter and provides structural support for the waste package. The outer shell is comprised of a 25-mm-thick high-nickel alloy, SB-575 N06022 (Alloy 22), that is rolled to a 1.869-m outside diameter and provides a corrosion resistant barrier. The waste package contains two lower lids that are welded to the shells and annealed at the time of fabrication. This allows the disposal container to be loaded and sealed in a vertical orientation. The shells are loose fit in the following manner: the outer shell is heated to 350 °C to allow the inner shell to be slid into place. Once the outer shell cools, a gap in the range of 0-4 mm (radius) is present between the shells. The thickness of the waste package shells has been determined by the criterion to withstand a rock-fall design basis event. The *Rock Fall and Vertical Drop Calculations of Waste Packages* (CRWMS M&O 1999d, Table 6.1-4) calculation considers a 21-PWR waste package to determine the effect of a rock-fall design basis event on the containment shells of the waste package. The thickness of shells for the rest of the waste package designs is obtained by correlation with the 21-PWR waste package shell thickness. Considering the difference in waste package diameters and accounting for the effects of stress within the components, an increase of 5 mm was judged necessary for the thickness of the Alloy 22 shell to prevent perforation. Three upper lids will be welded in place after loading the disposal container with the appropriate naval canister. Each lid is fitted with a centered lifting feature (see Attachment II, page 2), which allows it to be robotically placed and welded. The inner shell lid is 130-mm thick, made of stainless steel SA-240 S31600, and once welded will not be annealed or peened. The outer shell closure lid weld will be laser peened to reduce tensile stresses and prevent stress corrosion cracking (see Section 6.4.2 for a description of the laser peening process). The outer shell extended lid weld will be induction annealed to reduce tensile stresses and prevent stress corrosion cracking (see Section 6.4.1 for a description of the induction annealing process). To allow vertical and horizontal handling of loaded waste packages, each end of the disposal container is fitted with trunnion collar sleeves. The trunnion collar sleeves, 40-mm thick and 340-mm in width (minimum) allow the placement and removal of lifting trunnions. No pyrophoric or explosive materials are used in the design of the naval disposal container. It is composed of stainless steel and low-carbon nickel-molybdenum-chromium alloys, which are made of solid elements, as shown in Table 1. The waste package cavity is 5.415 m in length. The waste package cavity allows emplacement of one naval SNF canister. The dimensions and materials of the naval long SNF WP components are summarized in Table 9.

Table 9. Dimensions and Material Specifications for the Disposal Container

Component	Material	Thickness (mm)	Mass (kg)
Inner shell	SA-240 S31600	50	12,376
Outer shell	SB-575 N06022	25	7,430
Inner shell lid	SA-240 S31600	130	2,390
Extended outer shell lid	SB-575 N06022	25	158
Extended outer shell lid base	SB-575 N06022	25	528
Extended lid reinforcement ring	SB-575 N06022	50	118
Outer shell flat closure lid	SB-575 N06022	10	227
Outer shell flat bottom lid	SB-575 N06022	25	564
Inner lid lifting feature	SA-240 S31600	27	12
Outer lid lifting feature	SB-575 N06022	27	13
Inner shell support ring	SB-575 N06022	20	49
Upper Trunnion Collar Sleeve	SB-575 N06022	40	604
Lower Trunnion Collar Sleeve	SB-575 N06022	40	592
Total Alloy 22 welds	SFA-5.14 N06022	-	416
Total 316 welds	SFA-5.9 S31600	-	243
Waste package assembly	-	-	28,005
Naval SNF canister	-	-	44,452
WP with naval SNF canister	-	-	72,457

6.3 SATISFACTION OF SDD CRITERIA

This section contains the demonstration that a waste package design can be created that will satisfy the applicable SDD criteria (see Table 7). This demonstration will not address all of the SDD criteria. In some cases, the demonstration of a particular criterion is not appropriate for Site Recommendation because it relies on details of the design of other components that will not be formulated for Site Recommendation (e.g., transporter design for preclosure fire and transporter runaway design basis events). In other cases, the particular SDD criterion rely on the details of processes that will not be defined for Site Recommendation (e.g., closure weld process). Finally, there are some analyses for which the naval SNF long waste package is less representative or less limiting than another waste package design.

6.3.1 System Performance Criteria

6.3.1.1 Limiting Total Effective Dose (1.2.1.1)

The waste package designs developed in this analysis were provided to Performance Assessment Operations (PAO). The demonstration of compliance with this criterion is in the Total System Performance Assessment report for Site Recommendation. Since that report will not be completed before the initial issuance of this document, satisfaction of this criterion cannot be demonstrated.

6.3.1.2 Accommodation of Naval SNF Canisters (1.2.1.2)

There are two naval SNF canisters that must be accommodated by waste package designs. The naval canisters have the same diameter (1.6794 m) and different lengths. The short canister is 4.715 m in length and the long canister is 5.350 m in length (CRWMS M&O 1999a). Two waste packages have been designed and developed. The naval SNF short waste package accommodates the naval short canister and the naval SNF long waste package accommodates the long canister. The two packages, differing only in length, are identical in materials, diameter, lid and weld details. A sketch of the naval long SNF WP is given in Attachments II. Compliance with this criterion is demonstrated.

6.3.1.3 Thickness and Composition of Cylinders (1.2.1.3)

The SDD specifies that the outer cylinder be constructed of approximately 20-mm-thick Alloy 22. Due to the SDD criterion for preclosure rock fall, an outer cylinder thickness of 25 mm has been specified by WPD (see Section 6.3.2.1). The 25-mm thick outer shell exceeds the 20-mm criterion. The material callout shown in Attachment II specifies the use of SB-575 N06022, which is the ASTM material designation for Alloy 22.

The SDD specifies the inner cylinder be constructed of approximately 50-mm-thick 316L stainless steel. This criterion is in conflict with Section 2.2.1.1.10 of the *Monitored Geologic Repository Project Description Document* (CRWMS M&O 1999c). Section 2.2.1.1.10 specifies the use of SS 316 NG. The material callout located in Attachment II specifies the use of SA-240 S31600, which is ASTM SS-316 NG (nuclear grade).

The required thickness of the waste package shells is dictated by a number of considerations, including long-term performance and reliability, as well as demonstrated survival of mechanical challenges to the waste package. The latter analyses are enumerated in Table 10. Compliance is demonstrated for this criterion.

Table 10. List of Design Basis Events Important to Sizing Shell Thickness

Design Basis Event	Discussion for Navy Long SNF WP
Avoidance of breach for transfer, emplacement, and retrieval	6.3.1.7, 6.3.1.8
Preclosure rock fall without breach	6.3.2.1
Preclosure impact on end of waste package without breach	N/A
Preclosure vertical drop without breach	6.3.2.3
Preclosure horizontal drop without breach	6.3.2.4
Preclosure horizontal drop without puncture	6.3.2.2
Preclosure tip over and slap down without breach	6.3.2.5
Sustain a design basis earthquake	6.3.2.6
Preclosure missile impact without breach	6.3.2.7
Sustain preclosure design basis transporter accident	N/A
Preclosure internal pressure limit	6.3.2.8
Sustain design basis fire	N/A

NOTE: N/A = Not Applicable

6.3.1.4 Waste Package Heat Rejection Flux (1.2.1.4)

The naval SNF canister and waste package were represented in a single calculation using finite element analysis (FEA). The FEA is used as implemented in the computer code ANSYS, Version 5.4. ANSYS V5.4 is identified as CSCI 30040 V5.4 and is obtained from SCM in accordance with appropriate procedures. ANSYS V5.4 is a commercially available FEA code. ANSYS V5.4 software is qualified as documented in the SQR for ANSYS V5.4.

Compliance with naval SDD criterion 1.2.1.4 is not possible because the criterion is TBD. Performance of the naval SNF long WP is presented in *Thermal Evaluation for the Naval SNF Waste Package*, (CRWMS M&O 2000m). The boundary conditions for the calculation were developed in a series of thermal calculations. These calculations utilized a multi-scale representation of the repository.

The larger representation approximates the repository as a drift segment within an infinitely repeating series of "pillars", extending from the top of the mountain to a plane well into the saturation zone (CRWMS M&O 2000j). Layers corresponding to the stratigraphy of the mountain represent the host rock of the repository. For each of these layers thermal transport properties appropriate to the local properties were used. Adiabatic surfaces occur laterally at the center of the rock masses between the drifts. The drift segment contains two and one-half waste packages with time-dependent heat generation rates. The attributes of each waste package (diameter, length, heat generation rate, etc.) can be adjusted to represent any waste package or configuration of waste packages. Typically, one waste packages heat generation rate was adjusted to create a thermally balanced drift segment, which accurately represents the entire repository. This representation calculated the time-dependent boundary conditions present on the surface of various waste packages. Once the time-dependent surface temperatures were known, they served as boundary conditions for the smaller representation. The smaller representation (CRWMS M&O 2000m) is of the canister and waste package as a 2-D cross section. The interior of the waste package is explicitly modeled and the time-dependent temperatures at several points within the waste package and canister are calculated and the heat flux from the surface of the naval SNF canister is determined. The SDD criterion is intended as a protection of the waste form and the radionuclide barrier to assist in the prevention of the release of radionuclides (waste isolation). The current SDD as written is TBD and implies a minimum required flux. A minimum flux criterion places an impractical constraint upon the design of the waste package. However, in an earlier naval transmittal, a heat flux criterion based on the maximum allowable heat flux for a given range of temperatures was presented for the naval SNF canister (Naples 1999, Table 6). Table 11 shows the information given in Naples (1999).

Table 11. Maximum Allowable Heat Flux for the Naval SNF Canister

Heat Flux at Canister Surface (kW/m^2)	Peak Canister Surface Temperature (°C)
0.600	50
0.535	131
0.491	197
0.224	216

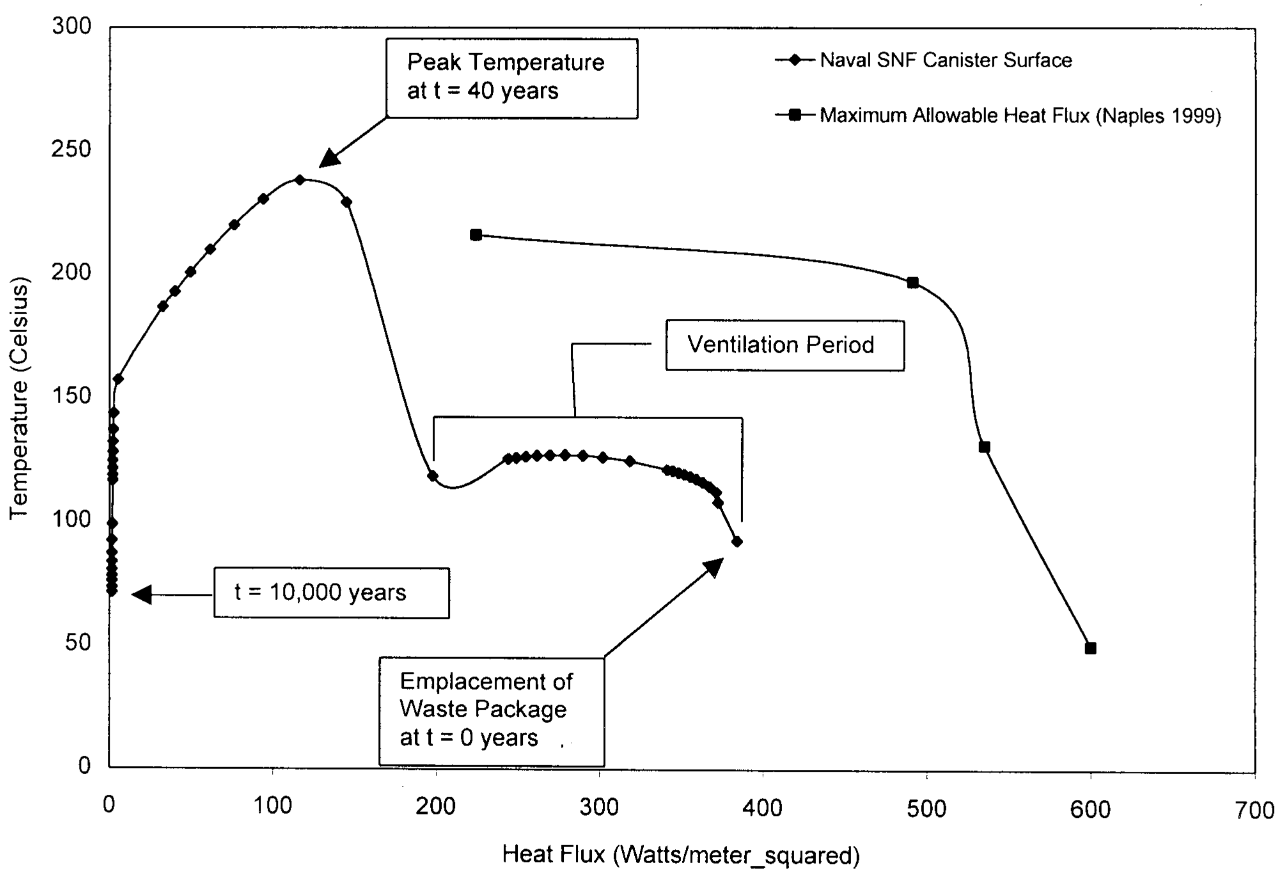

Figure 2. Naval SNF Canister Surface Heat Flux Versus Temperature

The *Thermal Evaluation for the Naval SNF Waste Package* (CRWMS M&O 2000m, Attachment XXII) gives the calculated heat flux on the surface of a design basis naval SNF canister experiencing conditions expected within the current repository design. Figure 2 shows a comparison of the maximum allowable heat flux curve given in Table 11 with the calculated heat flux on the surface of the naval SNF canister.

6.3.1.5 Retrieval Contingency Period (1.2.1.6)

The waste package must be designed to allow retrieval up to 300 years after emplacement. The naval long SNF waste package is the heaviest waste package for the purposes of retrieval. The following calculations demonstrate the waste package ability to withstand retrieval loads: *Tensile Stresses Developing in an Outer Shell of a Waste Package Mounted on an Emplacement Pallet* (CRWMS M&O 2000f) and *Structural Calculations for the Lifting of a Loaded Emplacement Pallet* (CRWMS M&O 2000g). These calculations utilized FEA. The FEA is used as implemented in the computer code ANSYS, Version 5.4. ANSYS V5.4 is identified as CSCI 30040 V5.4 and is obtained from SCM in accordance with appropriate procedures. ANSYS V5.4 is a commercially available FEA code. ANSYS V5.4 software is qualified as documented in the SQR for ANSYS V5.4.

The calculation *Tensile Stresses Developing in an Outer Shell of a Waste Package Mounted on an Emplacement Pallet* (CRWMS M&O 2000f) demonstrates the ability of the waste package to be emplaced without plastic deformation or damage to the outer shell. The method used developed a three-dimensional finite element representation as a one-fourth-symmetry representation of the emplacement pallet and waste package. In addition, the representation is simplified by replacing the internal structure of the waste package with an equivalent set of forces acting along the line of contact between the inner shell and the naval canister in the direction of gravitational acceleration. The benefit of using this approach is to reduce the computer execution time while preserving all features of the problem relevant for the structural calculation. Though the design of the naval WP has been changed, the mass of the naval canister and the dimensions of the outer and inner shells remained intact, while the mass of the loaded WP assembly is even smaller than that in the original design. Therefore, the calculation results are not affected and it is not necessary to repeat the calculation. The results show that the maximum tensile stress magnitudes developed in the outer shell in the tangential (hoop) and axial directions are 17 MPa and 7 MPa, respectively. These stress intensity magnitudes are less than one-fifth of the yield strength for the Alloy 22. This calculation also satisfies criterion 2 of CRWMS M&O (2000c, Table 6.2).

The calculation *Structural Calculations for the Lifting of a Loaded Emplacement Pallet* (CRWMS M&O 2000g) demonstrates the ability of the waste package and pallet to be lifted together as a single unit. This is necessary for emplacement and retrieval of the waste package. The method used developed a three-dimensional finite element representation that took advantage of two planes of symmetry. The resulting one-eighth symmetry representation shows the waste package mounted on the emplacement pallet. By disregarding the internal structure of the waste package, its representation is reduced to a cylinder of uniform mass density. The density is defined by the overall mass and size of waste package and is appropriately modified to take into account its one-eighth symmetry. Though this calculation was performed for a previous version of the naval WP, the mass of naval canister and the dimensions of the outer and inner shells remained unchanged. While the overall mass of loaded WP is less than that of the previous design, the calculation results are not affected, and it is not necessary to repeat the calculation. The results show that the maximum stress intensities among the emplacement pallet Alloy 22 and 316L SS components are 96 MPa and 39 MPa, respectively. These stress intensity magnitudes are less than one-third of the yield strength and one-fifth of the tensile strength for each of the corresponding materials. Atmospheric corrosion penetration rates for Alloy 22 and 316L SS are 0.0093 μm/y and 0.025 μm/y, respectively. Therefore, the expected cumulative decrease of thickness of the structural members of the emplacement pallet over 300 years of preclosure emplacement is 2.8 μm for Alloy 22 and 7.5 μm for 316L SS. This negligible level of corrosion renders the waste package retrieval calculation unnecessary since the consequential change of the results presented in this document would be insignificant.

The composite results of the above calculations show compliance with the SDD criteria.

6.3.1.6 Inspectability of Waste Packages (1.2.1.8)

It may be demonstrated by inspection of the sketch in Attachment II that all surfaces are accessible for visual inspection and decontamination.

6.3.1.7 Capacity of Lifting Devices – Tensile Yield Strength (1.2.1.12); Transfer, Emplacement, and Retrieval Operations (1.2.1.15)

The naval SNF waste package is lifted using attachable trunnion rings. Each trunnion ring locks into grooves located at both ends of the WP and hereafter identified as collar sleeves. The following calculation demonstrated the ability of the waste package lifting device to withstand loads: *Waste Package Lifting Calculation* (CRWMS M&O 2000l). This calculation utilized FEA. The FEA is used as implemented in the computer code ANSYS, Version 5.4. ANSYS V5.4 is identified as CSCI 30040 V5.4 and is obtained from SCM in accordance with appropriate procedures. ANSYS V5.4 is a commercially available FEA code. ANSYS V5.4 software is qualified as documented in the SQR for ANSYS V5.4.

The method used evaluates the lifting of the Naval SNF waste package both horizontally and vertically. To calculate the structural response of the waste pacakge to a horizontal lifting operation, a 3-D half waste package representation was developed to take advantage of symmetry. For the naval waste package, the 3-D representation did not include the naval canister. The mass of the naval canister has been applied to the inner shell to match the mass of the waste package. The lifting mechanism is designed such that the trunnion rings will be placed around both collar sleeves to lift the waste package horizontally. Therefore, the bottom half of the collar sleeve surface is constrained as a boundary condition. To calculate the structural response of the waste package to a vertical lifting operation, a 3-D representation of half a waste package was developed to take advantage of symmetry. Only inner and outer shells and collar sleeves are included in the ANSYS representations for the naval waste package. The masses of the components internal to the inner shell are added to the inner shell to match the total waste package mass. Since the critical part of the waste package for vertical lifting are the collar sleeve welds, the lifting sleeves are modified to leave small gaps between the outer shell and sleeves. Mesh refinement has been performed around the weld regions to give resolution of stress.

Boundary conditions constrained the upper surface of the collar sleeve and gravitational acceleration was applied in both the horizontal and vertical directions.

The criterion is for the tensile yield strength to be at least three times the magnitude of the maximum expected lifting stress. The structural response of the waste package to lifting is reported using maximum stress values obtained from a finite element solution to the problem (CRWMS M&O 2000l). The greater value between the stress intensity and the first principal stress is presented for each component of the waste package, in Tables 12 and 13.

Table 12. Calculation Results for Horizontal Lifting of Naval Long Waste Package

Waste Package Component	Maximum Stress (MPa)
Upper lifting collar sleeves	12.6
Lower Lifting collar sleeves	14.5
Outer shell and lids	7.5
Inner shell and lids	4.3

Table 13. Calculation Results for Vertical Lifting of Naval Long Waste Package

Waste Package Component	Maximum Stress (MPa)
Upper lifting collar sleeves	15.6
Outer shell and lids	9.1
Inner shell and lids	2.1

Compliance is demonstrated with criterion 1.2.1.12. The tensile yield strength of Alloy 22 (310 MPa) is greater than three times the maximum expected stress (3 x 15.6 MPa = 46.8 MPa). Compliance is demonstrated with criterion 1.2.1.15 by demonstrating the ability to safely lift and handle the WP. Simultaneous compliance of criteria 1.2.1.12 and 1.2.1.13 demonstrate an ability to lift and handle the WP. See Section 6.3.1.8 compliance with criterion 1.2.1.13 and overall demonstration of compliance with criterion 1.2.1.15.

6.3.1.8 Capacity of Lifting Devices – Ultimate Tensile Strength (1.2.1.13); Transfer, Emplacement, and Retrieval Operations (1.2.1.15)

The method used evaluates the lifting of the Naval SNF waste package can be found in Section 6.3.1.7. The following calculation demonstrated the ability of the waste package lifting device to withstand loads: *Waste Package Lifting Calculation* (CRWMS M&O 2000l). This calculation utilized FEA. The FEA is used as implemented in the computer code ANSYS, Version 5.4. ANSYS V5.4 is identified as CSCI 30040 V5.4 and is obtained from SCM in accordance with appropriate procedures. ANSYS V5.4 is a commercially available FEA code. ANSYS V5.4 software is qualified as documented in the SQR for ANSYS V5.4.

The criterion is for the ultimate tensile strength of the material to be at least five times the magnitude of the maximum expected lifting stress. The structural response of the waste package to lifting is reported using the maximum stress values obtained from the finite element solution to the problem (CRWMS M&O 2000l). Maximum stress is reported in Table 12 and Table 13 for each component of the waste package.

Compliance with criterion 1.2.1.13 is demonstrated by showing the ultimate tensile strength of Alloy 22 (690 MPa) is greater than five times the maximum expected stress (5 x 15.6 MPa = 78.0 MPa). Compliance is demonstrated with criterion 1.2.1.15 by demonstrating the combined compliance of criteria 1.2.1.12 and 1.2.1.13 to show the ability to safely lift and handle the waste package.

6.3.1.9 Waste Package Reliability for 10,000 Years (1.2.1.16)

The waste package designs developed in this report are provided to PAO. The demonstration of compliance with the criterion is in the Total System Performance Assessment report for Site Recommendation. Since that report will not be completed before the initial issuance of this document, satisfaction of this criterion cannot be demonstrated.

6.3.1.10 Use of Non-combustible and Heat Resistant Materials (1.2.1.17)

Compliance is demonstrated by inspection of the sketch shown in Attachment II, which shows the material call-outs for all components of the waste package are metallic and, hence, non-combustible. Similarly, the metals selected, which are not necessarily refractory, are resistant to heat. It can also be shown that the naval canister and its internal components must conform to Section 4.2.2 of the *Waste Acceptance System Requirements Document* (DOE 1999b), which precludes the use of these materials.

6.3.1.11 Exclusion of Explosive or Pyrophoric Materials (1.2.1.18)

Compliance is demonstrated by inspection of the sketch shown in Attachment II, which shows the material call-outs for all components of the waste package exclude explosive and pyrophoric materials. It can also be shown that the naval canister and its internal components must conform to Section 4.2.2 of the *Waste Acceptance System Requirements Document* (DOE 1999b), which precludes the use of these materials.

6.3.1.12 Exclusion of Free Liquids (1.2.1.19)

Compliance is demonstrated by inspection of the sketch shown in Attachment II, which shows the material call-outs for all components of the waste package exclude the use of free liquids. It can also be shown that the naval canister and its internal components must conform to Section 4.2.2 of the *Waste Acceptance System Requirements Document* (DOE 1999b), which precludes the use of free liquids.

6.3.2 Safety Criteria

6.3.2.1 Preclosure Rock Fall Without Breach (1.2.2.1.1)

The 21-PWR waste package was chosen as the representative waste package for preclosure rockfall. A calculation entitled *Rock Fall Calculations for Single Corrosion Resistant Material Waste Packages* (CRWMS M&O 1999e) describes the method and results for the 21-PWR WP. It is the most common package and, hence, the most likely to suffer a rock fall event. It was also chosen for its thinner wall thickness in the outer shell Alloy 22 (20 mm vs. 25 mm) and its greater sensitivity to internal basket deformation. The method used to evaluate the 21-PWR will be used to evaluate the naval SNF WP for compliance.

6.3.2.2 Preclosure Horizontal Drop onto a Steel Support or Concrete Pier Without Breach (1.2.2.1.5)

The 44-BWR waste package was chosen as the representative waste package for a preclosure horizontal drop of 1.9-m onto a steel support or 2.4-m onto a concrete pier. However, in-drift drops of waste packages would also include the attached pallet. A drop of the pallet/waste package combination would allow the pallet to act as a crush zone or impact buffer for the waste package. Pallet puncture of the waste package is of greater concern than is steel support or concrete pier puncture. Future consideration of this criterion will address a pallet/waste package drop onto an unyielding surface. A calculation entitled *Puncture Drop of 44-BWR Waste Package* (CRWMS M&O 2000n) describes the method and results for the 44-BWR WP. It was chosen for its thinner wall thickness in the outer shell Alloy 22 (20 mm vs. 25 mm) and its greater sensitivity to internal basket deformation. The method used to evaluate the 44-BWR will be used to evaluate the naval SNF WP for compliance.

6.3.2.3 Preclosure Vertical Drop Without Breach (1.2.2.1.3)

The survivability of a naval SNF waste package due to a vertical drop has been demonstrated in a calculation entitled *Vertical Drop of the Naval SNF Long Waste Package on Unyielding Surface* (CRWMS M&O 2000e). This calculation utilized FEA. The FEA is used as implemented in the computer code ANSYS, Version 5.4. ANSYS V5.4 is identified as CSCI 30040 V5.4 and is obtained from SCM in accordance with appropriate procedures. ANSYS V5.4 is a commercially available FEA code. ANSYS V5.4 software is qualified as documented in the SQR for ANSYS V5.4.

The method used is as follows. A two-dimensional (2-D) axisymmetric finite element representation was developed for the waste package by taking advantage of its axial symmetry. The internal structure of the WP was simplified by reducing the structure of the naval SNF canister to a cylinder of circular cross section and uniform mass density. The density was calculated from the total mass and the geometric dimensions of the canister.

The results show that the maximum stress intensities among the waste package Alloy 22, except for the lower trunnion collar sleeve, and 316 NG SS components are 433 MPa and 275 MPa, respectively. These stress intensities are less than nine-tenths of the tensile strength for each of the corresponding materials; hence, compliance is demonstrated. The maximum stress intensity in the lower trunnion collar sleeve in the region of contact with the unyielding surface is 799 MPa, which exceeds the tensile strength of Alloy 22. However, the lower trunnion collar sleeve acts as a crush zone for the waste package at the point of impact and is not a part of the fuel containment.

6.3.2.4 Preclosure Horizontal Drop Without Breach (1.2.2.1.4)

The survivability of a naval SNF waste package to a horizontal drop has been demonstrated in a calculation entitled *Horizontal Drop of the Naval SNF Long Waste Package on Unyielding Surface* (CRWMS M&O 2000o).

One of the computer codes used to perform this calculation was ANSYS V5.4. ANSYS V5.4 is identified as CSCI 30040 V5.4 and is obtained from SCM in accordance with appropriate procedures. ANSYS V5.4 is a commercially available FEA code. ANSYS V5.4 software is qualified as documented in the SQR for ANSYS V5.4.

The second FEA computer code used to perform this calculation was LS-DYNA Livermore Software Technology Corporation (LSTC) Version 940, which is being qualified in accordance with AP-SI.1Q, *Software Management*. LS-DYNA LSTC Version 940 qualification is being performed as part of the qualification of ANSYS V5.6 since LS-DYNA LSTC Version 940 is available both as a component (module) of ANSYS and as a separate finite element code. Currently, Waste Package Department licensed LS-DYNA LSTC Version 940 directly from LSTC and was obtained from software configuration management in accordance with subsection 5.11 of AP-SI.1Q. ANSYS V5.6 is identified with the Software Tracking Number 10145-5.6-00 and was obtained from Software Configuration Management in accordance with appropriate procedures. LS-DYNA LSTC Version 940 is a commercially available FEA code and is appropriate for the structural investigation of the naval SNF waste package. This calculation (CRWMS M&O 2000o) was executed on a Hewlett-Packard (HP) 9000 series workstation (CPU [Computer Processing Unit] tag #115288). Evaluations performed are fully within the range of the validation that will be performed for the LS-DYNA LSTC Version 940 code.

A three-dimensional finite element representation was developed for the WP. The finite element representation was created with a radial gap between the inner and outer shell of 4 mm. This represents the worst case assembly of the inner and outer shells. Since the WP is dropped in a horizontal orientation, the inner shell and Naval SNF canister were placed lying flat against the bottom, such that a 0-mm gap is at the bottom and an 8-mm gap is at the top. The internal structure of the WP was simplified by reducing the structure of the Naval SNF canister to a cylinder of circular cross section and uniform mass density. The finite element representation was then used in LS-DYNA V940 to perform the transient dynamic analysis for the horizontal drop of the Naval SNF WP. The result of this simulation required the inclusion of elastic and plastic deformations for Alloy 22 and SS 316 NG. When the materials are driven into the plastic range, the slope of stress-strain curve continuously changes. Thus, a simplification for this curve is needed to incorporate plasticity into the finite element representation. A standard approximation commonly used in engineering is to use a straight line that connects the yield point and the ultimate tensile strength point of the material.

The results show that the maximum stress intensities occur in the lower trunnion collar with a level of 798 MPa, which exceeds the tensile strength of Alloy 22. However, the lower trunnion collar sleeve is not part of the containment barrier. It acts as an impact-limiter (crush zone) for the containment barrier in this case. The maximum stress intensity on the outer surface of the outer shell has a level of 694 MPa, which exceeds the tensile strength of Alloy 22. However, a closer examination of the region in which this level of intensity occurs, shows the stress decreases significantly along the thickness of the shell. Thus, the maximum stress intensity on the inner surface of the outer shell has a maximum level of 580 MPa. This is less than nine-tenths of the tensile strength of Alloy 22. Hence, a breach of the outer shell is not anticipated. The maximum stress intensity in the inner shell is 484 MPa Again, closer examination of the region in which this level of intensity occurs, shows the stress decreases significantly along the thickness of the shell. Thus, the maximum stress intensity on the inner surface of the inner shell has a maximum level of 430 MPa. This is less than nine-tenths of the tensile strength of 316 NG SS. Hence, a breach of the inner shell is not anticipated and compliance is demonstrated.

6.3.2.5 Preclosure Tip Over and Slap Down Without Breach (1.2.2.1.6)

The 21-PWR waste package was chosen as the representative waste package for preclosure tip over and slap-down evaluation. A calculation entitled *Waste Package Tipover of 21-PWR* (CRWMS M&O 2000p) describes the method and results for the 21-PWR WP. It is the most common package and, hence, the most likely to suffer a tip over and slap down design basis event. It was also chosen for its thinner wall thickness in the outer shell Alloy 22 (20 mm vs. 25 mm) and its greater sensitivity to internal basket deformation. The method used to evaluate the 21-PWR WP will be used to evaluate the naval SNF WP for compliance.

6.3.2.6 Withstand a Design Basis Earthquake (1.2.2.1.7)

It is a limitation of this document that the results of the seismic calculation are not available. However, the balance of information given is sufficient for Site Recommendation.

6.3.2.7 Sustain Preclosure Missile Impact Without Breach (1.2.2.1.8)

The survivability of a Naval SNF waste package due to a missile impact has been demonstrated in a calculation entitled *Pressurized System Missile Impact on Waste Packages* (CRWMS M&O 2000k). The method used in CRWMS M&O (2000k) is as follows. The analytical method for missile impact on a waste package consists of an analysis using basic strength of materials and empirical relationships used in the perforation of flat metal plates. The perforation of a plate by a projectile involves a complex mechanism of impact and subsequent failure if the projectile has a large amount of kinetic energy. Thus, there is no complete theoretical model that incorporates all of the relevant phenomena and that is capable of predicting accurately all of the aspects of an impact perforation event. However, there are some empirical relationships developed for low-velocity impact analysis. One of the empirical relationships used widely in design is the Ballistics Research Laboratory (BRL) method. No limitations are associated with this method in terms of the missile velocity range or the ratio of the target span to the missile diameter. Hence, the use of BRL method is more general compared to other empirical relationships. A detailed description of this method can be found in CRWMS M&O (2000k, Section 5.2).

The response of the waste package to three different types of pressurized system missile impacts has been calculated. The structural response of the waste package to a pressurized system missile is reported in terms of the minimum velocity necessary to cause perforation of the waste package shells. The calculation results are summarized in Table 14.

Table 14. Calculation Results for Missile Impact on a Naval SNF Waste Package

	Case1	Case 2	Case 3
Missile Diameter (mm)	10	20	30
Missile Mass (kg)	0.5	1.0	1.5
Missile Velocity (m/s)	5.7	6.0	6.3
	Minimum Velocity of Projectile to Cause Perforation of WP Shells (m/s)		
Naval SNF WP	339	403	446

The criterion for a missile impact is to withstand a 0.5-kg missile (1 cm in diameter) travelling at 5.7 m/s. The calculated minimum velocity to perforate the shell, as a result of such an impact, is 339 m/s. Compliance with this criterion is demonstrated by an empirical comparison. A missile with a velocity of 5.7 m/s has only 1.7 percent of the necessary impact velocity to compromise the waste package integrity.

6.3.2.8 Sustain Maximum Internal Pressure Limit (1.2.2.1.10)

The survivability of a Naval SNF waste package due to an internal pressurization event has been demonstrated in a calculation entitled *Internal Pressurization Due to Fuel Rod Rupture in Waste Packages* (CRWMS M&O 2000q). Due to the confidential nature of navy fuel, no knowledge of its internal structure has been given to the WPD. A correlation has been made from calculations performed for the 21-PWR WP in which all rods within the WP are assumed to rupture at once. The internal pressure for the naval SNF WP was calculated using the thermodynamic equation of state for constant density and knowledge of the void space between the naval canister and the naval WP. This calculation determined the membrane and bending stress, over a range of temperatures, extant on the closure weld of the inner shell of the naval SNF WP. The inner lid closure weld is considered the weakest point on the inner shell. No credit has been given for the outer shell or lids. At 600 °C the membrane plus bending stress equals 202 MPa and is below nine-tenths of the yield strength for 316 NG SS. This criterion is TBD and therefore, compliance cannot be demonstrated until the TBD is resolved.

6.3.2.9 Preclosure Criticality (1.2.2.1.12)

Due to the confidential nature of naval fuel, no criticality calculations will be performed by the WPD. The U.S. Navy has provided an addendum to the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998), which outlines the criticality methodology used by the NNPP. Compliance with this criterion is beyond the scope of this document.

6.3.2.10 Postclosure Criticality (1.2.2.1.13)

Due to the confidential nature of naval reactor fuel, no criticality calculations will be performed by the WPD. The U.S. Navy has provided an addendum to the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998), which outlines the criticality methodology used by the NNPP. Compliance with this criterion is beyond the scope of this document.

6.3.3 System Environment and Interfacing Criteria

6.3.3.1 Limitation of Waste Package Surface Radiation Dose Rate (1.2.4.3)

Details of dose rate calculations and results for the naval SNF WP are given in *Calculation of the Surface Dose Rates for the Single-CRM Naval SNF Waste Package* (CRWMS M&O 2000d).

The analytical method for criticality calculations is Monte Carlo radiation transport, as implemented in the Monte Carlo N-Particle (MCNP), Version 4B2, transport code. The qualification of MCNP 4B2 and its neutron and photon interaction cross-section data is documented in the SQR for MCNP, Version 4B2. The code and its associated cross-sections libraries are identified as CSCI 30033 V4B2LV, and are obtained from SCM in accordance with appropriate procedures. This code uses continuous-energy cross section data processed from the evaluated nuclear data files ENDF/B-V. These cross-section libraries are part of the qualified MCNP code system. The MCNP features employed in the shielding calculations for the naval SNF waste packages are the surface source and the surface flux tally.

A surface source specification is needed because neutron and photon currents exiting the top, bottom, and side of the naval SNF canister were made available by the U.S. Department of the Navy (Naples 1999, Enclosure 2, Tables 1 and 3). The sources on the surface of the naval SNF canister are spatially sampled according to the source intensities of each surface region: side, bottom, and top. Then, within each source surface region, the locations of source particles are sampled uniformly. Two MCNP calculations, one for the neutron source and one for the photon source are necessary to determine the total dose rates.

Based on the photon and neutron current intensities and the relatively thin shells on the side of the disposal container, it is expected that the maximum dose rate occurs on the side of the WP and that the dose rates on the axial surfaces are relatively uniform. Therefore, surface tallies are employed in MCNP to estimate the dose rates of the WP. A surface tally provides the average flux over a surface. Surface segments on the radial and axial surfaces of the WP are specified. The size and location of each segment are chosen such that the statistical behavior of the tally is satisfactory. In a MCNP calculation, photon or neutron fluxes on surface segments are estimated using surface tallies. Then, the photon and neutron flux-to-dose-rate conversion factors are applied to obtain the corresponding surface dose rates for the segments. The flux-to-dose rate conversion factors were extracted from ANSI/ANS (American National Standards Institute/American Nuclear Society) 6.1.1-1977.

The dose rates on segments of the naval SNF WP outer surfaces are summarized in Table 15. The WP side surface, between the bottom and top planes of the WP cavity, has been equally divided in five segments, Segments 1 through 5. Each segment of the WP side surface is 90.25-cm tall. The summarized results are obtained for the neutron and photon currents exiting the surface of the naval SNF canister, at 2-year decay time. These currents by energy groups are provided in Enclosure 2, Tables 1 and 2, of *Thermal, Shielding, and Structural Information on the Naval Spent Nuclear Fuel (SNF) Canister* (Naples 1999).

Spatially, a degenerate cylindrical volume distribution is used to specify particle sampling from the top, bottom, and side surfaces of the naval SNF canister. The outer dimensions of the degenerate cylinder are 0.0001 cm beyond the outer surfaces of the naval SNF canister. This is the only standard source option that allows input of a cylindrical surface source in MCNP (Briemeister 1997, p. 3-43). This representation of the surface sources does not make any detectable difference in the answers, and makes possible this calculation using MCNP. Also, a cylinder with reflective surfaces is used to represent the naval canister. This representation has the following advantages:

- The material and geometry details are not necessary to represent the naval canister.
- The reflective surfaces transform the default isotropic source for a cylindrical volume distribution to an isotropic distribution only in the outward direction of the naval canister, which corresponds to the physical reality.

Table 15. Dose Rates on the Surface of the Naval SNF Waste Package

Axial Location[a]	Gamma		Neutron		Total[b]	
	Dose Rate (rem/h)	Relative Error	Dose Rate (rem/h)	Relative Error	Dose Rate (rem/h)	Relative Error
Segment 1	3.8147E+02	0.0011	8.3463E-02	0.0019	3.8155E+02	0.0011
Segment 2	4.1192E+02	0.0010	9.2285E-02	0.0018	4.1201E+02	0.0010
Segment 3	4.1176E+02	0.0010	9.2056E-02	0.0018	4.1185E+02	0.0010
Segment 4	4.1228E+02	0.0010	9.2165E-02	0.0018	4.1237E+02	0.0010
Segment 5	4.1159E+02	0.0010	9.1895E-02	0.0018	4.1168E+02	0.0010
Segment 6	4.0456E+02	0.0010	8.8181E-02	0.0018	4.0465E+02	0.0010
WP top surface	1.7204E-03	0.0094	1.2228E-02	0.2618	1.3948E-02	0.2295
WP bottom surface	4.7931E-02	0.0124	1.5418E-01	0.0745	2.0211E-01	0.0569

NOTES: [a] Segments 1 through 6 are equal segments of the WP radial surface, each of 90.25-cm length, between the bottom and the top planes of the WP cavity.
[b] The values for the WP top and bottom surfaces have been obtained for a developing WP design that had only the inner and the outer shell lids (see CRWMS M&O 2000d, Attachment II). These values can be used in this analysis and do not change the conclusion of this analysis because they bound the values that would be obtained for the present design. The present design shows an additional 25-mm-thick extended outer shell lid (Alloy 22) at the top of the waste package with a space between the two lids. The addition of the lid decreases the surface dose rates.

The second-level confidence interval for the estimate of the maximum dose rates on the external surfaces of the naval SNF WP is 412 ± 1 rem/h. It should be noted that this value does not consider the scattering effect due to the emplacement drift wall. The emplacement drift surface dose rate would likely be greater due to scattering. Table 15 shows that the gamma dose rate dominates along the length of the waste package. The quality factor for gamma radiation is unity, therefore, the total dose rate in rad/h would be nearly identical to the rem/h values given. The naval SDD criterion 1.2.4.3 specifies the maximum dose rate as TBD; therefore, compliance can not be measured. The performance of the WP has been demonstrated.

6.3.3.2 Maximum Thermal Output of Waste Package (1.2.4.4)

A maximum heat-generation rate of 11.8 kW has been imposed by management direction (CRWMS M&O 1999a) on all waste package designs. The design basis heat-generation rate for the naval SNF canister is 8.01 kW and therefore, well below the 11.8-kW limit and in compliance with this criteria.

6.3.3.3 Limitation on the Quantity of the Waste Form (1.2.4.5)

There are 300 naval canisters, totaling exactly 65 metric tons heavy metal (MTHM), scheduled for emplacement within the repository. This quantity is in compliance with the 65-MTHM limit imposed in the criteria.

6.3.3.4 Vertical Loading and Sealing of Waste Packages (1.2.4.6)

Compliance is demonstrated by inspection of the sketch in Attachment I. The waste package can be loaded while in a vertical orientation.

6.3.3.5 Allow Horizontal and Vertical Handling of the Waste Package (1.2.4.7)

It may be seen by reviewing the sketch shown in Attachment I, that the waste package is designed to accept trunnion rings. The use of such rings permits attachments of fixtures that may be used for both vertical and horizontal handling of the waste package, as well as any orientation between vertical and horizontal. This is illustrated in Figures 3 and 4. The structural response of the waste package to lifting is reported using maximum stress values obtained from the finite element solution to the problem (see Sections 6.3.1.7 and 6.3.1.8) (CRWMS M&O 2000l). Tables 12 and 13 show the maximum stress for each component of the waste package. These trunnion rings are removed after the waste package is placed on the emplacement pallet; therefore, the use of such rings does not create a site for crevice corrosion cracking. Further, the trunnion rings are attached to a corresponding built-up area on the waste package and will not induce stresses that might exacerbate corrosion of the outer shell.

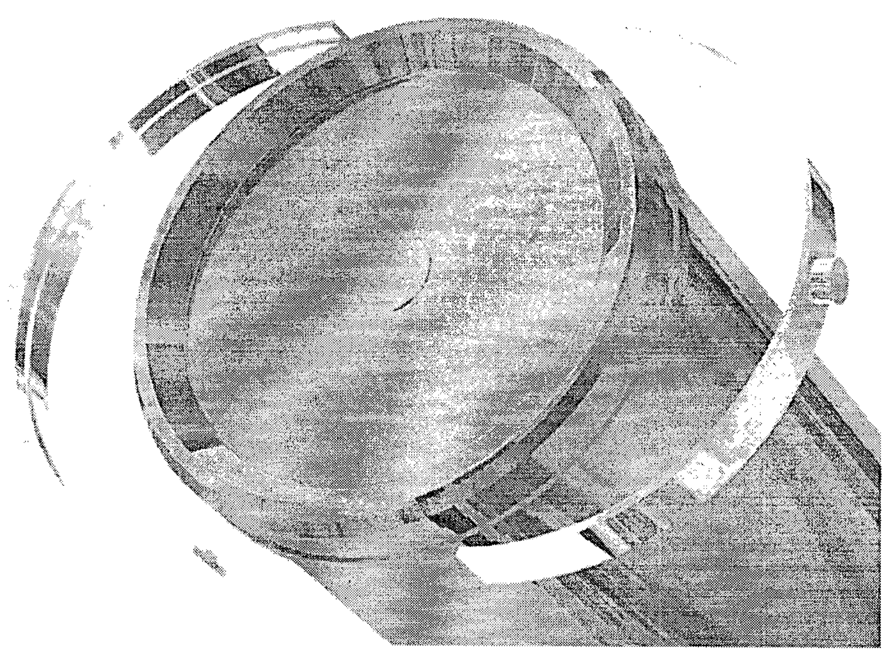

Figure 3. Trunnion Ring Sections Before Installation

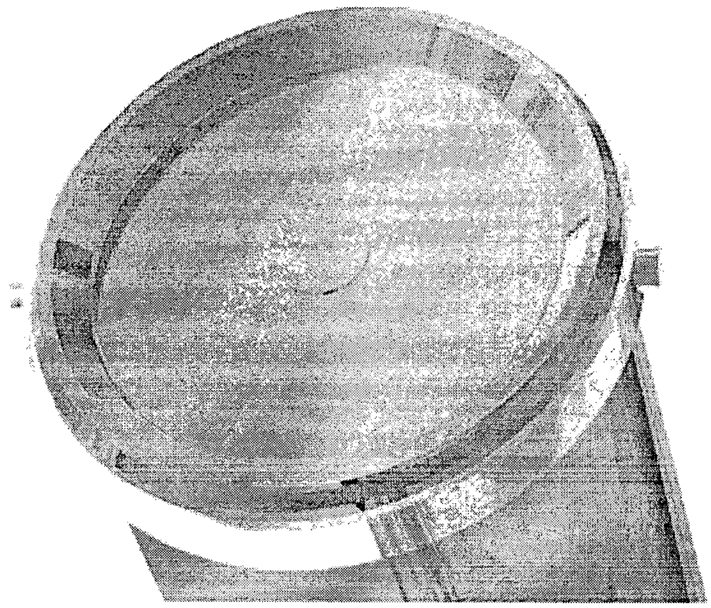

Figure 4. Trunnion Ring Sections After Installation

6.3.4 Codes and Standards Criteria

6.3.4.1 1995 Boiler and Pressure Vessel Code (1.2.6.1)

There are no codes or standards that apply directly to the design of disposal containers; however, the ASME Boiler and Pressure Vessel Code (Section III, Div. 1, Sub-section NG-1995) has been chosen as a guide for setting stress limits for the waste package components. Applications of subsections of Section III of the 1995 ASME Boiler and Pressure Vessel Code are shown in Table 16.

Table 16. Applicability of 1995 ASME Boiler and Pressure Vessel Code

Analysis Type	Component[a]	Section III, Subsection Applied	Service Limits[b]
Static	Barriers	Subsection NB	Level A
	Basket	Subsection NG	Level A
Seismic	Barriers	Subsection NB, Appendix F	Level D
	Basket	Subsection NG, Appendix F	Level D
Rock fall Internal pressure Missile impact	Barriers	Subsection NB, Appendix F	Level D

NOTE: [a] Barriers are identical to shells and are used in this table for consistency with the 1995 ASME Code.
[b] Level A Service Limits are for normal operation, and Level D Service Limits are for off-normal conditions.

As may be seen from this table, Subsection NG is used for operations consistent with normal activities with the Level A Service Limits. From the code, the limitation on membrane and bending stresses at Level A are:

$$P_m + P_b = 1.5 \cdot S_m$$

Here, P_m is the membrane stress, P_b is the bending stress, and S_m is the design stress intensity for the material. For design purposes, the design stress is assumed to be two thirds of the yield stress; therefore, the allowable total stress (including both membrane and bending) is equal to the yield stress.

6.3.4.2 1995 Boiler and Pressure Vessel Code (1.2.6.2)

For Level D Service Limits, Section III, Div. 1, Sub-section NB-1995 of the ASME Boiler and Pressure Vessel Code is used, as shown in Table 16. From the code, the limitation on membrane and bending stresses at Level D are:

$$P_m + P_b < 0.9 \cdot S_u$$

Here, S_u is the ultimate tensile strength of the material.

6.4 SATISFACTION OF OTHER CONSIDERATIONS

6.4.1 Tensile Stress Relaxation of Final Closure Weld by Induction Annealing

For the final closure welds, solution annealing is not possible due to the presence of the waste form. To improve the microstructure of the weld region for the outer shell extended lid, induction annealing of the weld region and adjacent metal will be performed. For the outer shell closure lid, laser peening will be performed. Both of these will be performed on the two lids of the corrosion resistant shell (SB-575 N06022), but not for the single lid of the structural shell (SA-240 S31600). To ensure adequate corrosion resistance, the final closure weld must have a residual stress level less than 20% (CRWMS M&O 2000i) of the yield stress for the material for a depth of TBD (CRWMS M&O 1999a). A minimum penetration depth of 7.5 mm (CRWMS M&O 2000s), based on the corrosion rate of Alloy 22, must be achieved. To demonstrate the maximum possible depth of tensile stress reduction in the final closure weld by induction annealing, a calculation entitled *Residual Stress Minimization of Waste Packages from Induction Annealing* (CRWMS M&O 2000h) was performed. The calculation represented an axisymmetric portion of the waste package outer shell that contained the final closure weld for the outermost lid. It is assumed that the outer shell is sufficiently de-coupled from the inner shell such that any heat transfer is negligible. This is true both for heat transfer into the waste package from the annealing process and heat transfer from the decaying waste form. CRWMS M&O (2000h) looked at 5 different weld designs to determine which offered the best induction annealing stress relief. Design #5 outperformed the others with a calculated residual stress field after the annealing process that was 5.5 mm in depth. Therefore, this waste package design has been selected for use in the current waste package designs. This calculation satisfies criterion 1 of CRWMS M&O (2000c). However, the actual depths for each closure weld must sum to 7.5 mm; the stress relaxation region for the outer lid is shown to be 5.5 mm (CRWMS M&O 2000h), so the depth for laser peening must be at least 2 mm.

6.4.2 Tensile Stress Relaxation of Final Closure Weld by Laser Peening

Laser peening will be used to reduce tensile stresses in the closure weld of the outer shell closure lid (see Attachment II). Laser peening changes the stress field in metallic materials from tensile to compressive by the impulse effect of laser induced plasma. A part of the light is absorbed and vaporizes a small amount of surface material. The vapor is heated to a very high temperature. At such temperatures electrons are stripped from the vaporized atoms to form plasma. The rapid vaporization generates a stress wave at the surface, which propagates into the material. It changes the metal's microstructure, hence, improving the material property. Generating high amplitude stress waves involves placing a material, which is transparent to the incident laser, on the surface. This material can be solid or liquid and functions to confine the vaporized surface material.

6.4.3 Adequacy of Stress Reduction

It was determined in *Waste Package Degradation Process Model Report* that a reduction to 20 percent or less of the initial yield stress for a depth between 2 mm and 3 mm by laser peening is sufficient (CRWMS M&O 2000r, Section 3.1.7.6.3).

7. CONCLUSIONS

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

Confirmation of the thickness of the Alloy 22 shell and the 20 percent reduction in the tensile stresses of the outer barrier should not impact the conclusions that are provided herein.

7.1 SUMMARY

This section summarizes the satisfaction of criteria to support Site Recommendation.

7.1.1 Accommodation of SDD Criteria

The satisfaction of the SDD criteria is summarized in Table 17. Short statements in the 'Comment' column of Table 17 are defined below:

'Compliance Demonstrated'	indicates compliance with the given criterion.
'Performance Demonstrated'	indicates a calculation was completed to demonstrate the performance of the waste package but the criterion is TBD and therefore, compliance can not be demonstrated.
'Method Demonstrated'	indicates a representative calculation was completed on another WP.
'N/A'	indicates criteria which will not be addressed by the WPD.

Table 17. Satisfaction Summary of Naval Waste Package Criteria

Section		Brief Description of the Criterion	SR/LA	Comment
SDD	Herein			
1.2.1.1	6.3.1.1	The disposal container/waste package shall be designed such that the expected annual dose to the average member of the critical group shall not exceed 25 mrem total effective dose equivalent at any time during the first 10,000 years after permanent closure.	N/A	Demonstration of compliance with criterion is contingent upon the completion of TSPA.
1.2.1.2	6.3.1.2	The disposal container shall accommodate short (185.63 inches) and long (210.63 inches) naval SNF canisters made of 316L stainless steel.	SR	Compliance Demonstrated
1.2.1.3	6.3.1.3	The disposal container shall consist of two cylinders; an inner cylinder that is 5-cm (2-in) thick stainless steel alloy 316L, and an outer cylinder that is 2-cm ($^3/_4$-in.) thick Alloy 22 material.	SR	Compliance Demonstrated
1.2.1.4	6.3.1.4	The waste package shall have a minimum heat rejection flux of (TBD).	SR	Performance Demonstrated
1.2.1.5	N/A	The disposal container/waste package shall prevent the breach of the naval SNF canister during normal handling operations.	LA	N/A

Table 17. (Continued)

Section		Brief Description of the Criterion	SR/LA	Comment
SDD	Herein			
1.2.1.6	6.3.1.5	The disposal container/waste package shall be designed to support/allow retrieval up to 300 years after the start of emplacement operations.	SR	Compliance Demonstrated
1.2.1.7	N/A	The disposal container/waste package, excluding the labels, shall have an external surface finish Roughness Average of 250μin (6.36μm) or less.	LA	N/A
1.2.1.8	6.3.1.6	The disposal container/waste package shall have all external surfaces accessible for visual inspection and decontamination.	SR	Compliance Demonstrated
1.2.1.9	N/A	The disposal container/waste package shall have a label or other means of identification with a unique package identifier and contents information.	LA	N/A
1.2.1.10	N/A	All labels applied to the disposal container shall not impair the integrity of the waste package.	LA	CRWMS M&O 2000c list the SR/LA status as N/A.
1.2.1.11	N/A	All information contained on all labels applied to the disposal container/waste package shall be legible or read by remote means until permanent closure of the repository.	LA	N/A
1.2.1.12	6.3.1.7	Lifting features of the disposal container/waste package shall be designed for three times the maximum weight of the waste package without generating a combined shear stress or maximum tensile stress in excess of the corresponding minimum tensile yield strength of the materials.	SR	Compliance Demonstrated
1.2.1.13	6.3.1.8	The lifting features of the disposal container/waste package shall be designed for five times the weight of the waste package without exceeding the ultimate tensile strength of the materials.	SR	Compliance Demonstrated
1.2.1.14	N/A	The disposal container shall withstand the worst case handling environments encountered during loading, sealing, and transfer operations.	LA	N/A
1.2.1.15	6.3.1.7 6.3.1.8	The waste package shall withstand the worst case handling environments encountered during transfer, emplacement, and retrieval operations.	SR	Compliance Demonstrated
1.2.1.16	6.3.1.9	The waste package shall be designed to achieve a reliability of (TBD) during the first 10,000 years after emplacement.	N/A	Demonstration of compliance with criterion is contingent upon the completion of TSPA.
1.2.1.17	6.3.1.10	The disposal container/waste package shall be constructed of non-combustible and heat resistant materials.	SR	Compliance Demonstrated
1.2.1.18	6.3.1.11	Disposal container/waste package materials shall exclude the use of explosive or pyrophoric materials.	SR	Compliance Demonstrated
1.2.1.19	6.3.1.12	Disposal container/waste package materials shall exclude the use of free liquids.	SR	Compliance Demonstrated
Safety Criteria				
1.2.2.1.1	6.3.2.1	During the preclosure period, while in a horizontal orientation, the waste package shall be designed to withstand a 13-MT rock falling 3.1 m onto the side of the waste package without breaching.	SR	Method Demonstrated 21-PWR

Table 17. (Continued)

Section		Brief Description of the Criterion	SR/LA	Comment
SDD	Herein			
1.2.2.1.2	N/A	During the preclosure period, while in a vertical orientation, the disposal container shall be designed to withstand a 2.3-MT object falling 2 m onto the end of the waste package without breaching.	LA	N/A
1.2.2.1.3	6.3.2.3	During the preclosure period, the disposal container/waste package, shall be designed to withstand (while in a vertical orientation) a drop from a height of 2 m onto a flat, unyielding surface.	SR	Compliance Demonstrated
1.2.2.1.4	6.3.2.4	During the preclosure period, the waste package, shall be designed to withstand (while in a horizontal orientation) a drop from a height of 2.4 m onto a flat, unyielding surface without breaching.	SR	Compliance Demonstrated
1.2.2.1.5	6.3.2.2	During the preclosure period, the waste package shall be designed to withstand (while in a horizontal orientation) the greater stress resulting from a drop of 1.9 m onto a steel support in an emplacement drift, or a drop of 2.4 onto a concrete pier, without breaching by puncture.	SR	Method Demonstrated 44-BWR
1.2.2.1.6	6.3.2.5	During the preclosure period, the waste package shall be designed to withstand a tip over from a vertical position with slap down onto a flat, unyielding surface without breaching.	SR	Method Demonstrated 21-PWR
1.2.2.1.7	6.3.2.6	The waste package shall be designed to withstand a Frequency Category 2 Design Basis Earthquake. Both vibratory ground motion and fault displacement must be considered.	SR/LA	It is a limitation of this document that this criterion in not addressed.
1.2.2.1.8	6.3.2.7	During the preclosure period, the waste package shall be designed to withstand the impact of a 0.5-kg missile (a 1-cm diameter, 5-cm long valve stem) travelling at 5.7 meters per second.	SR	Compliance Demonstrated
1.2.2.1.9	N/A	During the preclosure period, the waste package shall be designed to withstand, without breaching, the maximum impact resulting from a transporter runaway, derailment, and impact at a speed of 63 km/h, taking credit as appropriate for interfacing systems that prevent derailment and impact with the walls of the repository drifts or mitigate the impact on the waste package.	LA	N/A
1.2.2.1.10	6.3.2.8	During the preclosure period, waste package shall be designed to withstand, without breaching, the maximum internal pressure of (TBD) at an ambient temperature less than or equal to (TBD) as generated by (TBD).	SR	Performance Demonstrated
1.2.2.1.11	N/A	The waste package shall be designed to withstand the hypothetical fire criteria defined in 10 CFR 71, Section 73(c)(4).	LA	CRWMS M&O 2000c list this criterion as SR/LA. CRWMS M&O 2000c credits work presented in Section 6.3.2.8 as partial compliance for this criterion.

Table 17. (Continued)

Section		Brief Description of the Criterion	SR/LA	Comment
SDD	Herein			
1.2.2.1.12	6.3.2.9	During the preclosure period, the waste package shall be designed in coordination with the naval SNF canisters such that nuclear criticality shall not be possible unless at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. The calculated effective neutron multiplication factor (k_{eff}) must be sufficiently below unity to show at least a 5 percent margin after allowance for the bias in the method of calculation and the uncertainty in the experiments used to validate the method of calculation.	N/A	Compliance with this criterion is outside the scope of this document. Naval Reactors will perform the analysis to show compliance with this criterion. CRWMS M&O 2000c list the SR/LA status of this criterion as SR.
1.2.2.1.13	6.3.2.10	During the postclosure period, the naval SNF waste package shall be designed such that nuclear criticality shall not be credible for intact naval spent fuel. The calculated effective neutron multiplication factor (k_{eff}) must be shown to have at least a 5 percent margin to criticality.	N/A	Compliance with this criterion is outside the scope of this document. Naval Reactors will perform the analysis to show compliance with this criterion.
System Environment Criteria				
1.2.3.1	N/A	The waste package shall meet all performance requirements during and after exposure to the emplacement drift environments.	LA	N/A
System Interfacing Criteria				
1.2.4.1	N/A	Comply w/ SRF to WPO interface control document.	LA	N/A
1.2.4.2	N/A	Comply w/ EBSO to WPO interface control document.	LA	N/A
1.2.4.3	6.3.3.1	Disposal container design shall reduce the dose rate at all external surfaces of a waste package to (TBD).	SR	Performance Demonstrated
1.2.4.4	6.3.3.2	The waste package shall be designed to have a maximum thermal output of 11.8 kW.	SR	Compliance Demonstrated
1.2.4.5	6.3.3.3	The quantity of waste forms disposed of in this suite of disposal containers shall total approximately 65 MTHM.	SR	Compliance Demonstrated
1.2.4.6	6.3.3.4	The disposal container shall be designed for loading and sealing in a vertical orientation.	SR	Compliance Demonstrated
1.2.4.7	6.3.3.5	The disposal container/waste package shall be designed to be handled while in the horizontal orientation, the vertical orientation, and when the disposal container/waste package is transitioning between the horizontal and vertical position.	SR	Compliance Demonstrated
1.2.4.8	N/A	The disposal container/waste package shall be designed to support required welding times.	LA	N/A
Codes and Standards Criteria				
1.2.6.1	6.3.4.1	1995 ASME Boiler and Pressure Vessel Code (Section III, Division 1, Subsection NG-1995)	SR	Compliance Demonstrated
1.2.6.2	6.3.4.2	1995 ASME Boiler and Pressure Vessel Code (Section III, Division 1, Subsection NB-1995)	SR	Compliance Demonstrated
1.2.6.3	6.3.4.3	Nuclear Criticality Control of Special Actinide Elements (ANSI/ANS-8.15-1981)	LA	N/A

Table 17. (Continued)

Section		Brief Description of the Criterion	SR/LA	Comment
SDD	Herein			
1.2.6.4	6.3.4.4	Nuclear criticality Safety in Operations with Fissionable Materials Outside Reactors (ANSI/ANS-8.1-1998)	LA	N/A
1.2.6.5	6.3.4.5	Criteria for Nuclear Safety Controls in Operations with Shielding and Confinement (ANSI/ANS-8.10-1983)	LA	N/A
1.2.6.6	6.3.4.6	Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors (ANSI/ANS-8.17-1984)	LA	N/A

NOTE: LA-License Application
N/A-Not Applicable
SR-Site Recommendation
w/-with

7.1.2 Accommodation of Other Considerations

Additional waste package criteria are listed for consideration in the *Waste Package Design Sensitivity Report* (CRWMS M&O 2000c). In addition to the criteria listed there, the reduction of tensile stresses within the closure weld must be addressed. Table 18 outlines the satisfaction of other considerations.

Table 18. Satisfaction of Other Considerations

Source	Brief Description of the Criterion	SR/LA	Comment
1[a]	This criterion imposes a manufacturing residual stress in the outer shell material. The residual stress must be below 20 percent of the yield strength for a depth of (TBD-235) from the outer surface.	SR	Method Demonstrated 21-PWR
2[a]	This criterion imposes a limit for the static loads in the outer shell material at the interface with the emplacement pallet. The static load must be below 20 percent of the yield strength.	SR	Compliance Demonstrated
3[a]	This criterion imposes a limit for the seismic loads in the outer shell material. The seismic loads must be less than the yield strength.	SR/LA	N/A
N/A[b]	Tensile stress reduction in closure weld to a depth of 7.5 mm. Tensile stresses must be less than 20 percent of yield strength.	SR	Compliance Demonstrated

SOURCE: [a]CRWMS M&O 2000c
[b]CRWMS M&O 2000i
NOTE: LA-License Application
N/A-Not Applicable
SR-Site Recommendation

7.2 UTILITY FOR SITE RECOMMENDATION

This design analysis describes activities used by the WPD to design naval SNF WPs; however, it does not make any recommendations regarding the final design of either the WP or the repository. The treatment of uncertainties in this design analysis falls into one of two categories. First is that input parameters are selected which produce net conservative results. Secondly, benchmark comparisons of computational methods used in supporting calculations must be performed. Uncertainty identification and experimental and computational benchmarks are to be addressed in License Application.

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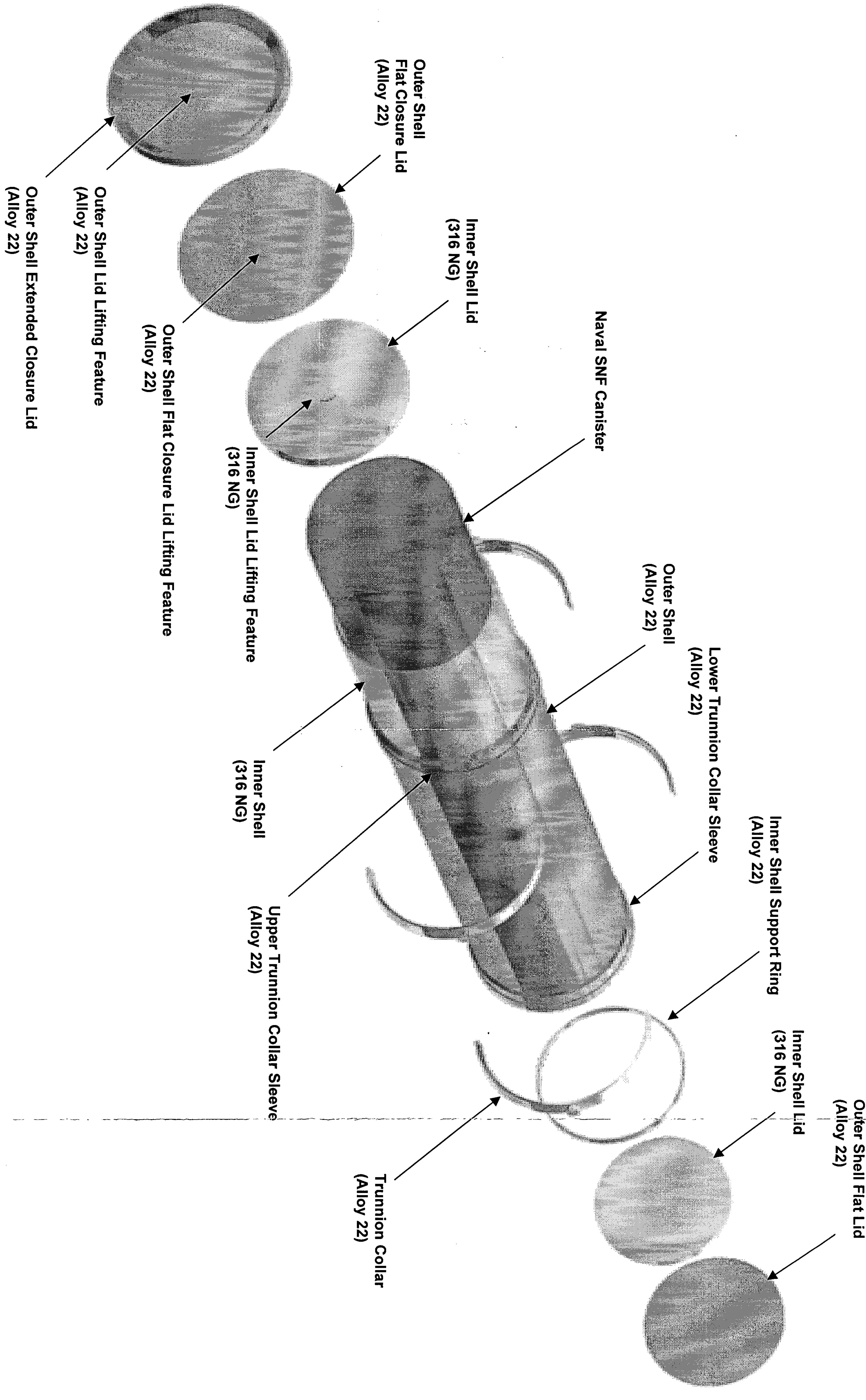
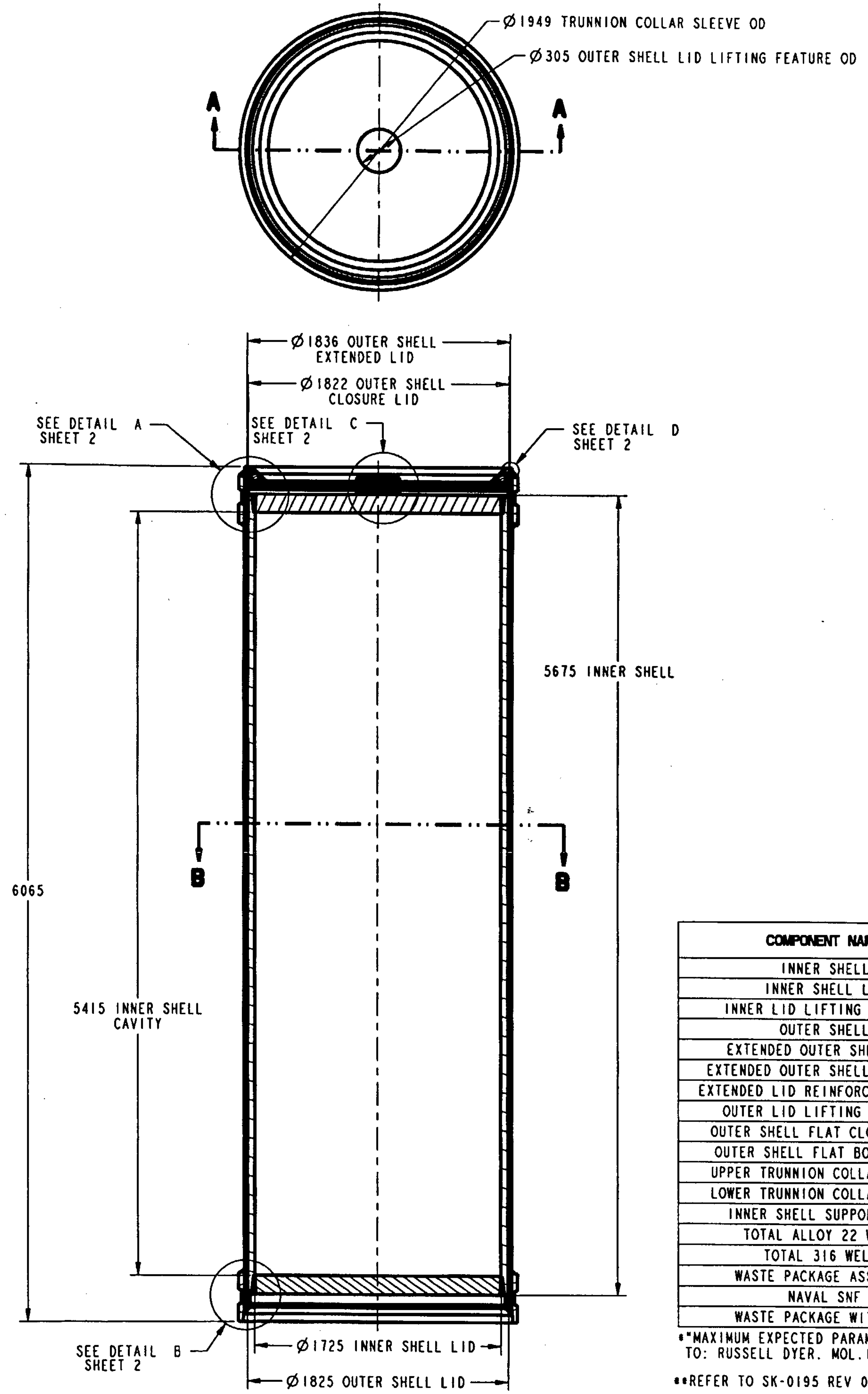
ATTACHMENTS

Table 19. List of Attachments

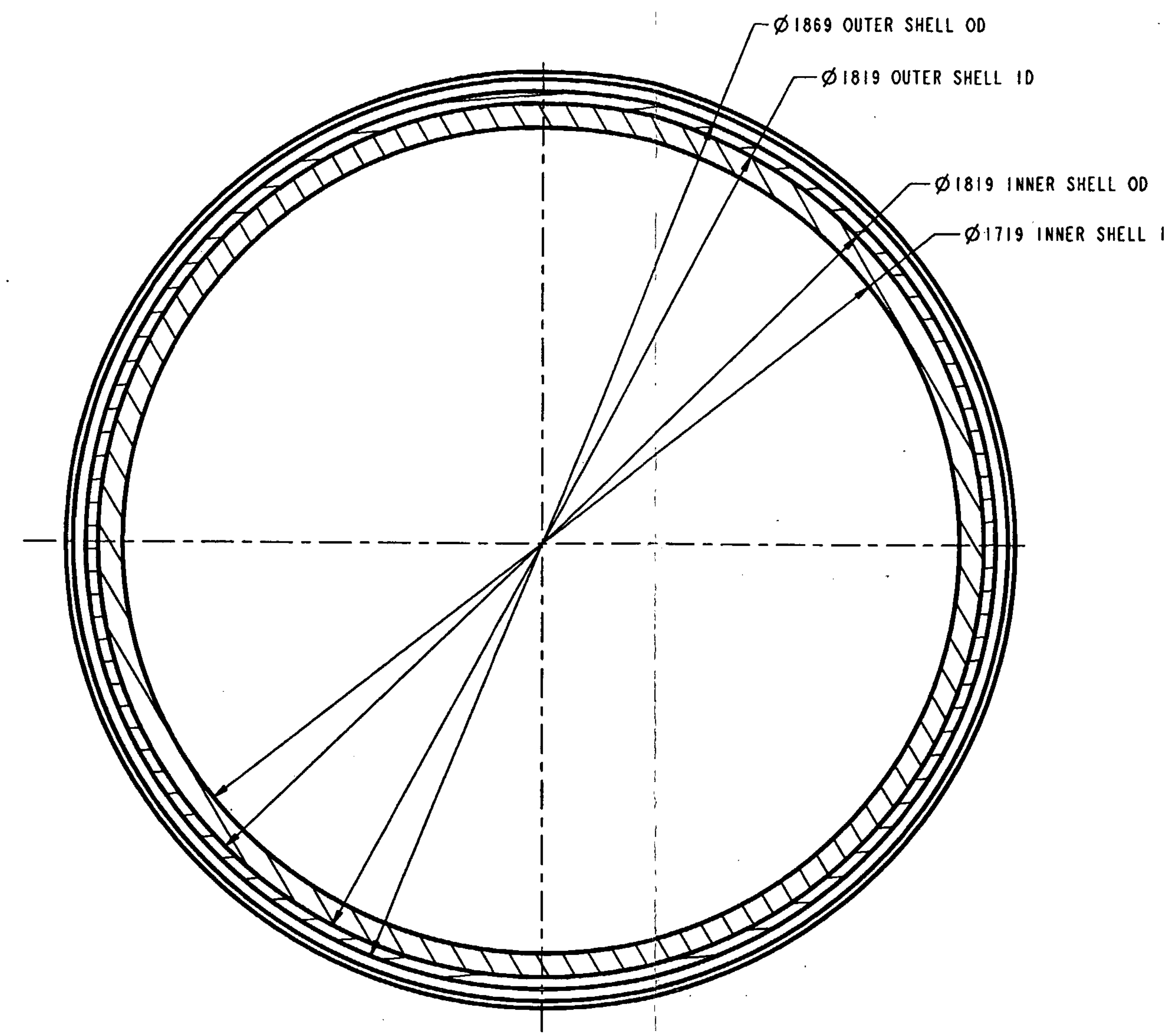
Number	Description	Pages
I	Naval SNF Long Waste Package Assembly Configuration	1
II	Naval SNF Long Waste Package Configuration for Site Recommendation. SK-0194 Rev. 01	2
III	Naval SNF Long Waste Package Weld Configuration. SK-0195 Rev. 00	1

NOTE: Attachment II references Guida (1997) as listed in Section 8.


Outer Shell Flat Closure Lid (Alloy 22)
Outer Shell Lid Lifting Feature (Alloy 22)
Outer Shell Extended Closure Lid (Alloy 22)
Inner Shell Lid (316 NG)
Outer Shell Flat Closure Lid Lifting Feature (Alloy 22)
Naval SNF Canister
Inner Shell Lid Lifting Feature (316 NG)
Outer Shell (Alloy 22)
Lower Trunnion Collar Sleeve (Alloy 22)
Inner Shell (316 NG)
Inner Shell Support Ring (Alloy 22)
Upper Trunnion Collar Sleeve (Alloy 22)
Inner Shell Lid (316 NG)
Outer Shell Flat Lid (Alloy 22)
Trunnion Collar (Alloy 22)



SECTION A-A



SECTION B-B

COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY RQD
INNER SHELL	SA-240 S31600	50	12372	1
INNER SHELL LID	SA-240 S31600	130	2390	2
INNER LID LIFTING FEATURE	SA-240 S31600	27	12	1
OUTER SHELL	SB-575 N06022	25	7430	1
EXTENDED OUTER SHELL LID	SB-575 N06022	25	158	1
EXTENDED OUTER SHELL LID BASE	SB-575 N06022	25	528	1
EXTENDED LID REINFORCEMENT RING	SB-575 N06022	50	118	1
OUTER LID LIFTING FEATURE	SB-575 N06022	27	13	2
OUTER SHELL FLAT CLOSURE LID	SB-575 N06022	10	227	1
OUTER SHELL FLAT BOTTOM LID	SB-575 N06022	25	564	1
UPPER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	604	1
LOWER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	592	1
INNER SHELL SUPPORT RING	SB-575 N06022	20	49	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	298	**
TOTAL 316 WELDS	SFA-5.9 S31680	-	243	**
WASTE PACKAGE ASSEMBLY	-	-	28005	1
NAVAL SNF	-	-	44452*	1
WASTE PACKAGE WITH SNF	-	-	72457	1

*"MAXIMUM EXPECTED PARAMETERS FOR NAVAL REACTORS CANISTERS" 10/29/97 FROM: RICHARD GUIDA TO: RUSSELL DYER. MOL.19980121.0011

**REFER TO SK-0195 REV 00 "NAVAL SNF LONG WASTE PACKAGE WELD CONFIGURATION"

UNITS: mm

DO NOT SCALE FROM SKETCH

"FOR INFORMATION ONLY"

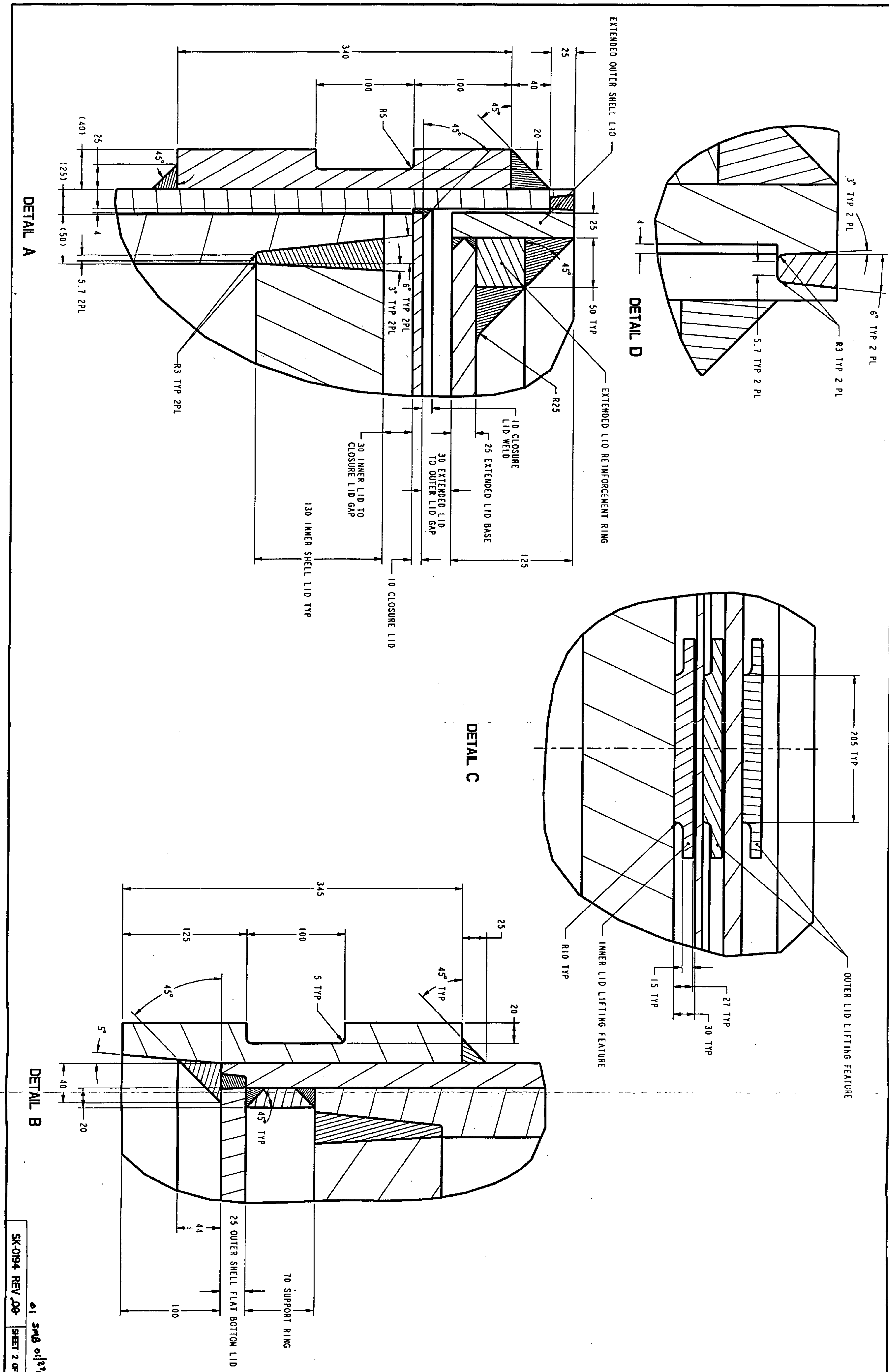
NAVAL SNF LONG WASTE PACKAGE CONFIGURATION FOR SITE RECOMMENDATION

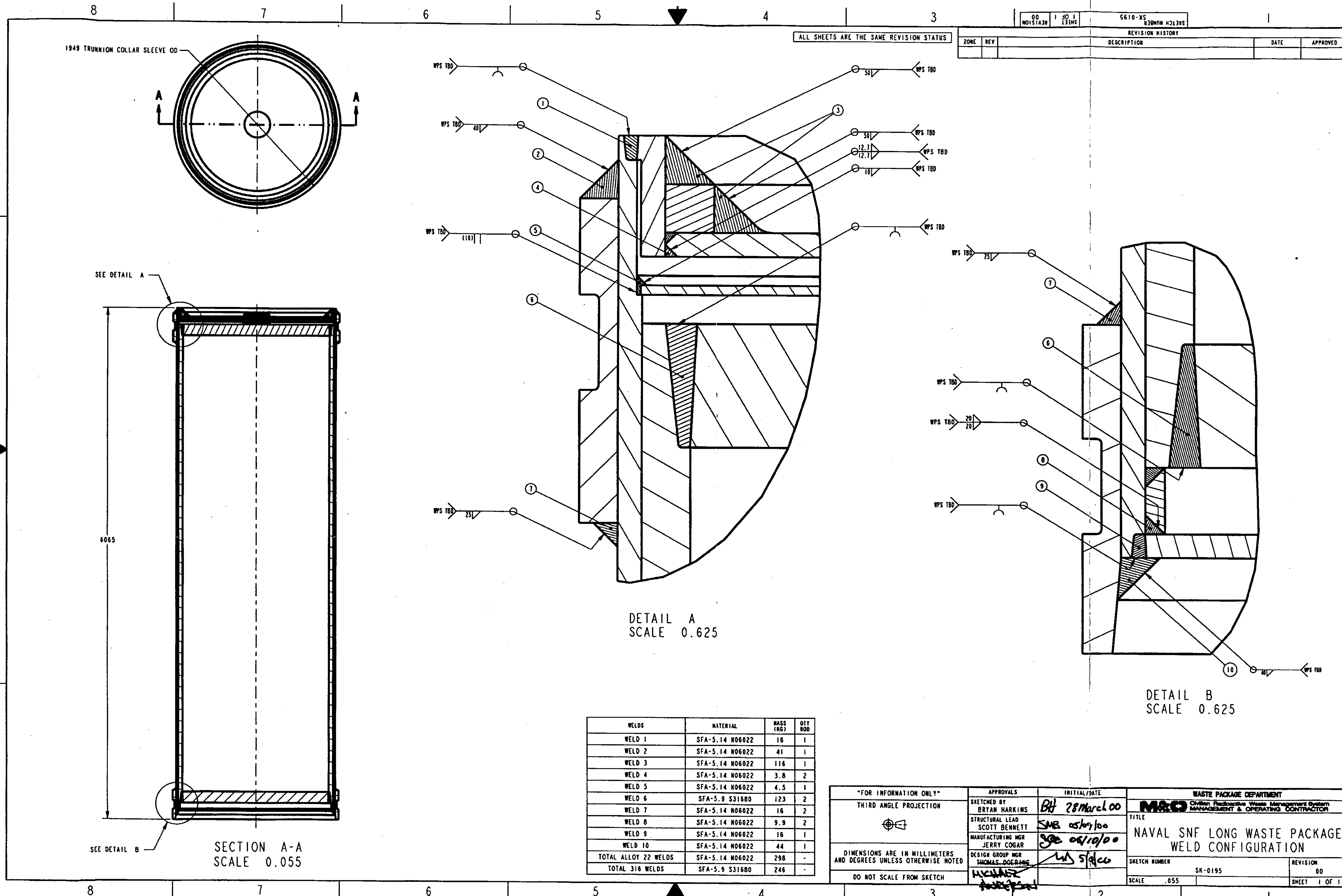
SKETCH NUMBER: SK-0194 REV 01 SHEET 1 OF 2

SKETCHED BY: GENE CONNELL *gjc 01/26/00* *SMB 01/26/00* *Jae 1/26/00*

DATE: 01/11/00 *Jan 1, 2600*

FILE: /home/pro_library/checkout/sketches/naval/naval snf long/SK-0194.dwg


DETAIL A
DETAIL B
DETAIL C
DETAIL D
EXTENDED OUTER SHELL LID
EXTENDED LID REINFORCEMENT RING
10 CLOSURE LID WELD
25 EXTENDED LID BASE
30 EXTENDED LID TO OUTER LID GAP
30 INNER LID TO CLOSURE LID GAP
130 INNER SHELL LID TYP
10 CLOSURE LID
R3 TYP 2PL
R25
5.7 2PL
6° TYP 2PL
3° TYP 2PL
50 TYP
R5
340
R3 TYP 2 PL
5.7 TYP 2 PL
6° TYP 2 PL
3° TYP 2 PL
205 TYP
R10 TYP
INNER LID LIFTING FEATURE
OUTER LID LIFTING FEATURE
15 TYP
27 TYP
30 TYP
345
5 TYP
45° TYP
25 OUTER SHELL FLAT BOTTOM LID
70 SUPPORT RING
SK-0194 REV 01
SHEET 2 OF 2



WELDS	MATERIAL	MASS (KG)	QTY ROD
WELD 1	SFA-5.14 N06022	16	1
WELD 2	SFA-5.14 N06022	41	1
WELD 3	SFA-5.14 N06022	116	1
WELD 4	SFA-5.14 N06022	3.8	2
WELD 5	SFA-5.14 N06022	4.5	1
WELD 6	SFA-5.9 S31680	123	2
WELD 7	SFA-5.14 N06022	16	2
WELD 8	SFA-5.14 N06022	9.9	2
WELD 9	SFA-5.14 N06022	16	1
WELD 10	SFA-5.14 N06022	44	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	298	-
TOTAL 316 WELDS	SFA-5.9 S31680	246	-

ZONE	REV	DESCRIPTION	DATE	APPROVED

REVISION HISTORY

SKETCH NUMBER SK-0195 | SHEET 1 OF 1 | REVISION 00

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THIRD ANGLE PROJECTION

DIMENSIONS ARE IN MILLIMETERS AND DEGREES UNLESS OTHERWISE NOTED

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APPROVALS	INITIAL/DATE
SKETCHED BY BRYAN HARKINS	BH 28March00
STRUCTURAL LEAD SCOTT BENNETT	SMB 05/04/00
MANUFACTURING MGR JERRY COGAR	JGC 05/10/00
DESIGN GROUP MGR ~~THOMAS DOERING~~ MICHAEL ANDERSON	MA 5/9/00

WASTE PACKAGE DEPARTMENT

M&O Civilian Radioactive Waste Management System MANAGEMENT & OPERATING CONTRACTOR

TITLE NAVAL SNF LONG WASTE PACKAGE WELD CONFIGURATION

SKETCH NUMBER SK-0195 | REVISION 00

SCALE .055 | SHEET 1 OF 1