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

1. QA: QA

Page: 1 of: 60

2. ☒ Analysis — Check all that apply

Type of Analysis	☒ Engineering ☐ Performance Assessment ☐ Scientific
Intended Use of Analysis	☐ Input to Calculation ☐ Input to another Analysis or Model ☒ Input to Technical Document ☐ Input to other Technical Products

Describe use:

Design description of the waste packages containing defense high-level waste and the U.S. Department of Energy spent nuclear fuel in disposable canisters

3. ☐ Model — Check all that apply

Type of Model	☐ Conceptual Model ☐ Abstraction Model ☐ Mathematical Model ☐ System Model ☐ Process Model
Intended Use of Model	☐ Input to Calculation ☐ Input to another Model or Analysis ☐ Input to Technical Document ☐ Input to other Technical Products

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9.	Checker	T. Lewis Mitchell	T. Lewis Mitchell	6/1/00
10.	Lead/Supervisor	Michael J. Anderson	Scott M. Bennett for M.J. Anderson	06/07/00
11.	Responsible Manager	Michael J. Anderson	Scott M. Bennett for M.J. Anderson	06/07/00

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CONTENTS

Page

1. PURPOSE 9

2. QUALITY ASSURANCE 10

3. COMPUTER SOFTWARE AND MODEL USAGE 11

4. INPUTS 12
   4.1 DATA AND PARAMETERS 12
      4.1.1 Material Specifications 12
      4.1.2 SRS DHLW Glass Pour Canister 13
      4.1.3 DOE Standardized SNF Canister 14
   4.2 CRITERIA 18
      4.2.1 System Description Document Criteria 18
      4.2.2 Interface Control Document Criteria 23
      4.2.3 Other Requirements 25
   4.3 CODES AND STANDARDS 25
      4.3.1 ASME Boiler and Pressure Vessel Code 25
      4.3.2 ANSI/ANS Standards 26

5. ASSUMPTIONS 27
   5.1 STRUCTURAL 27
   5.2 THERMAL 27
   5.3 SHIELDING 28
   5.4 CRITICALITY 28

6. ANALYSIS 29
   6.1 DHLW DISPOSAL CONTAINER/WASTE PACKAGE DESIGN 29
      6.1.1 5-DHLW/DOE SNF-Short Waste Package Design 30
      6.1.2 DOE SNF and HLW 32
      6.1.3 5-DHLW/TRIGA SNF Codisposal Waste Package 33
   6.2 ANALYTICAL METHODS AND RESULTS 35
      6.2.1 Source Term 35
      6.2.2 Structural 36
         6.2.2.1 Analytical Method for Waste Package Internal Pressurization 36
         6.2.2.2 Method of Solution for Missile Impact on Waste Packages 36
         6.2.2.3 Analytical Method for Waste Package Lifting 37
         6.2.2.4 Calculations and Results 37
      6.2.3 Thermal 39
         6.2.3.1 Thermal Analytical Method 39
         6.2.3.2 Calculations and Results 39
      6.2.4 Shielding 42
         6.2.4.1 Shielding Analytical Method 42
         6.2.4.2 Calculations and Results 43

CONTENTS (Continued)

Page

6.2.5 Criticality 45
6.2.5.1 Criticality Analysis Method 45
6.2.5.2 Calculations and Results 46
6.3 SATISFACTION OF PROJECT REQUIREMENTS 47

7. CONCLUSIONS 50

8. INPUTS AND REFERENCES 55
8.1 DOCUMENTS CITED 55
8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES 58

ATTACHMENTS 60

FIGURES

Page

1. SRS DHLW Glass Pour Canister 14
2. Plan View of the 18-in.-OD DOE Standardized SNF Canister 15
3. Isometric View of the Basket Assemblies for TRIGA SNF 16
4. Cross-Sectional Sketch of TRIGA-SS Rods in an 18-in.-OD DOE SNF Canister 17
5. Emplacement of the Advanced Neutron Absorber Matrix Coat 17
6. Isometric View of the Codisposal Waste Package 30
7. Horizontal Cross Section of the Codisposal Waste Package 34
8. Name and Location for the Temperature Nodes of the Waste Package 40
9. Name and Location for the Temperature Nodes of the DOE SNF Canister 40
10. Temperature History for TRIGA SNF Cladding and DHLW Glass 41
11. Surface Segments of the Waste Package Used in Dose Rate Calculations 44

TABLES

Page

1. Chemical Compositions for the Materials of the DHLW Disposal Container 12
2. Temperature Dependence for the Tensile Strength of Alloy SA-240 S31600 13
3. Geometry and Material Specifications for SRS DHLW Glass Canisters 13
4. Geometry and Material Specifications for the DOE SNF Canister 15
5. DHLW System Description Document Criteria 19
6. Additional Requirements 25
7. Applicability of the ASME Boiler and Pressure Vessel Code 25
8. Dimensions and Material Specifications for the Disposal Container 31
9. Variation of Stress from Internal Pressure with Temperature 37
10. Pressurized System Missile Impact 38
11. Maximum Stress in the Waste Package Components Due to Horizontal and Vertical Lift ... 38
12. Peak Temperature Histories of the TRIGA SNF Cladding and DHLW Glass 41
13. Dose Rates on the Waste Package Outer Radial Surface 43
14. Dose Rates on the Waste Package Axial Outer Surfaces 44
15. Satisfaction of Project Requirements 51
16. List of Attachments 60

ACRONYMS

ANS	American Nuclear Society
ANSI	American National Standards Institute, Inc.
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BRL	Ballistics Research Laboratory
BWR	boiling water reactor
CSCI	Computer Software Configuration Item
CRWMS	Civilian Radioactive Waste Management System
DHLW	defense high-level waste
DOE	U.S. Department of Energy
DWPF	Defense Waste Processing Facility
FEA	finite element analysis
HEU	highly enriched uranium
HLW	high-level waste
ICD	interface control document
k_{eff}	effective neutron multiplication factor
LA	License Applications
LCE	Laboratory Critical Experiment
LEU	low enriched uranium
M&O	Management and Operating Contractor
MCNP	Monte Carlo N-Particle
MCO	multi-canister overpack
MGR	Monitored Geologic Repository
MT	metric ton
MTU	metric ton uranium
N/A	not applicable
NEA	Nuclear Energy Agency
NSNFP	National Spent Nuclear Fuel Program
OD	outer diameter
PWR	pressurized water reactor
SCM	Software Configuration Management

SDD	System Description Document

ACRONYMS (Continued)

SNF	spent nuclear fuel
SQR	Software Qualification Report
SR	Site Recommendation
SRS	Savannah River Site
SS	stainless steel
TBD	to be determined
TBV	to be verified
TRIGA	Training, Research, Isotopes, General Atomics
TRIGA FLIP	TRIGA Fuel Life Improvement Program
TRIGA-SS	TRIGA stainless steel
TSPA	Total System Performance Assessment
UCF	uncanistered spent nuclear fuel
UZrH	uranium zirconium hydride
VA	Viability Assessment
WP	waste package
WPD	Waste Package Department
WQR	Waste Form Qualification Report

1. PURPOSE

The purpose of *Design Analysis for the Defense High-Level Waste Disposal Container* analysis is to technically define the defense high-level waste (DHLW) disposal container/waste package using the Waste Package Department's (WPD) design methods, as documented in *Waste Package Design Methodology Report* (CRWMS M&O [Civilian Radioactive Waste Management System Management and Operating Contractor] 2000a). The DHLW disposal container is intended for disposal of commercial high-level waste (HLW) and DHLW (including immobilized plutonium waste forms), placed within disposable canisters. The U.S. Department of Energy (DOE)-managed spent nuclear fuel (SNF) in disposable canisters may also be placed in a DHLW disposal container along with HLW forms.

The objective of this analysis is to demonstrate that the DHLW disposal container/waste package satisfies the project requirements, as embodied in *Defense High Level Waste Disposal Container System Description Document* (SDD) (CRWMS M&O 1999a), and additional criteria, as identified in *Waste Package Design Sensitivity Report* (CRWMS M&O 2000b, Table 4). The analysis briefly describes the analytical methods appropriate for the design of the DHLW disposal container/waste package, and summarizes the results of the calculations that illustrate the analytical methods. However, the analysis is limited to the calculations selected for the DHLW disposal container in support of the Site Recommendation (SR) (CRWMS M&O 2000b, Section 7).

The scope of this analysis is restricted to the design of the codisposal waste package of the Savannah River Site (SRS) DHLW glass canisters and the Training, Research, Isotopes General Atomics (TRIGA) SNF loaded in a short 18-in.-outer diameter (OD) DOE standardized SNF canister. This waste package is representative of the waste packages that consist of the DHLW disposal container, the DHLW/HLW glass canisters, and the DOE-managed SNF in disposable canisters.

The intended use of this analysis is to support Site Recommendation reports and to assist in the development of WPD drawings. Activities described in this analysis were conducted in accordance with the Development Plan *Design Analysis for the Defense High-Level Waste Disposal Container* (CRWMS M&O 2000c) with no deviations from the plan.

2. QUALITY ASSURANCE

The Quality Assurance program applies to this analysis. All types of waste packages were classified in accordance with QAP-2-3, *Classification of Permanent Items,* as Quality Level 1. This analysis applies to the waste packages identified in CRWMS M&O (1999a, Appendix B) as components of the overall system classified as Quality Level 1 in the Monitored Geologic Repository (MGR) Classification Analysis, *Classification of the MGR Defense High-Level Waste Disposal Container System* (CRWMS M&O 1999b, p. 7). The development of this analysis is conducted under Activity Evaluation *Waste Package Design Methodology and AMRs - 1101 2125 M1* (CRWMS M&O 1999c). The results of that evaluation were that the activity is subject to the *Quality Assurance Requirements and Description* (DOE 2000) requirements. This analysis directly supports the SR; therefore, it is subject to level-3 change control. A Technical Change Request will be processed in accordance with AP-3.4Q, *Level 3 Change Control.*

The control of this analysis 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 Yucca Mountain Project (YMP) electronic infrastructure (e.g., lotus notes or 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.*

3. COMPUTER SOFTWARE AND MODEL USAGE

No computer software or models are used in the development of this analysis.

4. INPUTS

4.1 DATA AND PARAMETERS

The material specifications in subsection 4.1.1 are from codes and standards identified in the SDD. A summary of other data and parameters used in calculations that support this analysis is provided in subsections 4.1.2 and 4.1.3 for reference purposes only. These calculations are based in part on unqualified data assigned as to-be-verified (TBV) information and tracked in accordance with AP-3.15Q, *Managing Technical Product Inputs*. Therefore, the data and parameters are appropriate for their intended purpose in this analysis.

4.1.1 Material Specifications

The materials selected for the inner shell, the outer shell, and the basket assembly (inner and outer brackets and divider plates in the case of the 5-DHLW/DOE SNF waste packages and divider plates in the case of the 2-MCO/2-DHLW waste packages) of the DHLW disposal container are the American Society for Testing and Materials (ASTM) alloys A 240 S31600, B 575 N06022 (Alloy 22), and A 516 K02700 (516 Carbon Steel Grade 70), respectively. The chemical compositions of these materials are presented in Table 1. Table 2 presents the temperature dependence for the tensile strength of alloy SA-240 S31600. The ultimate tensile strength and the yield strength of Alloy 22 are 690 MPa and 310 MPa, respectively (ASTM 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. 3).

Table 1. Chemical Compositions for the Materials of the DHLW Disposal Container

Element	Weight Percent		
	SB-575 N06022[a]	SA-516 K02700[b]	SA-240 S31600[c]
Molybdenum	12.5-14.5	-	2.00-3.00
Chromium	20.0-22.5	-	16.00-18.00
Iron	2.0-6.0	Remainder	Remainder
Tungsten	2.5-3.5	-	-
Cobalt	2.5 max	-	-
Carbon	0.015 max	0.28 max	0.08 max
Silicon	0.08 max	0.15-0.40 (heat analysis) 0.13-0.45 (product analysis)	0.75 max
Manganese	0.50 max	0.85-1.20 (heat analysis) 0.79-1.30 (product analysis)	2.00 max
Vanadium	0.35 max	-	-
Phosphorus	0.02 max	0.035 max	0.045 max
Sulfur	0.02 max	0.035 max	0.030 max
Nickel	Remainder	-	10.00-14.00
Nitrogen	-	-	0.10 max

SOURCES: [a] ASTM B 575-97, p. 2.

[b] ASTM A 516/A 516M-90, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*, p. 2.
[c] 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 516 K02700 is identical to ASME SA-516 K02700.
The material specification ASTM A 240 S31600 is identical to ASME SA-240 S31600.

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

Temperature (°F)	-20 to 100	200	300	400	700	750	800	850	900	950	1000
Temperature (°C)[a]	-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)[b]	517	517	506	495	495	492	489	481	472	459	444

SOURCE: American Society of Mechanical Engineers (ASME) 1995, Section II, Table U.
NOTES: [a] $t_{°C} = (t_{°F} - 32)/1.8$ (Parrington et al. 1996, p. 57).
[b] 1000 pound-force per in^2 (ksi) = 6.894757E+06 pascal (Pa) (Parrington et al. 1996, p. 57).

4.1.2 SRS DHLW Glass Pour Canister

The SRS Defense Waste Processing Facility (DWPF) DHLW canister, shown in Figure 1, is a cylindrical stainless steel (SA-240 304L) shell with an outer diameter of 610 mm (approximately 24 in.), a wall thickness of 9.525 mm, and a nominal length of 3,000 mm, which is approximately 10 ft (DOE 1992, p. 3.3-1). The flanged head and neck of the canister is 225.6-mm high. DHLW glass occupies approximately 85 percent of the volume of the canister. The DWPF demonstrates compliance with the project requirements for the acceptance of vitrified high-level waste forms in the DWPF Waste Form Qualification Report (WQR). In Volume 8 of the WQR, *DWPF Canister Procurement, Control, Drop Test, and Closure (U)* (Marra et al. 1995), the DWPF demonstrates that the requirements for canister dimensions and weights are satisfied through procurement specifications and process controls. However, variations in glass chemical composition and density are expected. An average glass density of 2.65 g/cm^3 is indicated in Marra et al. (1995) and an upper limit glass density of 2.85 g/cm^3 is indicated in Stout and Leider (1991). Table 3 summarizes the geometry and material specifications for the SRS DHLW glass canisters. A maximum heat generation from a single canister at the time of production and maximal (90 percent) fill levels of 752 W is provided in Volume 3 of the WQR, *Projected Radionuclide Inventories and Radiogenic Properties of the DWPF Product (U)* (Plodinec and Marra 1994, Table 6).

Table 3. Geometry and Material Specifications for SRS DHLW Glass Canisters

Component	Material	Characteristic	Value
Pour canister	SS 304L	Outer diameter (mm)	610
		Wall thickness (mm)	9.525
		Length (mm)	3,000
		Mass (kg)	500
SRS DHLW glass	Borosilicate glass	Mass (kg)	1,682
		Density[a] (g/cm^3)	2.73

SOURCE: DOE 1992, pp. 3.3-1 through 3.3-6.
NOTE: [a] The density of glass may have slight variations. Stout and Leider (1991, p. 2.2.1.1-4) indicate the following. "The average fill temperature (i.e., the average temperature of the glass upon completion of filling to 85% of canister volume) is 825 °C. The glass volume per canister when cooled to 25 °C is about 0.59 m^3. The density of the glass is about 2.69 g/cm^3 at 825 °C and 2.85 g/cm^3 at 25 °C."

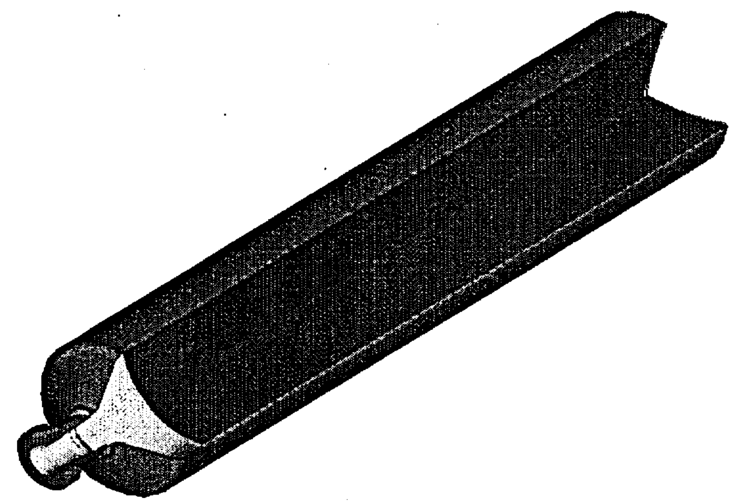


Figure 1. SRS DHLW Glass Pour Canister

4.1.3 DOE Standardized SNF Canister

The conceptual design for the short 18-in.-OD DOE standardized SNF canister is fully described on pages 4 to 6 and Appendix A in "Design Specification," Volume 1 of *Preliminary Design Specification for Department of Energy Standardized Spent Nuclear Fuel Canisters* (DOE 1999a). Since this design is conceptual only, the following dimensions and specifications are subject to change. The canister is a right circular cylinder of stainless steel (Type 316L) with an outer diameter of 457 mm and a wall thickness of 9.525 mm. The nominal internal length of the canister is 2,547 mm, and the nominal overall length is 2,999 mm (approximately 10 ft). A curved carbon-steel impact plate at the top and bottom of the canister, 50-mm thick, were designed to protect the integrity of the canister and fuel during the waste package drop or tip-over events. The skirts of the canister, which extend beyond the ends of the canisters, also help protect the integrity of the canister and the fuel during the canister or waste package drop event. Table 4 summarizes the dimensions and material specifications for the short 18-in.-OD DOE standardized SNF canister. The plan view of the canister is shown in Figure 2.

Table 4. Geometry and Material Specifications for the DOE SNF Canister

Component	Material	Characteristic	Dimension (mm)
Circular cylinder	SS 316L	Outer diameter	457
		Wall thickness	9.525
		Internal length	2,540
Impact plate	A 516 Carbon Steel Grade 70	Thickness	50
Top and bottom curved plates	SS 316L	Thickness	9.525

SOURCE: DOE 1999a, p. 5 and Appendix A.

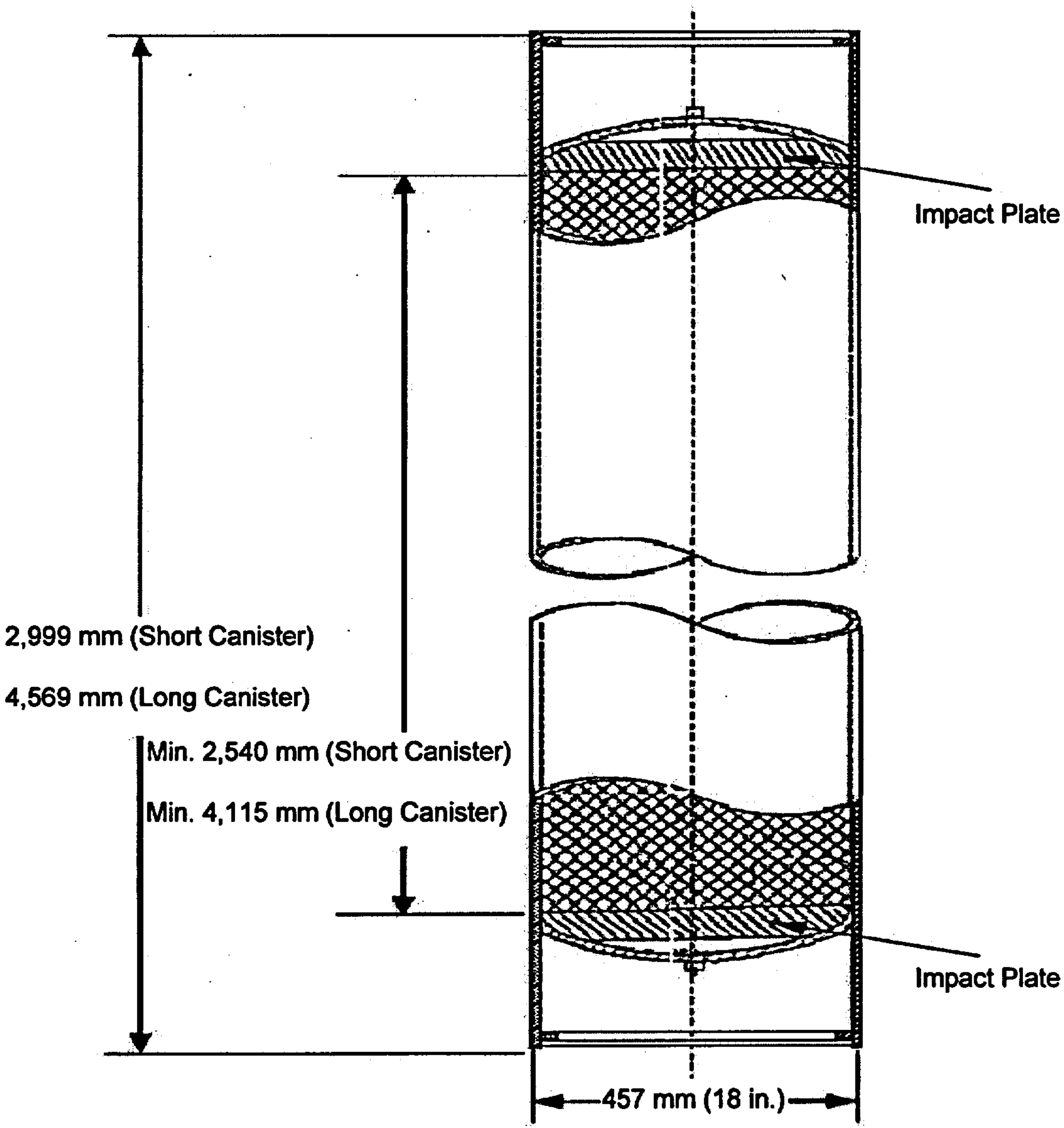


Figure 2. Plan View of the 18-in.-OD DOE Standardized SNF Canister

A basket for the DOE SNF canister will be constructed to hold 37 TRIGA SNF rods. It consists of 37 stainless steel tubes, bundled and welded to a stainless steel base plate, and 12 basket support brackets. For rods with maximum length of 774.7 mm, three such baskets will be stacked in the DOE SNF canister to provide 111 rods per canister. The Sketch SK-0124 REV 00, which shows the basket assembly for this case, is presented in Attachment II. For rods with maximum length of 1143.0 mm, two such baskets will be stacked in the DOE SNF canister to provide 74 rods per canister. For rods with maximum length of 1,689.1 mm, one such basket will be stacked in the DOE SNF canister to provide 37 rods per canister. An isometric view of the basket assemblies is provided in Figure 3 and a cross-sectional sketch of an arrangement of TRIGA-stainless steel (TRIGA-SS) rods in a DOE SNF canister is shown in Figure 4. Fuel descriptions including TRIGA SNF inventories and beginning-of-life and end-of-life fuel characteristics are provided in *TRIGA (UZrH) Fuel Characteristics for Disposal Criticality Analysis* (DOE 1999b).

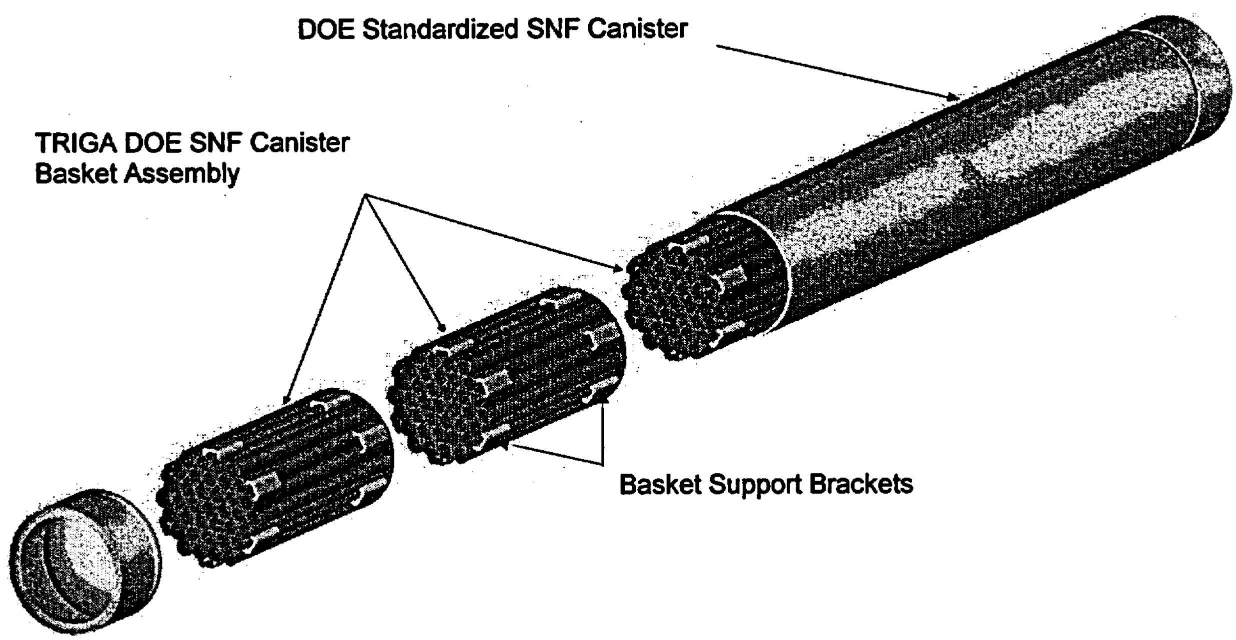


Figure 3. Isometric View of the Basket Assemblies for TRIGA SNF

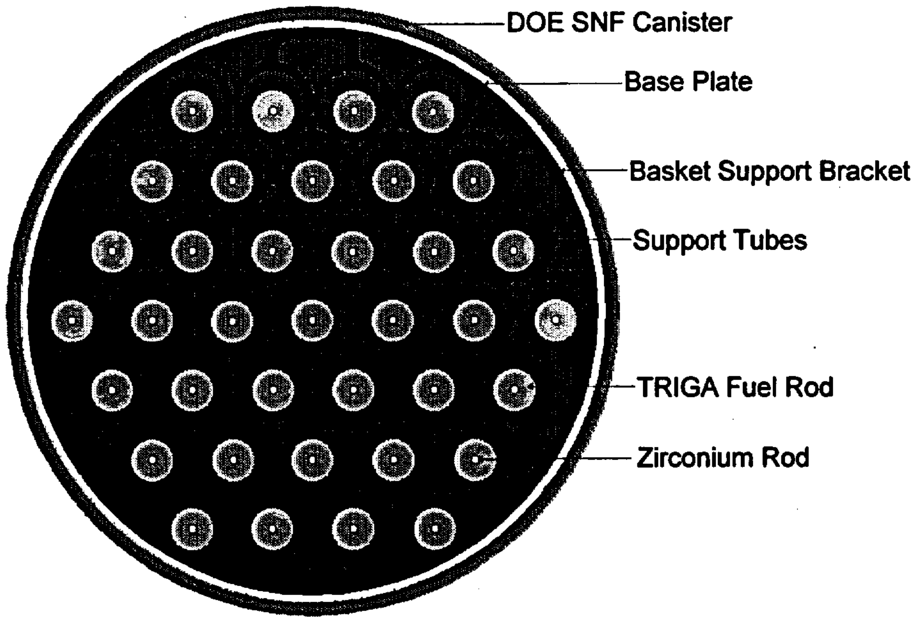


Figure 4. Cross-Sectional Sketch of TRIGA-SS Rods in an 18-in.-OD DOE SNF Canister

A 1-mm advanced neutron absorber matrix tube (Alloy 22 with 8 atom % Gd) is placed inside of 12 structural tubes per basket. The options for placement of these advanced neutron absorber matrix tubes, shown in Figure 5, are addressed in the criticality calculations (CRWMS M&O 1999e, pp. 36 and 37).

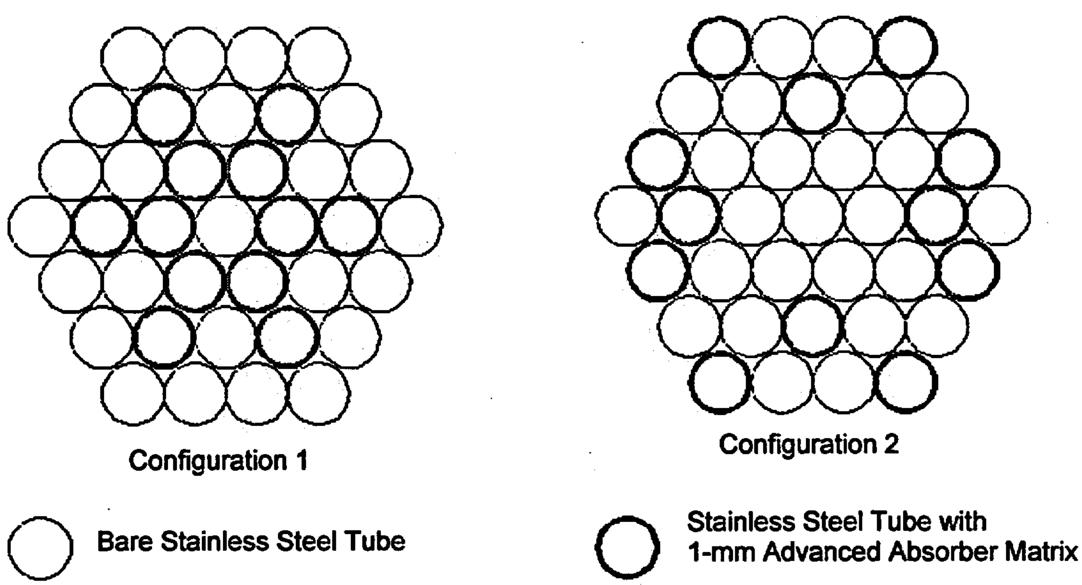


Figure 5. Emplacement of the Advanced Neutron Absorber Matrix Coat

4.2 CRITERIA

The DHLW disposal container/waste package must satisfy project requirements (as embodied in CRWMS M&O 1999a, Section 1.2), the interface agreements between WPD and other organizations, and additional criteria (as identified in CRWMS M&O 2000b, Table 4). The project requirements for the DHLW disposal container/waste package are presented in the following sections.

This analysis will address the compliance of the DHLW disposal container/waste package with a subset of the criteria. The selection of calculations that illustrate the design methodology of waste packages and the rationale for their selection are provided in CRWMS M&O (2000b). The demonstration of the DHLW disposal container/waste package compliance with the entire set of criteria will be available for License Application (LA). Criteria that specify the waste package performance parameters as to-be-determined (TBD) information are partially addressed for SR and fully shown compliant for LA. For these criteria, this analysis presents the design methods and the parameters of the current design.

4.2.1 System Description Document Criteria

Table 5 summarizes the SDD criteria for the DHLW disposal container/waste package (as established in CRWMS M&O 1999a, Section 1.2). It should be noted that the non-nuclear safety, operational, and subsystem design criteria have not been identified in the applicable SDD. These are planned to be addressed in a later revision of the SDD, if necessary (CRWMS M&O 1999a, Sections 1.2.2.2, 1.2.5, and 1.3).

In Table 5, the column denoted as "DHLW SDD Criterion" indicates the SDD criterion identifiers (as listed in CRWMS M&O 1999a, Section 1.2). The column denoted as "Method" specifies the method used to demonstrate the DHLW disposal container/waste package compliance. This column also specifies the type of waste package selected (CRWMS M&O 2000b) for calculations that represent the WPD design methods, if the waste package type is different from the codisposal waste package. In this column, "LA," "N/A," and "SR/LA" are used to identify the criteria that will be addressed in License Application, the criteria that will not be addressed by the WPD, and the criteria that will partially be addressed for SR, respectively (see CRWMS M&O 2000b, Section 6). The column denoted as "Performance Parameter" indicates the performance limit imposed by the criteria for the DHLW disposal container/waste package.

Table 5. DHLW System Description Document Criteria

DHLW SDD Criterion	Description	Method	Performance Parameter
System Performance Criteria			
1.2.1.1[a]	This criterion provides the size, weight, and materials for the HLW canisters that the disposal container shall accommodate.	Description	Accommodation of all HLW canisters as defined in CRWMS M&O (1999a, Table I-1)
1.2.1.2[b]	This criterion provides the DOE SNF waste forms and the sizes and weights for the DOE SNF disposable canisters that the disposal container shall accommodate.	Description	Accommodation of all NSNFP canisters as defined in CRWMS M&O (1999a, Table I-3)
1.2.1.3[c]	This criterion imposes the limit for the total effective annual dose to the average member of the critical group at any time during the first 10,000 years after permanent closure of the repository due to radioactive material release.	N/A	Shall be less than a total effective annual dose of 25 mrem, in conjunction with the Emplacement Drift System and natural barriers during the first 10,000 years
1.2.1.4[d]	This criterion imposes the thickness and material for the inner cylinder and the outer cylinder of the DHLW disposal container.	Description	The inner cylinder of stainless steel with a nominal thickness of 5 cm, and the outer cylinder of Alloy 22 with a nominal thickness of 2 cm
1.2.1.5[c]	This criterion requires reliability for the WP during the first 10,000 years after emplacement in an emplacement drift.	N/A	WP reliability of (TBD-3755) percent
1.2.1.6[e]	This criterion imposes the maximum temperature of HLW glass inside the WP under normal conditions and short-term exposure to fire.	Thermal SR/LA	HLW glass temperatures below 400 °C (TBV-092) under normal conditions, and below 460 °C (TBV-245) for short-term exposure to fire
1.2.1.7[e]	This criterion imposes the maximum temperatures for the zircaloy cladding and other types of cladding for the DOE SNF under normal conditions and for short-term exposure to fire.	Thermal SR/LA	Zircaloy cladding temperatures less than 350 °C (TBV-241) under normal conditions and below 570 °C (TBV-245) for short-term exposure to fire. The temperature of other types of DOE fuel cladding shall be limited to (TBD-179)
1.2.1.8	This criterion requires the waste package capability of preventing the breach of the waste form canisters during normal handling operations.	LA	Intact waste form canisters during the normal handling operations of the WP
1.2.1.9	This criterion requires the waste package capability of supporting/allowing retrieval after the start of emplacement operations.	Structural	WP retrieval up to 300 years after the start of emplacement operations
1.2.1.10[f]	This criterion imposes the maximum combined concentrations of O_2, H_2, H_2O, CO_2, and CO within a waste package prior to WP breach.	N/A	A maximum of 0.25 percent of the internal volume filled with O_2,, H_2, H_2O, CO_2, and CO (TBV-094)
1.2.1.11	This criterion imposes an external surface finish Roughness Average for the disposal container/waste package, excluding the labels.	LA	Roughness Average of 6.36 μm or less
1.2.1.12	This criterion requires the waste package to have all external surfaces accessible for visual inspection and decontamination.	Description	WP external surfaces accessible for visual inspection and decontamination (e.g., no blind holes)
1.2.1.13	This criterion imposes a means of identification with a unique waste package identifier.	LA	Label with unique waste package identifier
1.2.1.14	This criterion imposes integrity of the waste package after labeling.	LA	WP integrity after labeling

Table 5. DHLW System Description Document Criteria (Continued)

1.2.1.15	This criterion requires labels be legible and readable by remote means until permanent closure of the repository.	LA	Labels be legible and readable
1.2.1.16	This criterion imposes lifting features 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 of construction.	Structural	WP lifting feature of three times the maximum weight of the loaded and sealed disposal container
1.2.1.17	This criterion imposes lifting features of the waste package without exceeding the ultimate tensile strength of the materials.	Structural	WP lifting feature of five times the weight of the loaded disposal container
1.2.1.18	This criterion imposes the WP capability of withstanding transfer, emplacement, and retrieval operations.	Structural	No breach
1.2.1.19	This criterion requires the disposal container/waste package to be constructed of non-combustible and heat-resistant materials.	Description	Non-combustible and heat resistant materials
1.2.1.20	This criterion excludes the use of explosive or pyrophoric materials.	Description	Non-explosive and non-pyrophoric materials
1.2.1.21	This criterion excludes the use of free liquids.	Description	No free liquids
Safety Criteria			
1.2.2.1.1[g]	This criterion imposes the WP capability of withstanding (while in a horizontal orientation), without breaching, a rock (spherical geometry assumed) falling onto the side of the waste package, during the preclosure period.	Structural 21-PWR	WP capability of withstanding a 13-MT (TBV-245) rock falling 3.1 m (TBV-245) onto the side of the WP
1.2.2.1.2	This criterion imposes the WP capability of withstanding (while in a vertical orientation), during the preclosure period, a spherical object falling onto the end of the disposal container.	Structural LA	WP capability of withstanding a 2.3-MT (TBV-245) spherical object falling 2 m (TBV-245) onto the end of the disposal container, without breaching
1.2.2.1.3	This criterion imposes the WP capability of withstanding (while in a vertical orientation) a drop onto a flat, unyielding surface, during the preclosure period.	Structural Naval	WP capability of withstanding a drop from a height of 2 m (TBV-245) onto a flat, unyielding surface without breaching
1.2.2.1.4	This criterion imposes the WP capability of withstanding (while in a horizontal orientation) a drop onto a flat, unyielding surface, during the preclosure period.	Structural Naval	WP capability of withstanding a drop from a height of 2.4 m (TBV-245) onto a flat, unyielding surface without breaching
1.2.2.1.5[h]	This criterion imposes the WP capability of withstanding (while in a horizontal orientation), the greater stress resulting from a drop onto a steel support or a concrete pier, during the preclosure period.	Structural 44-BWR	WP capability of withstanding a drop of 1.9 m (TBV-245) onto a steel support in an emplacement drift, or a drop of 2.4 m (TBV-245) onto a concrete pier, without breaching
1.2.2.1.6	This criterion imposes the WP capability of withstanding a tip over from a vertical position with slap down onto a flat, unyielding surface, during the preclosure period.	Structural 21-PWR	The WP capability of withstanding a tip over from a vertical position with slap down onto a flat, unyielding surface without breaching (TBV-245)

Table 5. DHLW System Description Document Criteria (Continued)

1.2.2.1.7[i]	This criterion imposes the WP capability of withstanding a design basis earthquake, and indicates the surface and subsurface parameters for the design basis earthquake.	Structural SR/LA	Withstand a Design Basis Earthquake of Frequency Category 2. The surface parameters for this design basis earthquake are (TBD-241), and the subsurface parameters are defined in CRWMS M&O (1999a, Tables I-4 through I-7) (TBD-241, TBV-273)
1.2.2.1.8	This criterion imposes the WP capability of withstanding, the impact of a missile, during the preclosure period.	Structural	Withstand the impact of a 0.5-kg (TBV-245) missile (modeled as a 1-cm diameter, 5-cm long valve steam) traveling at 5.7 m/s (TBV-245), without breaching (TBV-245)
1.2.2.1.9	This criterion imposes the WP capability of withstanding the maximum impact resulting from a transporter runaway, derailment, and impact, taking credit as appropriate, for interfacing systems that prevent or mitigate the impact on the waste package.	LA	Withstand the maximum impact resulting from a transporter runaway, derailment, and impact at a speed of 63 km/h (TBV-245), without breaching (TBV-245)
1.2.2.1.10[j]	This criterion requires the WP capability of withstanding, a maximum internal pressure, during the preclosure period.	Structural SR/LA	Maximum internal pressure of (TBD-235), without breaching (TBV-245)
1.2.2.1.11[k]	This criterion requires the waste package to withstand, a hypothetical fire, as defined in 10 CFR 71, Section 73(c)(4).	Structural SR Thermal LA	Withstand a hypothetical fire (TBV-245)
1.2.2.1.12	This criterion imposes the nuclear sub-criticality of the WP during the preclosure period unless at least two unlikely, independent, and concurrent or sequential changes have occurred, and indicates the method of calculating the effective neutron multiplication factor (k_{eff}) of the system.	Criticality	k_{eff}, assuming occurrence of design basis events, including those with the potential to flood (TBD-235) the disposal container prior to sealing, sufficiently below unity to show at least a 5% margin after allowance for the bias in the method of calculation and uncertainty in the experiments used to validate the method of calculation (TBV-245)
1.2.2.1.13	This criterion imposes a limit for the total radionuclide inventory in the WP due to criticality events during the postclosure period, and indicates the method of evaluating the increment of radionuclide inventory due to criticality.	Criticality 21-PWR	At 1,000 years following criticality shutdown, the increase in the total radionuclide inventory inside the disposal container less than 1 percent due to criticality events in the WP (TBV-096)
System Environment Criteria			
1.2.3.1[l]	This criterion identifies WP performance requirements during and after exposure to the emplacement drift external environments and the induced/handling environments.	LA	Performance requirements as identified in CRWMS M&O (1999a, Table I-8 and Table I-9) (TBD-234, TBD-276)
System Interfacing Criteria			
1.2.4.1	This criterion requires accordance with the interface agreements defined in CRWMS M&O (1998a).	LA	See Section 4.2.2
1.2.4.2	The criterion requires accordance with the interface agreements defined in CRWMS M&O (1998b).	LA	See Section 4.2.2

Table 5. DHLW System Description Document Criteria (Continued)

1.2.4.3[j]	This criterion imposes a maximum dose rate at all external surfaces of a waste package.	Shielding SR/LA	Maximum surface dose rate of (TBD-3764) rem/h or less
1.2.4.4	This criterion imposes a maximum thermal output for the waste package.	Thermal	WP maximum thermal output of 11.8 kW
1.2.4.5	This criterion imposes the quantity of waste forms disposed of in the suite of DHLW disposal container.	Description	A total of 640 MTU of commercial HLW, 4,027 MTU of DHLW, and, in combination with DOE SNF disposal containers, not more than 2,437 MTU of DOE SNF
1.2.4.6	This criterion requires the disposal container to be capable of being loaded and sealed in a vertical orientation.	Description	The capability of being loaded and sealed in a vertical orientation
1.2.4.7	This criterion requires the WP to be capable of being handled in both horizontal and vertical orientations.	Structural	The capability of being handled in both horizontal and vertical orientations
1.2.4.8	This criterion requires the WP to be capable of supporting required welding times.	LA	See Section 4.2.2
Codes and Standards Criteria			
1.2.6.1	This criterion requires the design to be performed according to Section III, Division 1, Subsection NG-1995 of *ASME Boiler and Pressure Vessel Code, 1995 Edition* (ASME 1995).	Structural	See Section 4.3.1
1.2.6.2	This criterion requires the design to be performed according to Section III, Division 1, Subsection NB-1995 of *ASME Boiler and Pressure Vessel Code, 1995 Edition* (ASME 1995).	Structural	See Section 4.3.1
1.2.6.3	This criterion requires the design to be performed according to applicable sections of *Nuclear Criticality Control of Special Actinide Elements* (ANSI/ANS-8.15-1981).	LA	See Section 4.3.2
1.2.6.4	This criterion requires the design to be performed according to applicable sections of *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* (ANSI/ANS-8.1-1998).	LA	See Section 4.3.2
1.2.6.5	This criterion requires the design to be performed according to applicable sections of *Criteria for Nuclear Safety Controls in Operations with Shielding and Confinement* (ANSI/ANS-8.10-1983).	LA	See Section 4.3.2
1.2.6.6	This criterion requires the design to be performed according to applicable sections of *Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors* (ANSI/ANS-8.17-1984).	LA	See Section 4.3.2

SOURCE: CRWMS M&O 1999a, Section 1.2.

NOTES: [a] The SRS, Idaho National Engineering and Environmental Laboratory, and West Valley Demonstration Project HLW canisters: 61-cm nominal outside diameter and 300-cm nominal overall height. Hanford Site-long HLW canister: 61-cm nominal outside diameter and 457.2-cm nominal overall height (TBV 264).

[b] NSNFP 18 in. x 10 ft (457-mm nominal diameter and 3000 mm maximum length); NSNFP 18 in. x 15 ft (457-mm nominal diameter and 4,570-mm maximum length).

[c] While the WPD supports the development of radionuclide inventories for Total System Performance Assessment (TSPA).
[d] A 25-mm thickness for the outer shell of the DHLW disposal container has been obtained in *Rock Fall and Vertical Drop Calculations of Waste Packages* (CRWMS M&O 1999d) by correlation with the 21-PWR waste package.
[e] The SR calculations will be for normal conditions. Short-term fire exposure will be addressed in LA.
[f] Operations issue.
[g] Rock has prismatic tetrahedral geometry.
[h] The drop of a waste package and pallet combination is now more appropriate (CRWMS 2000b, Table 5).
[i] Preclosure seismic events will be evaluated for SR. Postclosure seismic events are undefined.
[j] Performance parameter not defined. SR calculations will determine a performance parameter for the current design.
[k] Waste package pressurization will be performed for SR. A thermal analysis will be performed for LA.
[l] Because the requirements for this criterion are not defined, it is not possible to evaluate a design against this criterion for Site Recommendation.
ANS = American Nuclear Society.
ANSI = American National Standards Institute, Inc.
BWR = boiling water reactor.
MT = metric ton.
MTU = metric tons uranium.
N/A = not applicable.
NSNFP = National Spent Nuclear Fuel Program.
PWR = pressurized water reactor.
WP = waste package.

4.2.2 Interface Control Document Criteria

The current interface control documents, *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), and *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), do not address the current waste package designs. These criteria will be addressed in License Application (as shown in CRWMS M&O 2000b, Table 5).

An interface with the Disposal Container Handling System has been identified in CRWMS M&O (1999a, Section 1.2.4.8). The information concerning welding times will be addressed in License Application (CRWMS M&O 2000b). This analysis does not address several Interface Control Document (ICD) criteria associated with disposal container and waste package lifting, handling, loading, and sealing in the waste handling building and surface facilities (see CRWMS M&O 1998a). Additional analysis by both the Waste Package and Surface Facility Operations will be necessary to address ICD criteria during the license application design phase. Specific criteria and design interfaces that remain to be addressed include:

- Disposal container lid closure process, utilities, and equipment design criteria

- Closure lid process handling, equipment setup, welding, annealing, inspection, and operating time parameters for the Disposal Container Handling System

- Closure process equipment reliability and availability parameters (failure frequency/outage times) for the Disposal Container Handling System

- Closure weld equipment requirements for the Disposal Container Handling System

- Closure weld stress relief equipment requirements for the Disposal Container Handling System

- Closure weld non-destructive examination equipment requirements for the Disposal Container Handling System

- Closure lid weld repair and defect operational requirements for the Disposal Container Handling System and Waste Package Remediation System

- Closure lid cutting, removal, and opening requirements for Waste Package Remediation System

- Closure lid process dimensional tolerances for Disposal Container Handling System turntable rotation and alignment

- Disposal container closure lid lifting fixture and grapple design

- Disposal container inner lid penetrations and seals for helium gas filling

- Disposal container closure lid weld preparation surface cleaning criteria and equipment design

- Disposal container lifting and handling collar design

- Disposal container horizontal handling equipment design

- Disposal container horizontal handling seismic restraint criteria

- Disposal container vertical handling equipment design

- Disposal container vertical handling seismic restraint criteria

- Disposal container surface decontamination criteria and equipment design

- Waste package basket assembly insertion tolerances for loading and unloading of disposal container waste forms

- Disposal container and closure lids identification and labeling.

4.2.3 Other Requirements

Additional structural requirements for waste packages that were identified in CRWMS M&O (2000b, Table 4) are presented in Table 6.

Table 6. Additional Requirements

Criterion[a]	Description	Method	Performance Parameters
Structural-1	This criterion imposes a manufacturing residual stress in the outer shell material that prevents the initiation of stress corrosion cracking.	Structural 21-PWR	The manufacturing residual stresses maintained below 20 percent of the yield strength for a depth of (TBD) from the outer surface
Structural-2	This criterion imposes a limit for the static loads in the outer shell material at the interface with the emplacement pallet to prevent the initiation of stress corrosion cracking.	Structural Naval	Static loads in the outer shell maintained below 20 percent of the yield strength
Structural-3[b]	This criterion imposes a limit for the seismic loads in the outer shell material to prevent strains that could be the initiation point for stress corrosion cracking.	SR/LA	In the outer shell, seismic loads maintained below the yield strength

SOURCE: CRWMS M&O 2000b, Table 4.
NOTES: [a] Criterion identifier as in CRWMS M&O (2000b).
[b] Preclosure seismic loads to be evaluated for SR. Postclosure seismic loads have not been identified yet.

4.3 CODES AND STANDARDS

The codes and standards applicable to the design of the DHLW disposal container/waste package have been identified in CRWMS M&O (1999a). The applicability of ASME Boiler and Pressure Vessel Code is discussed in the following section.

4.3.1 ASME Boiler and Pressure Vessel Code

ASME Boiler and Pressure Vessel Code, 1995 Edition (ASME 1995) has been chosen as a guide for setting stress limits for the waste package components. The applicable subsections of Section III, Division 1, of this code are shown in Table 7.

Table 7. Applicability of the ASME Boiler and Pressure Vessel Code

Analysis Type	Waste Package Component	Section III, Subsection Applied	Service Limits[a]
Static	Barriers[b]	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

SOURCE: ASME 1995.
NOTES: [a] Level A Service Limits are for normal operation and Level D Service Limits are for off-normal conditions.
[b] Barriers, instead of shells, are used here in order to be consistent with the ASME Code.

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 (ASME 1995, Section III, Division 1, Subsection NB, Article NB-3221.3), the limitation on membrane and bending stresses at Level A is:

$$P_m + P_b = 1.5 \cdot S_m \qquad \text{(Eq. 1)}$$

where

P_m = membrane stress (MPa)
P_b = bending stress (MPa)
S_m = design stress intensity for the material (MPa)

The design stress intensity is two-thirds of the yield strength; therefore, the allowable total stress including both membrane and bending is equal to the yield stress.

For Level D Service Limits, Subsection NB of the ASME Boiler and Pressure Vessel Code is used, as shown in Table 7. From the code (ASME 1995, Section III, Division 1, Appendix F, Article F-1341.2), the limitation on membrane and bending stresses at Level D is:

$$P_m + P_b < 0.9 \cdot S_u \qquad \text{(Eq. 2)}$$

where

S_u = ultimate tensile strength of the material (MPa)

4.3.2 ANSI/ANS Standards

ANSI/ANS-8.15-1981, ANSI/ANS-8.1-1998, ANSI/ANS-8.10-1983, and ANSI/ANS-8.17-1984 have been cited in *Disposal Criticality Topical Report* (YMP 1998, pp. 2-9 and 2-10). YMP (1998) defines the methodology for all criticality evaluations. Therefore, the SR calculations based on the topical report could demonstrate compliance with applicable sections of these standards. However, when the final Nuclear Regulatory Commission's Safety Evaluation Report for the topical report is complete, the final draft of the topical report will supersede the DHLW SDD criteria 1.2.6.3 through 1.2.6.6 (CRWMS M&O 2000b, Table 2).

5. ASSUMPTIONS

The process and methodological assumptions used in calculations referenced in this analysis (CRWMS M&O 1999e, 1999f, 1999g, 2000d, 2000e, 2000f, and 2000g) are included in the *Waste Package Design Methodology Report* (CRWMS M&O 2000a, Section 5). Assumptions have been used in a conservative or equivalent manner to facilitate calculations whenever inputs were not available or the methodology allowed a simplified treatment. Specific assumptions follow.

5.1 STRUCTURAL

The internal pressure of a 21-PWR waste package, as a result of the fuel rod rupture design event, was assumed in CRWMS M&O (2000d, p. 5) to evaluate the temperature-dependent gas pressure inside a DHLW/DOE SNF waste package. The rationale for this methodological assumption is that it allows a parametric evaluation of the stress developed in the waste package structural components due to internal pressurization. It should be noted that the DHLW/DOE SNF waste packages contain canistered waste forms and therefore, there are no bare fuel rods inside these waste packages under normal conditions. This assumption has been used to obtain the results shown in Section 6.2.2.

5.2 THERMAL

The calculation *Thermal Evaluation of the TRIGA Codisposal Waste Package* (CRWMS M&O 1999g) considered the Viability Assessment (VA) design for the disposal container. It is assumed that its results can be used to demonstrate the waste package compliance with DHLW SDD 1.2.1.6 and 1.2.1.7 criteria. The rationale for this assumption is that the calculated glass temperature shows a large margin to the glass transition temperature and the effect of differences in the SR and VA designs for the DHLW disposal container on the peak glass temperature is small when compared with this margin. Insofar as the thermal calculation is concerned, the SR and VA designs differ from one another only in the thickness and composition of the two waste package shells. For the VA design, the outer, corrosion allowance shell was composed of carbon steel with a thickness of 100 mm and an inner, Alloy 22, corrosion resistant shell with a thickness of 20 mm (CRWMS M&O 1999g, p. 10 and Attachment V). For the design described in this analysis, the outer, corrosion resistant shell is composed of 25 mm of Alloy 22, supported by a 50-mm structural shell of stainless steel (see Attachment III). While the thermal resistances and capacitances of these two configurations differ somewhat due to the differences in thicknesses and the replacement of the carbon steel with Alloy 22, this effect on the peak glass temperature is small when compared with the large margin to the glass transition temperature. This assumption is used throughout Section 6.2.3.

The boundary temperature history for a DHLW/TRIGA SNF codisposal waste package was assumed to be bounded by the boundary temperature history for the average-heat 44 BWR waste package (CRWMS M&O 1999g, Assumption 3.26). The rationale for this assumption is that the 44 BWR waste package has a smaller diameter and a higher heat generation rate, providing conservative peak cladding temperatures within the waste package. This assumption has been used to obtain the results shown in Section 6.2.3.

5.3 SHIELDING

The gamma and neutron source terms of the DWPF Design-Basis Glass at one day after pouring were assumed for the SRS DHLW glass canisters (CRWMS M&O 2000f, p. 12). The rationale for this methodological assumption is that these source terms generate conservative (higher) surface dose rates. This assumption has been used to evaluate an upper limit for the waste-package surface dose rates, which are shown in Section 6.2.4.

5.4 CRITICALITY

The calculation *TRIGA Fuel Phase I and II Criticality Calculation* (CRWMS M&O 1999e) considered the VA design for the disposal container. It is assumed that its results do not change with the disposal container design for the SR. The rationales for this assumption follow. The contents of the waste package (i.e., the DOE SNF canister loaded with TRIGA SNF and the SRS DHLW glass canisters) mainly determine the criticality of the system. These contents are identical in the waste packages considered in CRWMS M&O (1999e) and in this analysis. Additionally, the number of neutrons that leave the system does not change significantly because the container materials (for the VA and SR designs) have similar reflective properties for neutrons. This assumption is used throughout Section 6.2.5.

The fuel was assumed to be fresh, and no credit was taken for the fuel burnup (CRWMS M&O 1999e, Assumption 3.4). The rationale for this assumption is that it is conservative because the fresh fuel is more reactive than the spent fuel. This assumption has been used to obtain the results shown in Section 6.2.5.

6. ANALYSIS

This section will demonstrate that the DHLW disposal container/waste package design satisfies the project criteria presented in Section 4.2, with the exception of the ICD requirements identified in Section 4.2.2. However, only the DHLW SDD criteria selected for Site Recommendation in CRWMS M&O (2000b) will be addressed. The remaining SDD requirements, as well as the ICD requirements identified in Section 4.2.2 will be addressed as a part of the licensing progress, which occurs after Site Recommendation.

There are criteria that impose the size and materials for the DHLW disposal container. For those criteria, an examination of the sketch that shows the design of the DHLW disposal container is the method of analysis. Designing a fully compliant waste package with the project criteria necessitates source term, structural, thermal, shielding, and criticality analytical methods. The analytical methods used in the WPD for designing waste packages are described in *Waste Package Design Methodology Report* (CRWMS M&O 2000a). This analysis briefly describes the WPD methodology for designing the 5-DHLW/DOE SNF-short codisposal waste package. The results of the structural, thermal, shielding, and criticality calculations, which illustrate the waste package design methodology for the codisposal waste package of the DHLW glass canisters and the DOE SNF canister loaded with TRIGA SNF, are also summarized in this section. It is a limitation of this document that the results of the seismic calculations are not available. However, the balance of information given is sufficient for Site Recommendation.

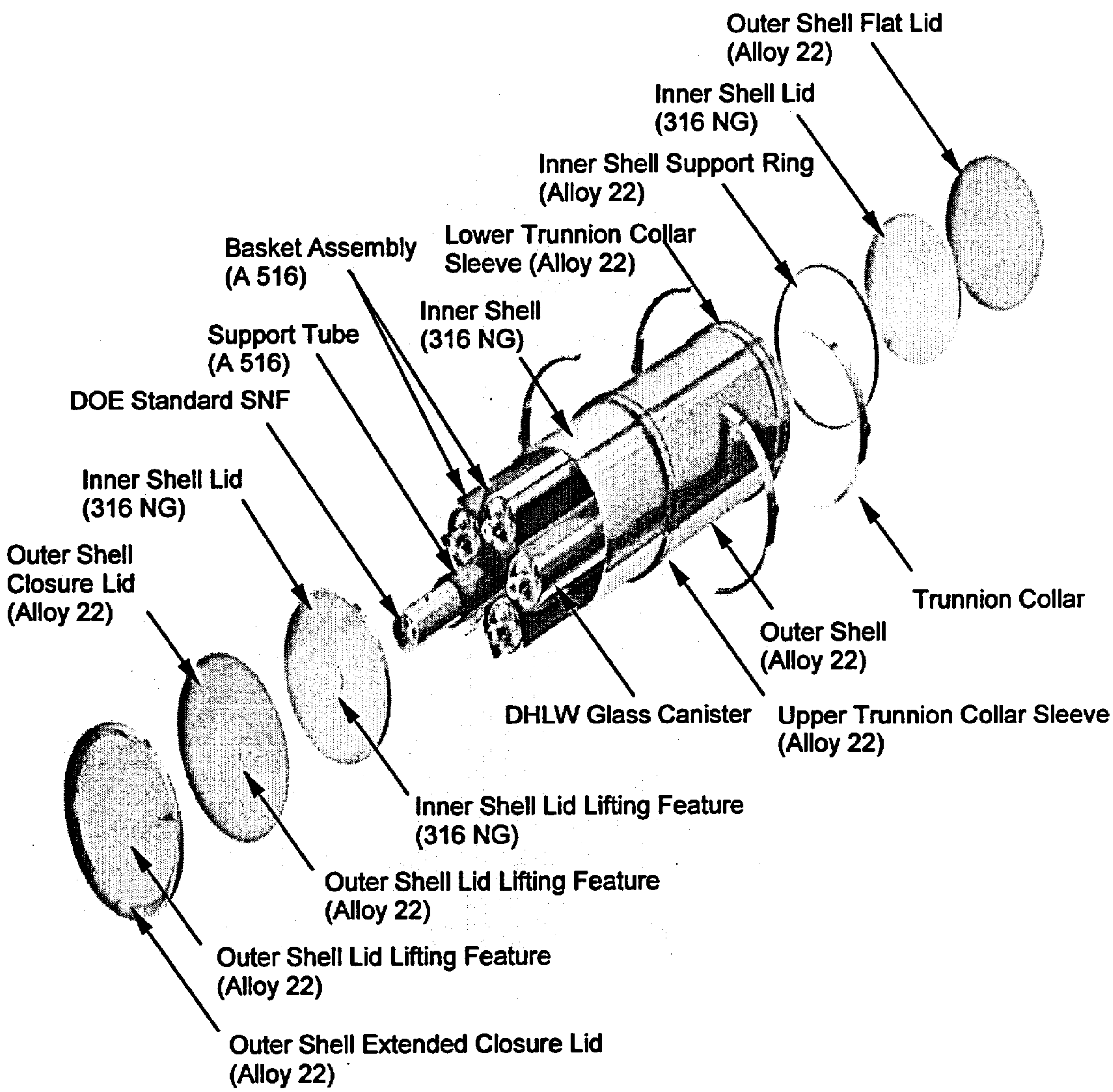
This section contains no discussion of alternate methods, as there are no alternate methods that are considered applicable. This analysis does not provide estimates of any of the factors for the Post-Closure Safety Case or Potentially Disruptive Events, and is, therefore, assigned Level 3 importance.

6.1 DHLW DISPOSAL CONTAINER/WASTE PACKAGE DESIGN

The DHLW disposal container provides long-term confinement of the DHLW and the commercial HLW placed within disposable canisters, and withstands the loading, transfer, emplacement, and retrieval loads and environments. The DOE-managed spent nuclear fuel in disposable canisters may also be placed in a DHLW disposal container along with the HLW forms. The designs developed for the DHLW disposal container system consist of a 5-DHLW/DOE SNF-short waste package design, a 5-DHLW/DOE SNF-long waste package design, and a 2-MCO (multi-canister overpack)/2-DHLW waste package design. The sketches developed for these designs are presented in Attachments III, V, and VII, respectively. The full inventory of the DOE SNF, DHLW, HLW, and immobilized plutonium in disposable canisters will be accommodated by 1,530 codisposal 5-DHLW/DOE SNF-short waste packages, 2,821 codisposal 5-DHLW/DOE SNF-long waste packages, and 199 codisposal 2-MCO/2-DHLW waste packages (CRWMS M&O 2000b, Table 1). The 5-DHLW/DOE SNF-short waste package design will also hold 5 canisters containing DHLW glass and immobilized plutonium, with no central DOE SNF canister. The only differences between the long and short five-pack designs consist of the lengths of the waste package cavity and basket assembly. In the case of the long five-pack waste package, the length of cavity is 4,617 mm and the length of the basket assembly is 4,607 mm. The 2-MCO/2-DHLW waste package design differs from the long-pack waste package design in that the cavity diameter was decreased to 1,584 mm, and the basket assembly was reduced to two perpendicular 10-mm-thick carbon steel (SA-516 K02700) plates. The plates allow the emplacement of two Hanford MCO canisters and two DHLW glass long canisters inside the DHLW disposal container. A detailed description of the 5-DHLW/DOE SNF-short waste package loaded with the TRIGA SNF is presented.

6.1.1 5-DHLW/DOE SNF-Short Waste Package Design

An isometric view of the 5-DHLW/DOE SNF-short waste package is shown in Figure 6.



NOTE: This figure shows conceptual trunnion collars, which have not been evaluated for surface handling and lifting.

Figure 6. Isometric View of the Codisposal Waste Package

The Sketch SK-0196 REV 03, *5-DHLW/DOE SNF-Short WP Assembly Configuration for Site Recommendation*, presented in Attachment III, shows the design of the short container for the disposal of five DHLW glass canisters and one DOE SNF canister. The dimensions and materials of the disposal container are summarized in Table 8. Attachment IV presents SK-0197 REV 00, which shows the weld configuration for the 5-DHLW/DOE SNF-short waste package.

Table 8. Dimensions and Material Specifications for the Disposal Container

Component	Material	Parameter	Dimension (mm)
Inner shell	SA-240 S31600	Thickness	50
Inner shell lid	SA-240 S31600	Thickness	80
Outer shell	SB-575 N06022	Thickness	25
Extended outer shell lid	SB-575 N06022	Thickness	25
Extended outer shell lid base	SB-575 N06022	Thickness	25
Support tube	SA-516 K02700	Inner diameter	501.5
		Thickness	31.75
		Length	3,030
Divider plate	SA-516 K02700	Thickness	12.7
		Length	3,030
Outer bracket	SA-516 K02700	Thickness	12.7
		Length	3,030
Inner bracket	SA-516 K02700	Thickness	25.4
		Length	3,030
Cavity		Length	3,040
		Diameter	1,880
Inner lid to closure lid gap[a]		Thickness	30
Closure lid to outer lid gap[a]		Thickness	30
Inner lid lifting feature[a]	SA-240 S31600	Thickness	27
Extended outer lid reinforcing ring	SB-575 N06022	Thickness	50
Outer lid lifting feature[a]	SB-575 N06022	Thickness	27
Outer shell flat closure lid	SB-575 N06022	Thickness	10
Outer shell flat bottom lid	SB-575 N06022	Thickness	25
Upper trunnion collar sleeve	SB-575 N06022	Thickness	40
Lower trunnion collar sleeve	SB-575 N06022	Thickness	40
Inner shell support ring	SB-575 N06022	Thickness	20

SOURCE: Sketch SK-0196 REV 03 (Attachment III).
NOTE: [a] The specified thickness is preliminary. Its adequacy is to be evaluated and analyzed by surface design for lifting and grappling.

The inner shell is a 50-mm-thick cylinder of stainless steel SA-240 S31600, which provides structural support. The outer shell is comprised of a 25-mm-thick cylinder of low-carbon nickel-molybdenum-chromium alloy SB-575 N06022 (Alloy 22), and serves as a corrosion resistant material. The thickness of the waste package shells, required to withstand a rock-fall design-basis event, has been determined in *Rock Fall and Vertical Drop Calculations of Waste Packages* (CRWMS M&O 1999d, Table 6.1-4). This 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 packages is obtained by correlation with the 21-PWR waste package shells thickness. Considering the difference in waste package diameters and accounting for the effects of other components of stress, an increase of 5 mm was deemed reasonable for the thickness of the Alloy 22 shell. The waste package contains two lower lids that are welded to the shells at the time of fabrication. This allows the disposal container to be loaded and sealed in a vertical orientation. The three upper lids will be welded in place after loading the disposal container with the appropriate waste forms. The DHLW disposal container is composed of stainless steel and low-carbon nickel-molybdenum-chromium alloys, which chemical compositions are shown in Table 1.

The waste package cavity allows an optimal emplacement of five 3,000-mm-long DHLW glass canisters surrounding a short 18-in.-OD DOE standardized SNF canister. A 31.75-mm-thick carbon steel (SA-516 K02700) support tube, with a nominal outer diameter of 565 mm, separates the DOE SNF canister from the DHLW glass canisters. The support tube helps the loading of the disposal container by providing a separate space for the DOE SNF canister to be inserted without having the five DHLW canisters lean over and infringe on its space. The support tube also isolates and protects the DOE SNF canister from the DHLW canisters during normal operation and abnormal events. The support tube is connected to the inside shell of the waste package by a web-like structure of carbon steel (SA-516 K02700) plates to support five 3,000-mm-long DHLW glass pour canisters. The support tube, divider plates, and inner and outer brackets, which constitute the waste package basket assembly, are 3,030-mm long. The basket assembly is made of carbon steel alloy, which chemical composition is shown in Table 1.

The disposal containers are designed to accept trunnion collars. The use of trunnion collars permits attachments of fixtures that may be used for both vertical and horizontal handling of the waste package, as well as attitudes between vertical and horizontal. These trunnion collars are removed after the waste package is placed on the emplacement pallet; therefore, the use of trunnion collars does not create a site for crevice corrosion cracking. Further, trunnion collars are attached to a corresponding built-up area on the waste package and will not induce stresses that might exacerbate corrosion of the outer barrier.

6.1.2 DOE SNF and HLW

In order to be accepted to the Monitored Geologic Repository, the nuclear waste forms must comply with CRWMS acceptance criteria, as embodied in *Waste Acceptance System Requirements Document* (DOE 1999c). The Producer/Custodian shall ensure that the government-managed nuclear materials comply with the following acceptance criteria defined in Revision 3 of DOE (1999c) concerning physical and chemical properties of the DOE-managed SNF and HLW:

- The HLW and/or SNF shall be in solid form and placed in sealed canisters (DOE 1999c, Section 4.2.2.B.1).

- Combustible HLW and/or SNF shall be reduced to a form such that they are noncombustible in the repository environment (DOE 1999c, Section 4.2.2.B.3).

- The HLW and/or SNF shall not contain or generate materials that are explosive, pyrophoric, or chemically reactive in the repository environment (DOE 1999c, Section 4.2.2.D.1).

- The HLW and/or SNF shall not contain or generate free liquids in the waste package (DOE 1999c, Section 4.2.2.D.2).

- The standard vitrified HLW form shall be borosilicate glass sealed inside an austenitic stainless steel canister with a concentric neck and lifting flange (DOE 1999c, Section 4.2.3.1.A.1).

- The heat generation rate shall not exceed 1500 W per 3-m-long HLW canister at the year of shipment (DOE 1999c, Section 4.2.3.1.A.6).

6.1.3 5-DHLW/TRIGA SNF Codisposal Waste Package

The waste package that is the subject of this analysis consists of the DHLW disposal container containing five SRS DHLW glass canisters and a short 18-in.-OD DOE standardized SNF canister loaded with TRIGA SNF. The NSNFP has designated the SNF from TRIGA reactors as the representative fuel for the uranium-zirconium hydride (UZrHx) SNF group, where x is the ratio of hydrogen to zirconium in the mixture of uranium and zirconium hydride (DOE 1999b). The H/Zr ratio is nominally 1.6, although earlier fuels used an H/Zr ratio of 1.0 (CRWMS M&O 2000h). The basket assembly that facilitates the emplacement of 111 TRIGA SNF rods inside the DOE SNF canister is shown in Sketch SK-0124 REV 00, which is presented in Attachment II. The conceptual design of a short 18-in.-OD DOE standardized SNF canister is shown in Sketch SK-0129 REV 00, which is presented in Attachment I. Descriptions of a SRS DHLW glass pour canister and an 18-in.-OD DOE standardized SNF canister are provided in Sections 4.1.2 and 4.1.3, respectively. A horizontal cross section of the waste package is presented in Figure 7. The thermal power generated inside the DOE SNF canister at 1-year decay time is 1.66 kW, which is 111 elements times 14.97 W/element (DOE 1999b, pp. B-8 and B-9). Therefore, the total thermal output of the waste package at 1-year decay time will not exceed 9.16 kW, considering the maximum allowable thermal power of 1.5 kW per 3,000-mm-long DHLW glass canister. However, a lower thermal output per waste package is expected at the time of emplacement in the repository. The thermal power generated inside the DOE SNF canister at 5-year decay time is 0.48 kW, which is 111 elements times 4.32 W/element (DOE 1999b, pp. B-8 and B-9). Therefore, the thermal output of a waste package that contains SRS DHLW glass and TRIGA SNF will be less than 4.23 kW, considering a maximum heat generation rate of 752 kW (see Section 4.1.2) per SRS DHLW glass canister.

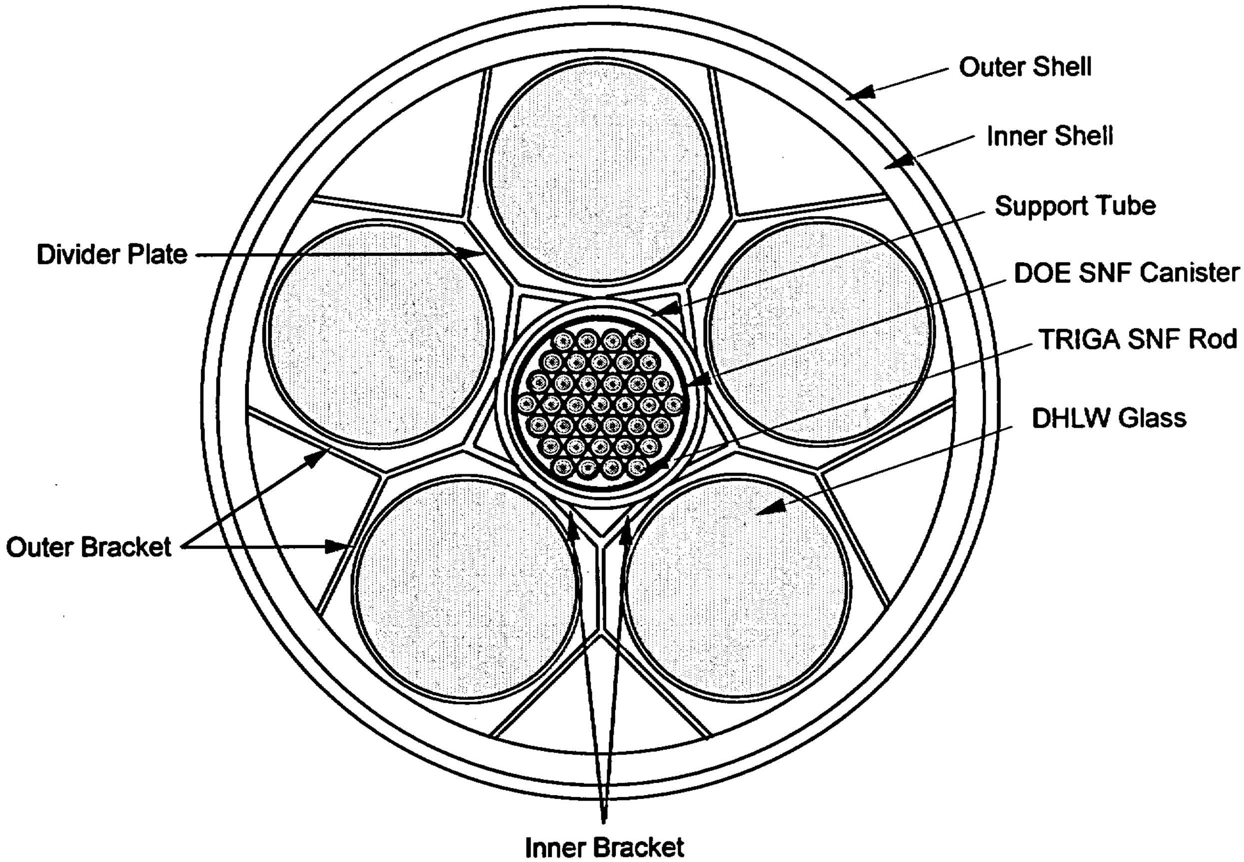


Figure 7. Horizontal Cross Section of the Codisposal Waste Package

6.2 ANALYTICAL METHODS AND RESULTS

6.2.1 Source Term

Source term calculations indirectly support the analysis of waste package designs. A source term calculation provides the decay heat rate for thermal evaluations of the waste package and repository designs, the gamma and neutron intensities and spectra for shielding evaluations of the waste package designs, and the radionuclide inventories for the criticality and total-system performance evaluations. The codisposal waste package contains two different radiation sources originating from the SRS DHLW glass and the TRIGA SNF. Therefore, source term calculations for the SRS DHLW glass and for the TRIGA SNF are required.

The gamma source, neutron source, and decay heat rate for the TRIGA SNF are provided in DOE (1999b, Tables B-2, B-3, and B-4, respectively). In the source term calculation for TRIGA SNF, the highest burnup and isotopics associated with a TRIGA Fuel Improvement Program (FLIP) fuel have been used, for conservative (higher) evaluations.

The source term calculation for the SRS DHLW glass decays the radionuclide inventory made available by the Savannah River Site. In the DWPF at the SRS, the nuclides contained in the 130 million liters of liquid high-level waste currently stored at the SRS will be immobilized in a durable borosilicate glass. The radionuclide compositions, per canister, for the most highly radioactive glass likely to be made from sludge-supernate processing, are presented in DOE (1992, Table 3.3.3). The radionuclide composition is based on sludge aged an average of five years and a cesium-containing precipitate derived from supernate aged an average of 15 years (DOE 1992, p. 3.3-1).

A more recent document, *Projected Radionuclide Inventories and Radiogenic Properties of the DWPF Product (U)* (Plodinec and Marra 1994), provides a radionuclide inventory for the DWFP Design-Basis Glass that is based on the same assumptions used in DOE (1992). However, the short-lived radionuclides in secular equilibrium with their nuclide parents have not been reported in this document because the Waste Acceptance Preliminary Specifications do not require sites to report these radionuclides. An initial radionuclide inventory that takes into account the short-lived radionuclides, present in DHLW along with the long-lived radionuclides, provides correct radiation spectra and intensities at short, as well as, long decay times. Therefore, the appropriate input information for source term calculations is provided in DOE (1992). The calculation *Source Terms for DHLW Canister for Waste Package Design* (CRWMS M&O 1999f) uses radionuclide compositions available in DOE (1992) for the SRS DHLW glass and provides conservative source terms for shielding evaluations.

6.2.2 Structural

This section summarizes the methods and results of the structural calculations for waste package internal pressurization, missile impact, and lifting, as presented in *Internal Pressurization Due to Fuel Rod Rupture in Waste Packages* (CRWMS M&O 2000d), *Pressurized System Missile Impact on Waste Packages* (CRWMS M&O 2000e), and *Waste Package Lifting Calculation* (CRWMS M&O 2000g), respectively. The results demonstrate the waste package compliance with DHLW SDD 1.2.1.16, 1.2.1.17, 1.2.1.18, 1.2.2.1.8, 1.2.2.1.10, and 1.2.4.7 criteria.

6.2.2.1 Analytical Method for Waste Package Internal Pressurization

One of the waste package design-basis events is the fuel rod rupture and subsequent internal pressurization. Therefore, a bounding calculation for the waste package during the fuel rod rupturing event is to determine the effect of the maximum internal pressure on the shells and the lids. The largest stress and deformation due to internal pressure take place on the welds between the shells and the lids. This region is also referred to as "junction".

The calculation uses a closed-form solution to the problem of a cylindrical shell subject to an internal pressure load to determine the maximum stresses at the inner shell and inner junction. The inner lid (top or bottom) is assumed to fail before the outer lids; therefore, no structural credit is taken for the outer lids. Evaluations are performed over uniform waste package temperature ranging from 20 °C to 600 °C. The peak stresses (membrane and bending) at the junction of the shell and the lid are compared to the ultimate tensile stress. Detailed descriptions of the mathematical expressions, algorithms, and numerical solution techniques are given in CRWMS M&O (2000d).

6.2.2.2 Method of Solution for Missile Impact on Waste Packages

The survivability of a waste package due to a missile impact has been demonstrated in a calculation entitled *Pressurized System Missile Impact on Waste Packages* (CRWMS M&O 2000e). The analytical method for a 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 the relevant phenomena and is capable of predicting accurately all 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 the BRL method is more general compared to other empirical relationships. A detailed description of the mathematical expressions and solution techniques are given in CRWMS M&O (2000e).

6.2.2.3 Analytical Method for Waste Package Lifting

The methodology utilized in *Waste Package Lifting Calculation* (CRWMS M&O 2000g) evaluates lifting the 5-DHLW/DOE-short waste package both horizontally and vertically. The finite element analysis (FEA) as implemented in the computer code ANSYS, Version 5.4, was used to analyze the waste package. ANSYS V5.4 is identified as Computer Software Configuration Item (CSCI) 30040 V5.4 and is obtained from Software Configuration Management (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 Software Qualification Report (SQR) for ANSYS V5.4 (CRWMS M&O 1998c). To calculate the structural response of the waste package to the horizontal lifting operation, three-dimensional half waste package representations were developed to take advantage of the symmetric geometry of the waste package. The three-dimensional representation does not include the lid lifting features, inner shell support ring, canisters, and SNF basket inside the inner shell. The mass of DHLW glass and DOE SNF canisters has been applied to the inner barrier to match the mass of the waste package. The lifting mechanism is designed such that the trunnion collar will be placed around both trunnion collar sleeves to lift the waste package horizontally. Therefore, the bottom half of the trunnion collar sleeve surfaces are constrained as boundary conditions. To calculate the structural response of the waste package to the vertical lifting operation, three-dimensional half-waste package representations were developed to take advantage of the symmetric geometry of the waste package. Only inner and outer shells and trunnion collar sleeves were included in the ANSYS representations for the waste package. The masses of the components internal to the inner shell were added to the inner shell to match the total waste package mass. Since the critical parts of the waste package for vertical lifting are the trunnion collar sleeve welds, the trunnion collar sleeves were modified to leave small gaps between the outer shell and sleeves. Mesh refinement was performed around the weld regions. Boundary conditions were constrained at the upper surface of the upper trunnion collar sleeve. Static loads were applied in both the horizontal and vertical representations.

The waste package must be designed to allow retrieval up to 300 years after emplacement. The calculation *Structural Calculations for the Lifting of a Loaded Emplacement Pallet* (CRWMS M&O 2000i) demonstrates the ability of the waste package and pallet to be lifted together as a single unit.

6.2.2.4 Calculations and Results

The internal pressure of a 21-PWR waste package was assumed inside the codisposal waste package (see Section 5). The internal pressures, peak stresses (membrane and bending) at the junction of the shell and lid, and the ASME Boiler and Pressure Vessel Code requirements on membrane and bending stresses (see Section 4.3.1) for different temperatures are presented in Table 9.

Table 9. Variation of Stress from Internal Pressure with Temperature

Temperature (°C)	20	200	400	600
Internal Pressure (MPa)[a]	0.38	0.62	0.88	1.14

S_{m+b} (MPa)[b]	130	211	298	384
$0.9 \cdot S_u$ (MPa)	465	446	443	370[c]

SOURCE: CRWMS M&O 2000d, pp. 5 through 7.
NOTES: [a] The temperature-dependent internal pressure in a 21-PWR SNF waste package is used in the parametric study.
[b] Membrane plus bending stress.
[c] Calculated by extrapolating the last two data points (66.5 ksi at 950 °F and 64.4 ksi at 1000 °F) provided in Table 2.

Table 10 summarizes the results of the calculations for missile impact on the waste package presented in CRWMS M&O (2000e). The required velocities of the projectile to cause perforation are reported for three cases for which projectile diameter, mass, and velocity vary.

Table 10. Pressurized System Missile Impact

Characteristic	Case 1	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 required velocity of the projectile to cause perforation (m/s)	339	403	446

SOURCE: CRWMS M&O 2000e, Table 6-1.

The 5-DHLW/DOE SNF-short waste package is lifted using attachable trunnion collars that lock into grooves called trunnion collar sleeves. The structural response of the waste package to lifting is reported in CRWMS M&O (2000g) using the maximum value between stress intensity and the absolute value of first principal stress obtained from the finite element solution to the problem. The greater value between stress intensity and first principal stress for each component of the waste package is presented in Table 11.

Table 11. Maximum Stress in the Waste Package Components Due to Horizontal and Vertical Lift

Waste Package Component	Maximum Stress for the Horizontal Lifting[a] (MPa)	Maximum Stress for the Vertical Lifting[a] (MPa)
Upper trunnion collar sleeve	5.2	9.1
Lower trunnion collar sleeve	4.1	-
Outer shell and lids	3.0	5.9
Inner shell and lids	1.9	1.9

SOURCE: CRWMS M&O 2000g, Tables 6-4 and 6-8.
NOTE: [a] Static loads only considered.

6.2.3 Thermal

This section summarizes the method and results of the thermal calculations as presented in *Thermal Evaluation of the TRIGA Codisposal Waste Package* (CRWMS M&O 1999g). The results of CRWMS M&O (1999g) are used to demonstrate the waste package design compliance with DHLW SDD 1.2.1.6 and 1.2.1.7 criteria (see Section 5).

6.2.3.1 Thermal Analytical Method

The FEA as implemented in the computer code ANSYS, Version 5.4, is used to analyze the waste package. 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 (CRWMS M&O 1998c).

A two-dimensional, finite-element representation of the waste package is specified for the ANSYS calculations. The time-dependent surface temperatures obtained for the design-basis waste packages in a three-dimensional representation of the repository (as described in CRWMS M&O 2000a, Section 6.3.2.3) will serve as boundary conditions for the two-dimensional analysis of the internals of the waste package.

6.2.3.2 Calculations and Results

The temperature histories for 13 node locations within the waste package are calculated for two cases. The first case assumes that the entire waste package and the DOE SNF canister are filled with helium. The second case assumes that the DOE SNF canister is filled with argon and the rest of the waste package is filled with helium. The 7 of 13 node locations on components of the finite-element representation of the waste package are shown in Figures 8 and 9. One-year decay time for the TRIGA SNF is assumed at the time of emplacement in repository. The temperature history extends over 1,000 years of emplacement in repository.

Table 12 contains the peak temperatures for the cladding of the TRIGA SNF rod located in the center of the DOE SNF canister and for the center of the SRS DHLW glass canister. Figure 10 shows the temperature variations for the cladding of the TRIGA SNF rod placed in the center of the DOE SNF canister and for the center of the SRS DHLW glass canister, over a period of 50 years after waste package emplacement. Maximum peak values of 261.2 °C (argon as the fill gas of the DOE SNF canister) and 223.8 °C (helium as the fill gas of the DOE SNF canister) occur in the cladding at 0.1 and 0.2 years after emplacement, respectively. A maximum peak value of 214.5 °C occurs in the DHLW glass at 20 years after emplacement. After 50 years, the temperature decreases gradually.

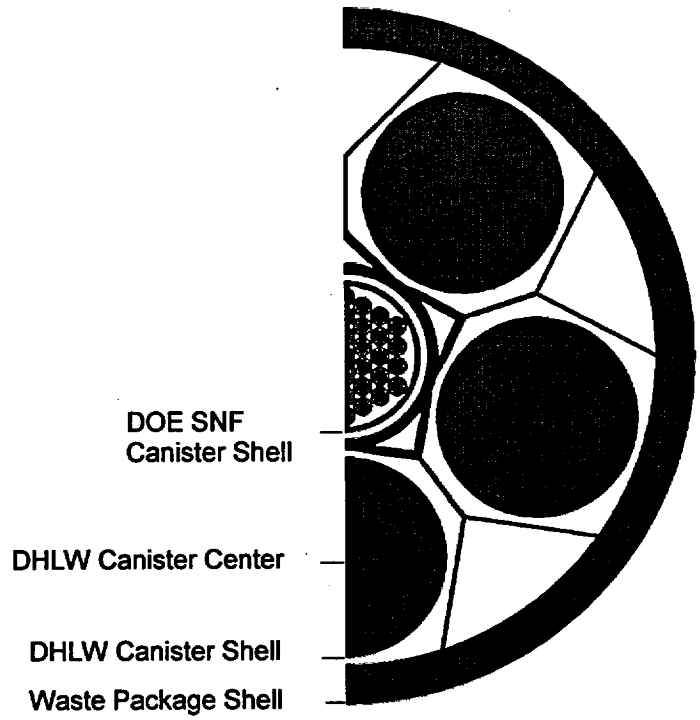


Figure 8. Name and Location for the Temperature Nodes of the Waste Package

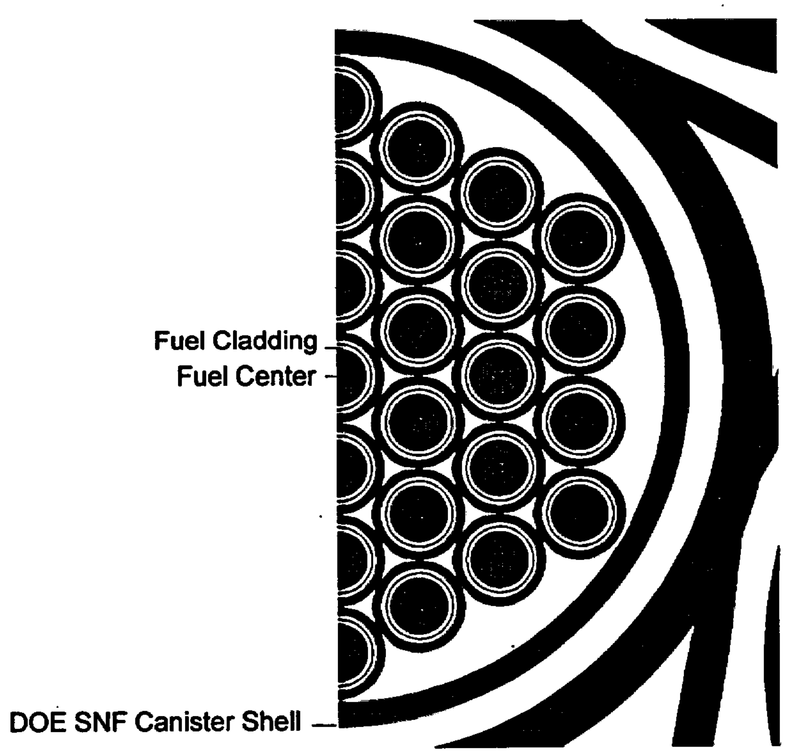


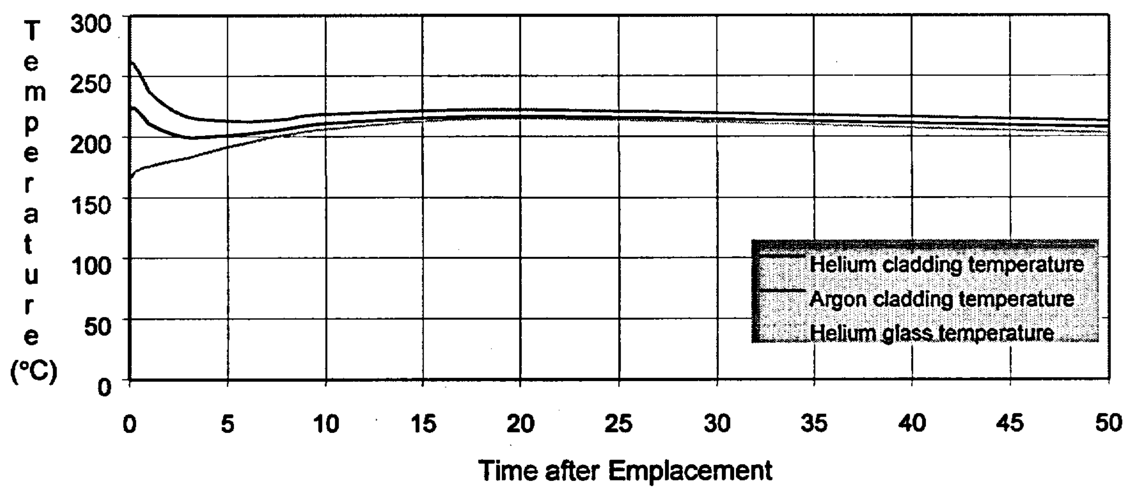
Figure 9. Name and Location for the Temperature Nodes of the DOE SNF Canister

Table 12. Peak Temperature Histories of the TRIGA SNF Cladding and DHLW Glass

Time After Emplacement (years)	Helium		Argon	
	Cladding Temperature (°C)	Glass Temperature (°C)	Cladding Temperature (°C)	Glass Temperature (°C)
0.1	223.1	166.0	261.2	166.0
0.2	223.8	169.4	260.5	169.4
1	210.4	175.6	237.4	175.6
3	199.5	182.6	216.1	182.6
10	210.5	206.0	218.3	206.0
20	216.6	214.5	221.9	214.5
1000	155.1	145.9	162.0	145.9

SOURCE: CRWMS M&O 1999g, Table 6-2.

NOTE: Cladding peak temperature pertains to the TRIGA SNF rod located in the center of the DOE SNF canister, and peak glass temperature occurs in the center of the SRS DHLW glass canisters.



NOTE: One-year decay heat for the TRIGA SNF at the time of emplacement in repository.

Figure 10. Temperature History for TRIGA SNF Cladding and DHLW Glass

6.2.4 Shielding

This section summarizes the method and results of the shielding calculations as presented in *Dose Rate Calculation for the DHLW/DOE SNF Codisposal Waste Package* (CRWMS M&O 2000f). This calculation was performed in relation to the DHLW SDD 1.2.4.3 criterion that specifies the maximum dose rate on the external surfaces of the waste package pressure as TBD.

6.2.4.1 Shielding Analytical Method

The analytical method for shielding calculations is the Monte Carlo radiation transport, as implemented in the Monte Carlo N-Particle (MCNP), Version 4B2, transport code (Breismeister 1997). The qualification of MCNP 4B2 and its neutron and photon interaction cross-section data is documented in the SQR for MCNP, Version 4B2 (CRWMS M&O 1998d). The code and its associated cross-sections libraries are identified as CSCI 30033 V4B2LV, and are obtained from SCM in accordance with appropriate procedures.

The MCNP features employed in the shielding calculations for the DHLW/DOE SNF waste packages are the general source and the surface flux tally. Two different radiation sources exist inside the DHLW/DOE SNF waste package. One source originates from the DHLW glass canisters, and the other comes from the DOE SNF. To facilitate the shielding calculation, the contents and the source inside the DOE SNF canister are assumed to be homogeneous (as shown in CRWMS M&O 1998e, Section 6). For each waste package, two MCNP calculations, one for the neutron source and one for the gamma source, are required to determine the total dose rates. The sources in the waste package are spatially sampled according to the source intensities of each canister, DHLW glass or DOE SNF canister. Then, within each canister, the locations of source particles are sampled uniformly. The gamma and neutron sources of the DOE SNF have axial spatial distributions. To account for these distributions, constant axial peaking factors are directly multiplied to the source strengths. This method yields conservative dose results for the waste package. However, the scattering effect from emplacement drift was not included in the shielding calculations.

Based on the source geometry and the relatively thin shells on the side of the waste package, it is expected that the maximum dose rate occurs on the side of the waste package and that the dose rates on the axial surfaces are relatively uniform. Also, the azimuthal variation of the surface dose rate is negligible, as shown in the shielding evaluation for the codisposal waste package of the DHLW glass canisters and the Fast Flux Test Facility Fuel (CRWMS M&O 1998f, Section 6). Therefore, surface tallies are employed in MCNP to estimate the dose rates of the waste package. A surface tally provides the average flux over a surface. Surface segments on the radial and axial surfaces of the waste package 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 the American National Standard Institute/American Nuclear Society (ANSI/ANS) Standard 6.1.1-1977 (Briesmeister 1997, App. H).

The shielding analysis only evaluates radiation dose due to neutron and primary gamma rays. Radiation dose due to secondary gamma rays (gamma rays from neutron capture) is neglected because the neutron dose rates are at least two orders of magnitude lower than the gamma dose rates and the production of secondary gamma rays is insignificant.

6.2.4.2 Calculations and Results

Details of the dose rate calculations and the results for the codisposal waste package of the SRS DHLW glass canisters and the DOE SNF canister loaded with TRIGA SNF are provided in CRWMS M&O 2000f.

In this calculation, the source terms for the SRS DHLW glass and for the TRIGA SNF correspond to day 1 after glass pouring (see Section 5) and 1-year decay time, respectively. The source terms for the SRS DHLW glass and for the TRIGA SNF are provided in *Source Terms from DHLW Canisters for Waste Package Design* (CRWMS M&O 1999f, Attachments VIII and IX) and *TRIGA (UZrH) Fuel Characteristics for Disposal Criticality Analysis* (DOE 1999b, Appendix B), respectively (see Section 6.2.1). An axial peaking factor of 1.25 was assumed for the TRIGA SNF.

Figure 11 shows the segments of the waste package outer radial surfaces used in the dose-rate calculations. The radial surface of the waste package is divided into six axial segments. Five of the axial segments, Segments 2 through 6, are equal subdivisions of the radial surfaces between the top and bottom planes of the DHLW glass. Each of these segments is 432.253-mm tall. The first axial segment, 878.735-mm tall, is the portion between the top of waste package cavity and the top of the DHLW glass. The waste package top and bottom surfaces are divided in two segments by a 30-cm radius. Tables 13 and 14 present the surface dose rates averaged over the segments of the radial and axial outer surfaces of the waste package.

Table 13. Dose Rates on the Waste Package Outer Radial Surface

	Gamma		Neutron		Total	
Axial Location[a]	Dose Rate (rem/h)	Relative Error	Dose Rate (rem/h)	Relative Error	Dose Rate (rem/h)	Relative Error
Segment 1	4.3531E+01	0.0069	3.4474E-02	0.0039	4.3565E+01	0.0069
Segment 2	9.5541E+01	0.0059	8.4805E-02	0.0034	9.5626E+01	0.0059
Segment 3	1.0272E+02	0.0057	1.0503E-01	0.0031	1.0283E+02	0.0057
Segment 4	1.0358E+02	0.0056	1.0740E-01	0.0030	1.0368E+02	0.0056
Segment 5	9.9835E+01	0.0057	1.0474E-01	0.0031	9.9940E+01	0.0057
Segment 6	8.3158E+01	0.0061	8.6445E-02	0.0034	8.3245E+01	0.0061

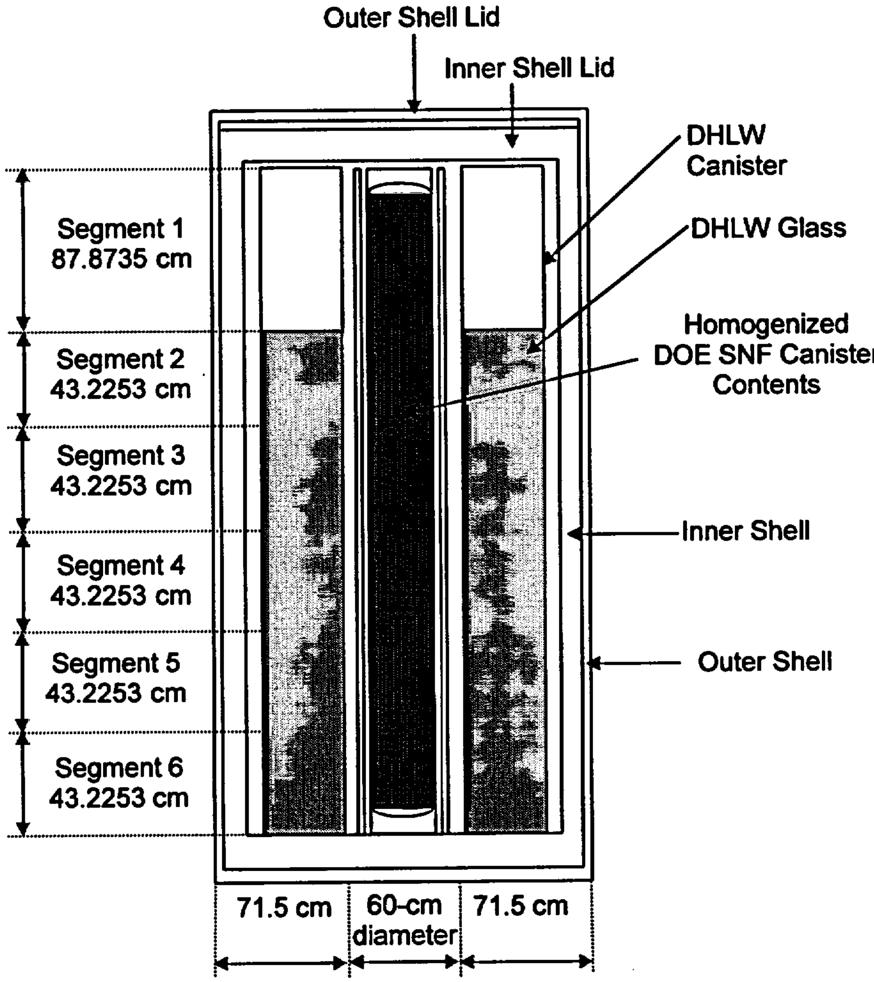
SOURCE: CRWMS M&O 2000f, p. 21.
NOTE: [a] See Figure 11.

Table 14. Dose Rates on the Waste Package Axial Outer Surfaces

Axial Location	Segment	Gamma		Neutron		Total	
		Dose Rate (rem/h)	Relative Error	Dose Rate (rem/h)	Relative Error	Dose Rate (rem/h)	Relative Error
WP bottom surface	Inside a 30-cm radius	2.1915E+01	0.0401	6.2788E-02	0.0109	2.1977E+01	0.0400
	Outside a 30-cm radius	1.2772E+01	0.0134	5.8474E-02	0.0039	1.2830E+01	0.0133
WP top surface	Inside a 30-cm radius	1.9846E+01	0.0416	1.8302E-02	0.0185	1.9864E+01	0.0416
	Outside a 30-cm radius	4.9351E+00	0.0232	2.1180E-02	0.0063	4.9563E+00	0.0231

SOURCE: CRWMS M&O 2000f, p. 22.

NOTE: The dose rates on the WP top and bottom surfaces have been obtained for a developing design that had only the inner and the outer shell lids at the waste package top (see CRWMS M&O 2000e, Attachment II). These values do not change the conclusion of the 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 at the waste package top and a space between the bottom lids, which decrease more the surface dose rates.



NOTES: This figure shows a developing design for the disposal container, which has only two upper lids and no space between the bottom lids.
Drawing not to scale.

Figure 11. Surface Segments of the Waste Package Used in Dose Rate Calculations

6.2.5 Criticality

This section establishes the bias in the method of calculation and uncertainty in the experiments used to validate the method of calculation. The analysis is based on the criticality calculations presented in *LCE for Research Reactor Benchmark Calculations* (CRWMS M&O 1999h) and *Laboratory Critical Experiment Reactivity Calculations* (CRWMS M&O 1999i). The method and results of the criticality calculations for the codisposal waste package, presented in *TRIGA Fuel Phase I and II Criticality Calculation* (CRWMS M&O 1999e), are also summarized in this section. The results of CRWMS M&O (1999e) are used to demonstrate the waste package design compliance with DHLW SDD 1.2.2.1.12 criterion (see Section 5).

6.2.5.1 Criticality Analysis Method

The analytical method for criticality calculations is the Monte Carlo radiation transport, as implemented in the MCNP 4B2 code (Breismeister 1997). The qualification of MCNP 4B2 and its neutron and photon interaction cross-section data is documented in the SQR for MCNP, Version 4B2 (CRWMS M&O 1998d). The code and its associated cross-section libraries are identified as CSCI 30033 V4B2LV, and are obtained from SCM in accordance with appropriate procedures.

The eigenvalue calculation for a critical system in MCNP is identified as a KCODE calculation. The MCNP criticality calculation employs a KCODE card that specifies the criticality source to be used for determining k_{eff}. A KCODE calculation provides the best estimate for k_{eff}, which is a combination of the collision, absorption, and track-length estimates for k_{eff}' and its confidence intervals.

The bias in the method of calculation and uncertainty in the experiments used to validate the method of calculation for the water-moderated uranium-zirconium hydride systems is based on the benchmark criticality calculations presented in CRWMS M&O (1999h and 1999i). Evaluations of Laboratory Critical Experiments (LCEs) are performed as part of the Disposal Criticality Analysis Methodology program. The experiments relevant to the TRIGA SNF with respect to intact criticality analyses are the TRIGA SNF rod experiments, available in *TRIGA Mark II Benchmark Experiment, Part I: Steady-State Operation* (Mele et al. 1994), and a series of critical experiments with water moderated hexagonal-pitched lattices containing highly enriched uranium (HEU) fuel rods, available in the *International Handbook of Evaluated Criticality Safety Benchmark Experiments* (Nuclear Energy Agency [NEA] 1998). The NEA critical benchmarks consist of the following highly-enriched uranium (HEU) compound (COMP) thermal (THERM) system: HEU-COMP-THERM-003, HEU-COMP-THERM-004, HEU-COMP-THERM-005, HEU-COMP-THERM-006, HEU-COMP-THERM-007, HEU-COMP-THERM-008, and HEU-COMP-THERM-010. A maximum bias of 0.019 has been determined for the MCNP criticality benchmark calculations for the TRIGA SNF rod and NEA critical experiments (see CRWMS M&O 1999h, pp. 12, 17, 18, and 19 for the experimental k_{eff}, and pp. 71 and 76 for the MCNP criticality benchmark calculations).

Critical experiments with highly enriched uranium nitrate solution are appropriate for the criticality analysis of a degraded waste package. The benchmark experiments available in NEA

(1998) and involving highly-enriched uranium (approximately 90 wt%) solution (SOL) thermal systems are HEU-SOL-THERM-001, HEU-SOL-THERM-008, HEU-SOL-THERM-013, HEU-SOL-THERM-014, HEU-SOL-THERM-015, HEU-SOL-THERM-016, HEU-SOL-THERM-017, HEU-SOL-THERM-018, and HEU-SOL-THERM-019. A maximum bias of 0.0018 for this set of critical experiments has been determined (CRWMS M&O 1999i, Table 6-1).

The critical limit of the TRIGA SNF system for criticality evaluations using MCNP Version 4B2 and the continuous cross sections processed from the evaluated nuclear data files (ENDF/B-V) (Briesmeister 1997, Appendix G) is 0.93. It combines the recommended five percent margin (DHLW SDD 1.2.2.1.12) and a bias in the method of calculation and uncertainty in the experiments used to validate the method of calculation of 0.02 (YMP 1998, p. 4-28).

The criticality methodology for the DOE-managed fuels considers the most reactive fuel type and optimum moderation. Therefore, the effects of different TRIGA fuel types and densities for the water flooding the DOE SNF canister on the k_{eff} of the system are evaluated.

6.2.5.2 Calculations and Results

Details of the criticality calculations for the intact components of the waste package are provided in CRWMS M&O 1999e. A description of the existing TRIGA fuel types is available in *TRIGA (UZrH) Fuel Characteristics for Disposal Criticality Analysis* (DOE 1999b).

All calculations are performed with fresh-fuel isotopics (CRWMS M&O 1999e, Assumption 3.3) and continuous-energy cross section data processed from the evaluated nuclear data files ENDF/B-V (Briesmeister 1997, App. G). Although the components (i.e., fuel rods, cladding, and DOE SNF canister) are considered structurally intact, water intrusion into the components is allowed to determine the highest k_{eff} resulting from the optimum moderation.

The highest k_{eff} for the system occurs for the most reactive fuel and the optimum moderation. Therefore, the criticality calculations consider various TRIGA fuel types and several water densities. Analyses to intact fuel rods indicated that 4-rod cluster type rods, FLIP, standard streamline type rods, and the low enrichment uranium (LEU) rods, FLIP-LEU-I, are below criticality (DOE 1999b, p. 19, and CRWMS M&O 1999e, Table 6-1). The maximum $k_{eff} + 2\sigma$ is 0.793 for the TRIGA-SS FLIP and FLIP in a 4-rod cluster type rods in a waste package flooded with water at 1-g/cm^3 density (CRWMS M&O 1999e, Table 6-1).

The criticality calculations for the waste package containing the standard streamline TRIGA-SS FLIP and the advanced neutron absorber matrix in the two locations indicated in Figure 5, show a maximum decrease of 0.207 for k_{eff}.

6.3 SATISFACTION OF PROJECT REQUIREMENTS

The design presented in Section 6.1 and the results of the analyses presented in Section 6.2 are summarized in this section.

The full inventory of the DOE SNF, DHLW, HLW, and immobilized plutonium in disposable canisters will be accommodated by 1,530 codisposal 5-DHLW/DOE SNF-short waste packages, 2,821 codisposal 5-DHLW/DOE SNF-long waste packages, and 199 codisposal 2-MCO/2-DHLW waste packages (CRWMS M&O 2000b, Table 1). For the waste package used in this analysis to illustrate the design analytical methods for the DHLW disposal container system, the DHLW disposal container accommodates five SRS DHLW glass canisters, each with the outside diameter of 610 mm and the overall length of 3,000 mm, and a short 18-in.-OD DOE standardized SNF canister loaded with TRIGA SNF. These demonstrate the compliance of the disposal container design with DHLW SDD 1.2.1.1, 1.2.1.2, and 1.2.4.5 criteria.

The inner shell is stainless steel with a thickness of 50 mm and the outer shell is Alloy 22 with a thickness of 25 mm. A 25-mm thickness for the outer shell was determined by imposing the DHLW SDD-1.2.2.1.1 criterion on waste packages (CRWMS M&O 1999d, Table 6.1-4). This demonstrates the compliance of the disposal container design with DHLW SDD 1.2.1.4 criterion.

The materials of the disposal container are solid, metallic alloys. The gas filling the waste package is helium. The DHLW glass canisters and DOE SNF canisters will not be accepted at the MGR unless they contain non-combustible and heat-resistant, non-explosive, non-pyrophoric, chemically non-reactive, and liquid-free materials. Therefore, the waste package materials are chemically non-reactive, non-combustible and heat-resistant, non-explosive and non-pyrophoric, and liquid-free materials. This demonstrates the compliance of the waste package design with DHLW SDD 1.2.1.19, 1.2.1.20, and 1.2.1.21 criteria, respectively.

The welded shell lids at one end of the disposal container allows the loading and sealing of the disposal container in a vertical position. This demonstrates the compliance of the DHLW disposal container design with DHLW SDD 1.2.4.6 criterion.

All waste package external surfaces are accessible for visual inspection, as the examination of the design presented in Attachment III demonstrates. This demonstrates the compliance of the disposal container design with DHLW SDD 1.2.1.12 criterion.

An upper limit of the total waste package thermal output is 9.16 kW. This value is below 11.8 kW, and demonstrates the waste package compliance with DHLW SDD 1.2.4.4 criterion.

The required glass and DOE SNF cladding peak temperatures inside the waste package are less than 400 °C (TBV-092) and limited to (TBD-179), respectively. Under normal conditions, maximum peak values of 261.2 °C (argon as the fill gas of the DOE SNF canister) and 223.8 °C (helium as the fill gas of the DOE SNF canister) occur in the cladding at 0.1 and 0.2 years after emplacement, respectively. These results determine the peak cladding temperature (TBD-179), as required by SDD DHLW 1.2.1.7 criterion. A maximum peak value of 214.5 °C occurs in the DHLW glass at 20 years after emplacement. Although these values have been determined for the VA design, the effect of differences in the SR and VA disposal container designs on the peak glass temperatures is small when compared with the large margin shown. This demonstrates the waste package compliance with DHLW SDD 1.2.1.6 criterion. The short-term exposure to fire and the limiting SNF cladding temperature are planned to be addressed in LA.

According to *1995 ASME Boiler and Pressure Vessel Code* (ASME 1995) (see Section 4.3.1), the limitation on membrane and bending stresses is 90% of the ultimate tensile strength of the material. The calculations for the waste package internal pressurization show that the total (membrane plus bending) stress at the junction of the shell and the lid is below this limitation for temperatures below 400 °C due to an internal pressure less than 0.88 MPa. The calculation was performed in relation to the DHLW SDD 1.2.2.1.10 criterion that specifies the maximum allowable waste package internal pressure as TBD.

The calculation for missile impact on the integrity of the waste package shows that the waste package withstands the impact of a 0.5-kg missile traveling at 5.7 m/s (verified TBV-245). It should be noted that this velocity is only 1.7 percent of the impact velocity that would compromise the waste package integrity. This demonstrates the waste package compliance with DHLW SDD 1.2.2.1.8 criterion.

A maximum expected stress of 9.1 MPa is generated in the upper trunnion collar sleeve during waste package horizontal and vertical normal lifting operations. DHLW SDD 1.2.1.16 criterion requires waste package lifting features that allow three times the maximum weight of the loaded and sealed disposal container without generating a combined shear stress or maximum tensile stress in excess of the corresponding minimum tensile yield strength of the materials of construction (Alloy 22). Considering the fact that the yield strength of the material is not exceeded, i.e., deformation remains in the elastic region of the stress-strain curve, a maximum stress of 27.3 MPa would be generated in the upper trunnion collar sleeve by increasing the loaded waste package weight three times. This value is well bellow the tensile yield strength of Alloy 22 (310 MPa). It should be noted that the maximum expected stress in the upper trunnion collar is about 30 times lower than the tensile yield strength of Alloy 22 (310 MPa), which allows larger stress design safety facts. The large margin of safety indicates that the waste package lifting features may withstand dynamic loads, reducing the probability of the occurrence of a design-basis event. This demonstrates the design compliance with DHLW SDD 1.2.1.16 criterion.

A maximum expected stress of 9.1 MPa is generated in the upper trunnion collar sleeve during horizontal and vertical lift of the waste package. DHLW SDD 1.2.1.17 criterion requires waste package lifting features that allow five times the maximum weight of the loaded and sealed disposal container without exceeding the ultimate tensile strength of the materials of construction (Alloy 22). Considering the fact that the yield strength of the material is not exceeded, i.e., deformation remains in the elastic region of the stress-strain curve, a maximum stress of 45.5 MPa would be generated in the upper trunnion collar sleeve by increasing the loaded waste package weight five times. This value is well bellow the ultimate tensile strength of Alloy 22 (690 MPa). It should be noted that the maximum expected stress in the upper trunnion collar is about 60 times lower than the ultimate tensile yield strength of Alloy 22 (690 MPa), which allows larger stress design safety facts. The large margin of safety indicates that the waste package lifting features may withstand dynamic loads, reducing the probability of the occurrence of a design-basis event. This demonstrates the design compliance with DHLW SDD 1.2.1.17 criterion.

CRMWS M&O (2000g) demonstrates the ability to safely lift and handle the waste package in both horizontal and vertical orientations using the trunnion collars attached at the upper and lower regions of the waste package. These trunnion collars are removed after the waste package is placed on the emplacement pallet; therefore, the use of such collars does not create a site for crevice corrosion cracking. Further, the trunnion collars 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. This demonstrates the waste package compliance with DHLW SDD 1.2.4.7 criterion, and partially demonstrates compliance with DHLW SDD 1.2.1.18 criterion.

The second-level confidence interval for the estimate of the maximum dose rate at the external surfaces of the 5-DHLW/TRIGA SNF codisposal waste package is 103.7 ± 1.2 rem/h. Therefore, the maximum dose rate at the external surfaces of this waste package is 105 rem/h. This result establishes the maximum dose rate at the external surfaces for the current design of the waste package, as required by DHLW SDD 1.2.4.3 criterion. This value is TBD (3764).

The results of the criticality calculations indicate that the DOE SNF canister loaded with TRIGA SNF is under-moderated even when it is flooded, and a maximum k_{eff} of 0.793 is obtained for water of 1-g/cm^3 density. This demonstrates the waste package design compliance with DHLW SDD 1.2.2.1.12 criterion.

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 thickness of Alloy 22 shell and MCNP criticality calculations for the intact DHLW/TRIGA SNF should not impact the conclusions that are provided herein.

The analysis illustrates the use of the WPD methodology (as described in CRWMS M&O 2000a) for designing the DHLW disposal container/waste package. The design is performed according to the project requirements as identified in CRWMS M&O (1999a, Section 1.2) and CRWMS M&O (2000b, Table 4). In support of this analysis, a set of calculations has been selected in CRWMS M&O (2000b, Section 7) to illustrate the WPD design methodology. The illustration of the WPD methodology that shows the waste package compliance with some of the project requirements are available in calculations supporting the analyses of the uncanistered spent nuclear fuel waste package and the naval spent nuclear fuel waste package. The methods used in calculations addressing these waste packages are representative of the methods that would be used in designing the DHLW disposal container/waste package. The sketches developed by the WPD according to the project requirements for the DHLW disposal container system, containing the 5-DHLW/DOE SNF-short waste package, 5-DHLW/DOE SNF-long waste package, and 2-MCO/2-DHLW waste package, are attached to this document.

The leading criteria used in designing this waste package type are the DHLW SDD 1.2.1.4, 1.2.1.1, and 1.2.1.2 criteria that impose the materials and dimensions of the waste package shells and the type of waste forms that this waste package should accommodate. Considerations of criticality events and other design-basis events that would affect the integrity of the waste canisters inside the waste package led to a design configuration inside the DHLW disposal container. It consists either of a central DOE SNF canister, five DHLW glass canisters surrounding the DOE SNF canister, and a basket assembly that separates the waste canisters and protects the integrity of the DOE SNF canister or two MCO and two DHLW glass canisters separated by two perpendicular plates. Structural, thermal, shielding, and criticality calculations were performed to demonstrate the compliance of the waste package design with specific criteria. A brief description of the design methods used in performing the calculations for a representative waste package, the codisposal waste package of five SRS DHLW glass canisters and a short 18-in.-OD DOE standardized SNF canister loaded with TRIGA SNF, is provided.

This analysis addresses only the selected criteria for the DHLW Disposal Container System (CRWMS M&O 2000b) and, based on the calculation results, evaluates the DHLW disposal container/waste package compliance with project requirements. However, compliance with DHLW SDD 1.2.2.1.7 and Structural-3 criteria is not demonstrated in this analysis. A summary of compliance with project requirements is presented in Table 15. In column denoted as "Design Compliance," "N/A" identifies the criteria that will be demonstrated for LA or by other organizations. Although this analysis addressed criteria that specify the waste package performance parameters as TBD, the compliance with these criteria will be demonstrated for LA.

This analysis describes the activities used by the WPD in designing the DHLW waste package. However, it does not make any recommendations regarding the final design of either the WP or the repository. The sources of uncertainties in this analysis fall into two categories. They are uncertainties due to input parameters used in calculations and uncertainties of the computational methods. For the first category, the input parameters are selected so that conservative results are produced. For the second category, benchmark comparisons of computational methods used in supporting calculations must be performed. Uncertainty identification and computational benchmarks are to be addressed in License Application.

Table 15. Satisfaction of Project Requirements

Criterion	Performance Parameter	Design Compliance	Comments
	System Performance Criteria		
1.2.1.1	Accommodation of HLW canisters	Yes	See Section 6.1 and 6.3
1.2.1.2	Accommodation of NSNFP canisters	Yes	See Section 6.1 and 6.3
1.2.1.3	Maximum total effective annual dose of 25 mrem, in conjunction with the Emplacement Drift System	N/A	To be demonstrated in a TSPA analysis
1.2.1.4	Inner shell of SA-240 S316000 with a thickness of 50 mm and the outer shell of SB-575 N06022 with a thickness of 20 mm	Yes[a]	See Section 6.1 and 6.3
1.2.1.5	WP reliability of (TBD-3755) percent	N/A	To be demonstrated in a TSPA analysis
1.2.1.6	HLW glass temperatures below 400 °C under normal conditions, and below 460 °C for short-term exposure to fire	Yes	See Sections 6.2.3 and 6.3. Short-term fire exposure to be demonstrated in LA.
1.2.1.7	TRIGA fuel cladding temperatures less than (TBD-179)	N/A[b]	See Sections 6.2.3 and 6.3. Short-term fire exposure to be demonstrated in LA.
1.2.1.8	Intact waste form canisters during the normal handling operations of the WP	N/A	To be demonstrated for LA
1.2.1.9	WP retrieval up to 300 years after the start of emplacement operations	Yes	See Section 6.2.2.3
1.2.1.10	Waste package free of O_2, H_2, H_2O, CO_2, and CO	N/A	Operations issue
1.2.1.11	Roughness Average of 250 μin (6.36 μm) or less	N/A	To be demonstrated for LA
1.2.1.12	WP external surfaces accessible for visual inspection and decontamination	Yes	See Section 6.1 and 6.3
1.2.1.13	Label with unique waste package identifier	N/A	To be demonstrated for LA
1.2.1.14	WP integrity after labeling	N/A	To be demonstrated for LA
1.2.1.15	Labels be legible and readable	N/A	To be demonstrated for LA
1.2.1.16	WP lifting feature of three times the maximum weight of the loaded and sealed disposal container	Yes	See Sections 6.2.2 and 6.3
1.2.1.17	WP lifting feature of five times the weight of the loaded disposal container	Yes	See Sections 6.2.2 and 6.3

Table 15. Satisfaction of Project Requirements (Continued)

1.2.1.18	WP capability of withstanding, without breaching, transfer, emplacement, and retrieval operations	Yes[c]	See Sections 6.2.2 and 6.3
1.2.1.19	Non-combustible and heat-resistant materials	Yes	See Sections 6.1.2 and 6.3
1.2.1.20	Non-explosive and non-pyrophoric materials	Yes	See Sections 6.1.2 and 6.3
1.2.1.21	No free liquids	Yes	See Sections 6.1.2 and 6.3
Safety Criteria			
1.2.2.1.1	WP withstands, without breaching, a 13-MT rock falling from 3.1 m onto the side of the WP.	N/A	A calculation will evaluate the 21-PWR WP compliance with UCF SDD 1.2.2.1.1. It is representative of the method that would show compliance with DHLW SDD 1.2.2.1.1.
1.2.2.1.2	The WP withstands (while in a vertical orientation), without breaching, a 2.3-MT spherical object falling 2 m onto the end of the disposal container.	N/A	To be demonstrated for LA
1.2.2.1.3	The WP withstands (while in a vertical orientation) a drop from a height of 2 m onto a flat, unyielding surface without breaching.	N/A	A calculation will evaluate the naval WP compliance with Naval SDD 1.2.2.1.3. It is representative of the method that would show compliance with DHLW SDD 1.2.2.1.3.
1.2.2.1.4	The WP withstands (while in a horizontal orientation) a drop from a height of 2.4 m onto a flat, unyielding surface without breaching.	N/A	A calculation will evaluate the naval WP compliance with Naval SDD 1.2.2.1.4. It is representative of the method that would show compliance with DHLW SDD 1.2.2.1.4.
1.2.2.1.5	The WP withstands (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.	N/A	A calculation will evaluate the 44-BWR WP compliance with UCF SDD 1.2.2.1.5. It is representative of the method that would show compliance with DHLW SDD 1.2.2.1.5.
1.2.2.1.6	The WP withstands, without breaching, a tip over from a vertical position with slap down onto a flat, unyielding surface without breaching.	N/A	A calculation will evaluate the 21-PWR WP compliance with UCF SDD 1.2.2.1.6. It is representative of the method that would show compliance with DHLW SDD 1.2.2.1.6.
1.2.2.1.7	The WP withstands a Design-Basis earthquake.	N/A	Document limitation
1.2.2.1.8	The WP withstands the impact of a 0.5-kg missile (modeled as a 1-cm diameter, 5-cm long valve steam) traveling at 5.7 m/s, without breaching.	Yes	See Section 6.2.2 and 6.3
1.2.2.1.9	The WP does not breach at the maximum impact resulting from a transporter runaway, derailment, and impact at a speed of 63 km/h.	N/A	To be demonstrated for LA
1.2.2.1.10	Maximum internal pressure of TBD-235	N/A[b]	A maximum internal pressure of 0.88 MPa (see Section 6.2.2 and 6.3)
1.2.2.1.11	The WP does not breach when a hypothetical fire occurs (TBV-245).	N/A	A structural calculation used the internal pressure for the 21-PWR WP to determine the maximum pressurization in the 5-DHLW/DOE SNF-short WP (DHLW SDD 1.2.2.1.11). A thermal analysis will be performed for LA.

Table 15. Satisfaction of Project Requirements (Continued)

1.2.2.1.12	k_{eff} below the critical limit	Yes	k_{eff} is 0.793 (see Section 6.2.5 and 6.3)
1.2.2.1.13	At 1,000 years following criticality shutdown, the total radionuclide inventory of the disposal container does not increase by more than 1 percent due to criticality events in the WP.	N/A	A calculation will evaluate the 21-PWR WP compliance with UCF SDD 1.2.2.1.13. It is representative of the method that would show compliance with DHLW SDD 1.2.2.1.13.
	System Environment Criteria		
1.2.3.1	Performance requirements identified in CRWMS M&O 1999a, Tables I-8 and I-9	N/A	To be demonstrated for LA
	System Interfacing Criteria		
1.2.4.1	Subsurface interfacing	N/A	See Section 4.2.2
1.2.4.2	Surface interfacing	N/A	See Section 4.2.2
1.2.4.3	Maximum dose rate of (TBD-3764) at the external surfaces of the WP	N/A[b]	A maximum dose rate of 105 rem/h at the external surfaces of the current WP design (see Section 6.2.4 and 6.3)
1.2.4.4	WP maximum thermal output of 11.8 kW	Yes	A maximum thermal output of 9.16 kW (see Sections 6.1.3 and 6.3)
1.2.4.5	Accommodation of a total of 640 MTU of commercial HLW, 4,027 MTU of DHLW, and, in combination with DOE SNF disposal containers, not more than 2,437 MTU of DOE SNF	Yes	1,530 5-DHLW/DOE SNF-short WP, 2,821 5-DHLW/DOE SNF-long WP, and 199 2-MCO/2 DHLW-long WP accommodate the full inventory of the DOE SNF, DHLW, HLW, and immobilized plutonium (see Sections 6.1 and 6.3)
1.2.4.6	WP loaded and sealed in a vertical orientation	Yes	See Section 6.1.1
1.2.4.7	WP handled in both horizontal and vertical orientations	Yes	See Sections 6.2.2. and 6.3
1.2.4.8	Welding times	N/A	To be demonstrated for LA
	Codes and Standards Criteria		
1.2.6.1	Design performed according to Section III, Division 1, Subsection NG-1995 of *ASME Boiler and Pressure Vessel Code, 1995 Edition* (ASME 1995)	Yes	See Sections 4.3.1 and 6.3
1.2.6.2	Design performed according to Section III, Division 1, Subsection NB-1995 of *ASME Boiler and Pressure Vessel Code, 1995 Edition* (ASME 1995)	Yes	See Sections 4.3.1 and 6.3
1.2.6.3	This criterion requires the design to be performed according to applicable sections of *Nuclear Criticality Control of Special Actinide Elements* (ANSI/ANS-8.15-1981).	N/A	See Section 4.3.2
1.2.6.4	This criterion requires the design to be performed according to applicable sections of *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors* (ANSI/ANS-8.1-1998).	N/A	See Section 4.3.2
1.2.6.5	This criterion requires the design to be performed according to applicable sections of *Criteria for Nuclear Safety Controls in Operations with Shielding and Confinement* (ANSI/ANS-8.10-1983).	N/A	See Section 4.3.2

Table 15. Satisfaction of Project Requirements (Continued)

1.2.6.6	This criterion requires the design to be performed according to applicable sections of *Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors* (ANSI/ANS-8.17-1984).	N/A	See Section 4.3.2
Other Criteria			
Structural-1	The manufacturing residual stress maintained below 20 percent of the yield strength for a depth of (TBD) from the outer surface	N/A	A calculation will evaluate the 21-PWR WP compliance with generic UCF 1. It is representative of the method that would show compliance with generic DHLW Structural-1.
Structural-2	Static loads in the outer barrier maintained below 20 percent of the yield strength	N/A	A calculation will evaluate the naval WP compliance with generic Naval 2. It is representative of the method that would show compliance with generic DHLW Structural-2.
Structural-3	Seismic loads in the outer barrier maintained below the yield strength	N/A	Document limitation

NOTES: [a] The current design exceeds the Alloy 22 required thickness (see Section 6.1).
[b] The performance parameter for the waste package design is TBD.
[c] Compliance partially demonstrated. A calculation has evaluated the horizontal lift of the naval SNF waste package on a pallet. The calculation is representative of the method that would show compliance with DHLW SDD 1.2.1.18.

8. INPUTS AND REFERENCES

8.1 DOCUMENTS CITED

Briesmeister, J.F., ed. 1997. *MCNP-A General Monte Carlo N-Particle Transport Code*. LA-12625-M, Version 4B. Los Alamos, New Mexico: Los Alamos National Laboratory. ACC: MOL.19980624.0328.

CRWMS M&O 1998a. *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*. B00000000-01717-8100-00021 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981229.0160.

CRWMS M&O 1998b. *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*. B00000000-01717-8100-00009 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980826.0139.

CRWMS M&O 1998c. *Software Qualification Report for ANSYS V5.4, A Finite Element Code*. CSCI: 30040 V5.4. DI: 30040-2003, Rev. 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980609.0847.

CRWMS M&O 1998d. *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code*. CSCI: 30033 V4B2LV. DI: 30033-2003, Rev. 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980622.0637.

CRWMS M&O 1998e. *Calculation of the Effect of Source Geometry on the 21-PWR WP Dose Rates*. BBAC00000-01717-0210-00004 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990222.0059.

CRWMS M&O 1998f. *Dose Calculations for the Co-Disposal WP of HLW Canisters and the Fast Flux Test Facility (FFTF) Fuel*. BBA000000-01717-0210-00019 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990129.0075.

CRWMS M&O 1999a. *Defense High Level Waste Disposal Container System Description Document*. SDD-DDC-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991217.0510.

CRWMS M&O 1999b. *Classification of the MGR Defense High-Level Waste Disposal Container System*. ANL-DDC-SE-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0142.

CRWMS M&O 1999c. *Waste Package Design Methodology and AMRs - 1101 2125 M1.* Activity Evaluation, September 23, 1999. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991001.0148.

CRWMS M&O 1999d. *Rock Fall and Vertical Drop Calculations of Waste Packages.* BBA000000-01717-0210-00058 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990712.0123.

CRWMS M&O 1999e. *TRIGA Fuel Phase I and II Criticality Calculation.* CAL-MGR-NU-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19991209.0195.

CRWMS M&O 1999f. *Source Terms from DHLW Canisters for Waste Package Design.* BBA000000-01717-0210-00044 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990222.0176.

CRWMS M&O 1999g. *Thermal Evaluation of the TRIGA Codisposal Waste Package.* BBAA00000-01717-0210-00022 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990712.0195.

CRWMS M&O 1999h. *LCE for Research Reactor Benchmark Calculations.* B00000000-01717-0210-00034 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990329.0394.

CRWMS M&O 1999i. *Laboratory Critical Experiment Reactivity Calculations.* B00000000-01717-0210-00018 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990526.0294.

CRWMS M&O 2000a. *Waste Package Design Methodology Report.* ANL-EBS-MD-000053 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0294.

CRWMS M&O 2000b. *Waste Package Design Sensitivity Report.* TDR-EBS-MD-000008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000518.0179.

CRWMS M&O 2000c. *Design Analysis for the Defense High-Level Waste Disposal Container.* TDP-DDC-ME-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000202.0169.

CRWMS M&O 2000d. *Internal Pressurization Due to Fuel Rod Rupture in Waste Packages.* CAL-EBS-ME-000005 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000315.0671.

CRWMS M&O 2000e. *Pressurized System Missile Impact on Waste Packages.* CAL-EBS-ME-000006 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000420.0397.

CRWMS M&O 2000f. *Dose Rate Calculation for the DHLW/DOE SNF Codisposal Waste Package*. CAL-DDC-NU-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000223.0505.

CRWMS M&O 2000g. *Waste Package Lifting Calculation.* CAL-EBS-ME-000007 REV 01. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0297.

CRWMS M&O 2000h. *Evaluation of Codisposal Viability for UZrH (TRIGA) DOE-Owned Fuel.* TDR-EDC-NU-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000207.0689.

CRWMS M&O 2000i. *Structural Calculations for the Lifting of a Loaded Emplacement Pallet.* CAL-WER-ME-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000223.0827.

DOE (U.S. Department of Energy) 1992. *Characteristics of Potential Repository Wastes.* DOE/RW-0184-R1. Volume 1. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.19920827.0001.

DOE (U.S. Department of Energy) 1998. "Design Specification." Volume 1 of *Preliminary Design Specification for Department of Energy Standardized Spent Nuclear Fuel Canisters.* DOE/SNF/REP-011, Rev. 1. Washington, D.C.: U.S. Department of Energy, Office of Spent Fuel Management and Special Projects. TIC: 241528.

DOE (U.S. Department of Energy) 1999a. "Design Specification." Volume 1 of *Preliminary Design Specification for Department of Energy Standardized Spent Nuclear Fuel Canisters.* DOE/SNF/REP-011, Rev. 3. Washington, D.C.: U.S. Department of Energy, Office of Spent Fuel Management and Special Projects. TIC: 246602.

DOE (U.S. Department of Energy) 1999b. *TRIGA (UZrH) Fuel Characteristics for Disposal Criticality Analysis.* DOE/SNF/REP-048, Rev. 0. Washington, D.C.: U.S. Department of Energy. TIC: 244162.

DOE (U.S. Department of Energy) 1999c. *Waste Acceptance System Requirements Document.* DOE/RW-0351, Rev. 03. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: HQO.19990226.0001.

DOE (U.S. Department of Energy) 2000. *Quality Assurance Requirements and Description.* DOE/RW-0333P, Rev. 10. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000427.0422.

Marra, S.L.; Harbour, J.R.; and Plodinec, M.J. 1995. *DWPF Canister Procurement, Control, Drop Test, and Closure (U).* WSRC-IM-91-116-8, Rev. 1. Aiken, South Carolina: Westinghouse Savannah River Company. TIC: 240797.

Mele, I.; Ravnik, M.; and Trkov, A. 1994. "TRIGA Mark II Benchmark Experiment, Part I: Steady-State Operation." *Nuclear Technology, 105,* (1), 37-51. Hinsdale, Illinois: American Nuclear Society. TIC: 240865.

Nuclear Energy Agency 1998. *International Handbook of Evaluated Criticality Safety Benchmark Experiments.* NEA/NSC/DOC(95)03. Paris, France: Nuclear Energy Agency. TIC: 243013.

Parrington, J.R.; Knox, H.D.; Breneman, S.L.; Baum, E.M.; and Feiner, F. 1996. *Nuclides and Isotopes, Chart of the Nuclides.* 15th Edition. San Jose, California: General Electric Company and KAPL, Inc. TIC: 233705.

Plodinec, M.J. and Marra, S.L. 1994. *Projected Radionuclide Inventories and Radiogenic Properties of the DWPF Product (U).* WSRC-IM-91-116-3, Rev. 0. Aiken, South Carolina: Westinghouse Savannah River Company. TIC: 242337.

Smith, K.E. 1997. *Multi-Canister Overpack Design Report.* HNF-SD-SNF-DR-003, Rev. 0. Richland, Washington: Duke Engineering Services Hanford. ACC: MOL.19980625.0219.

Stout, R.B. and Leider, H.R., eds. 1991. *Preliminary Waste Form Characteristics Report.* Version 1.0. Livermore, California: Lawrence Livermore National Laboratory. ACC: MOL.19940726.0118.

YMP (Yucca Mountain Project) 1998. *Disposal Criticality Analysis Methodology Topical Report.* YMP/TR-004Q, Rev. 0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990210.0236.

8.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

10 CFR 71. 1999. Energy: Packaging and Transportation of Radioactive Material. Readily Available.

ANSI/ANS-6.1.1-1977. *Neutron and Gamma-Ray Flux-to-Dose-Rate Factors.* La Grange Park, Illinois: American Nuclear Society. TIC: 239401.

ANSI/ANS-8.1-1998. *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors.* La Grange Park, Illinois: American Nuclear Society. TIC: 242363.

ANSI/ANS-8.10-1983. *Criteria for Nuclear Criticality Safety Controls in Operations with Shielding and Confinement.* La Grange Park, Illinois: American Nuclear Society. TIC: 205015.

ANSI/ANS-8.15-1981. *Nuclear Criticality Control of Special Actinide Elements.* La Grange Park, Illinois: American Nuclear Society. TIC: 231624.

ANSI/ANS-8.17-1984. *Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors*. La Grange Park, Illinois: American Nuclear Society. TIC: 231625.

AP-3.4Q, Rev. 1, ICN 1. *Level 3 Change Control*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.19991117.0140.

AP-3.10Q, Rev. 2, ICN 1. *Analyses and Models*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000512.0066.

AP-3.15Q, Rev 1, ICN 1. *Managing Technical Product Inputs*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000218.0069.

AP-6.1Q, Rev. 4, ICN 0. *Controlled Documents*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000104.0305.

AP-SV.1Q, Rev. 0, ICN 1. *Control of the Electronic Management of Data*. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000512.0068.

ASME (American Society of Mechanical Engineers) 1995. *1995 ASME Boiler and Pressure Vessel Code*. New York, New York: American Society of Mechanical Engineers. TIC: 245287.

ASTM A 516/A 516M-90. 1991. *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 240032.

ASTM A 240/A 240M-95a. 1995. *Standard Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 242434.

ASTM B 575-97. 1998. *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*. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 241816.

QAP-2-3, Rev. 10. *Classification of Permanent Items*. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990316.0006.

ATTACHMENTS

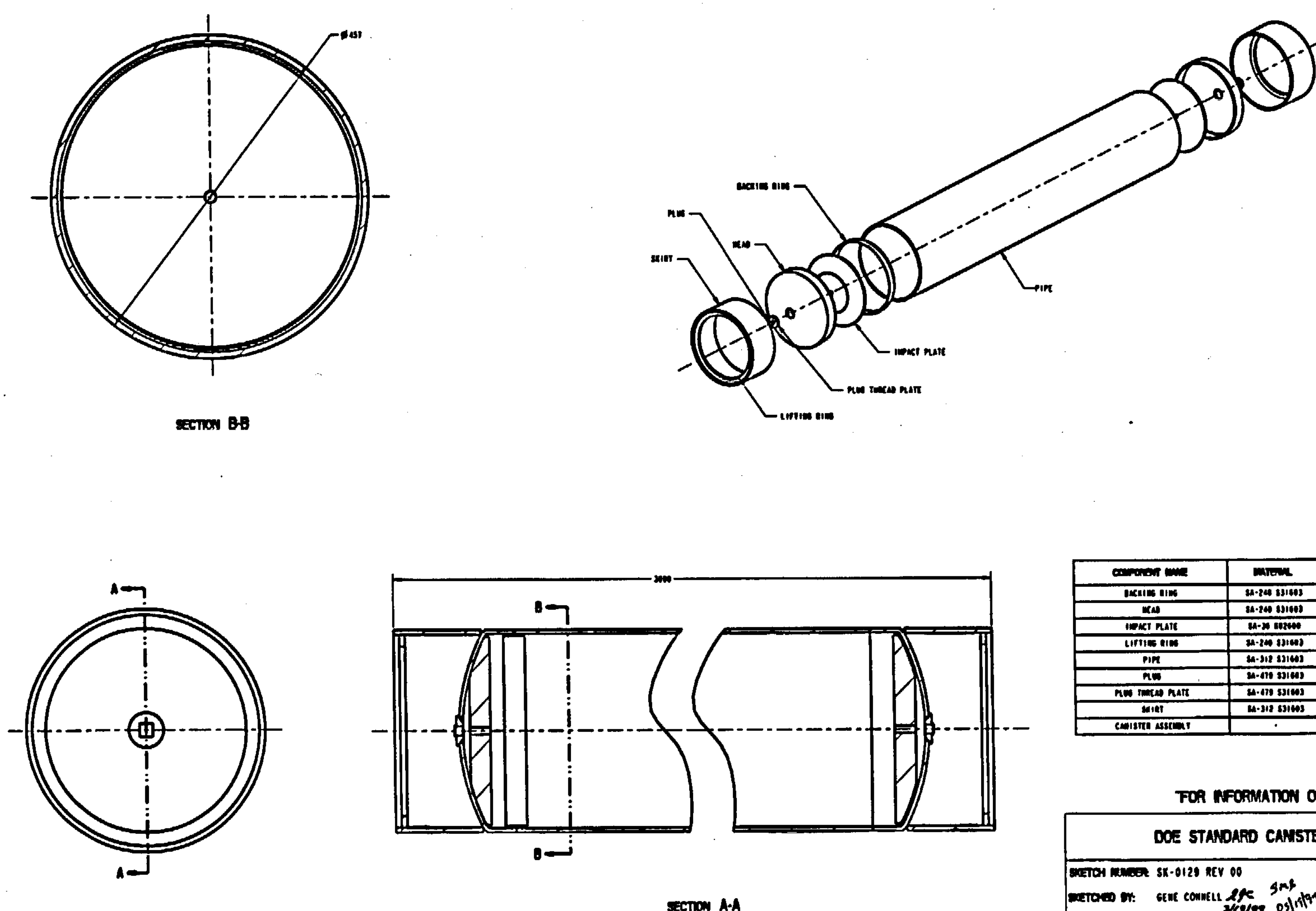
Table 16. List of Attachments

Description	Attachment Number	No. of Pages
SK-0129 REV 00 DOE Standard Canister (Short)	I	1
SK-0124 REV 00 TRIGA DOE SNF Basket Assembly	II	1
SK-0196 REV 03 5-DHLW/DOE SNF-Short WP Assembly Configuration for Site Recommendation[a, c]	III	2
SK-0197 REV 00 5-DHLW/DOE SNF-Short Weld Configuration	IV	1
SK-0200 REV 04 5-DHLW/DOE SNF-Long Waste Package Configuration for Site Recommendation[a, c]	V	2
SK-0201 REV 00 5-DHLW/DOE SNF-Long Weld Configuration	VI	1
SK-0198 REV 01 2-MCO/2-DHLW Waste Package Configuration for Site Recommendation[b, c]	VII	2
SK-0199 REV 00 2-MCO/2-DHLW Waste Package Weld Configuration	VIII	1

NOTES: [a] The documents referenced in this sketch, *Waste Acceptance System Requirements Document* and "Design Specification," Volume 1 of *Preliminary Design Specification for Department of Energy Standardized Spent Nuclear Fuel Canisters*, are identified in this document as DOE (1999c) and DOE (1998), respectively.

[b] The documents referenced in this sketch, *Waste Acceptance System Requirements Document* and *Multi-Canister Overpack Report*, are identified in this document as DOE (1999c) and Smith (1997), respectively.

[c] Detail C in the sketch shows preliminary specifications (see Section 6.1.1, Table 8).



COMPONENT NAME	MATERIAL	THICKNESS	MASS (kg)	QTY REQ
BACKING RING	SA-240 S31603	6.0	2	1
HEAD	SA-240 S31603	9.5	19	2
IMPACT PLATE	SA-36 K02600	50.8	42	2
LIFTING RING	SA-240 S31603	12.7	3	2
PIPE	SA-312 S31603	9.5	247	1
PLUG	SA-479 S31603	-	.06	2
PLUG THREAD PLATE	SA-479 S31603	-	.3	2
SKIRT	SA-312 S31603	9.5	25	2
CANISTER ASSEMBLY	-	-	427	1

"FOR INFORMATION ONLY"

UNITS: mm

DO NOT SCALE FROM SKETCH

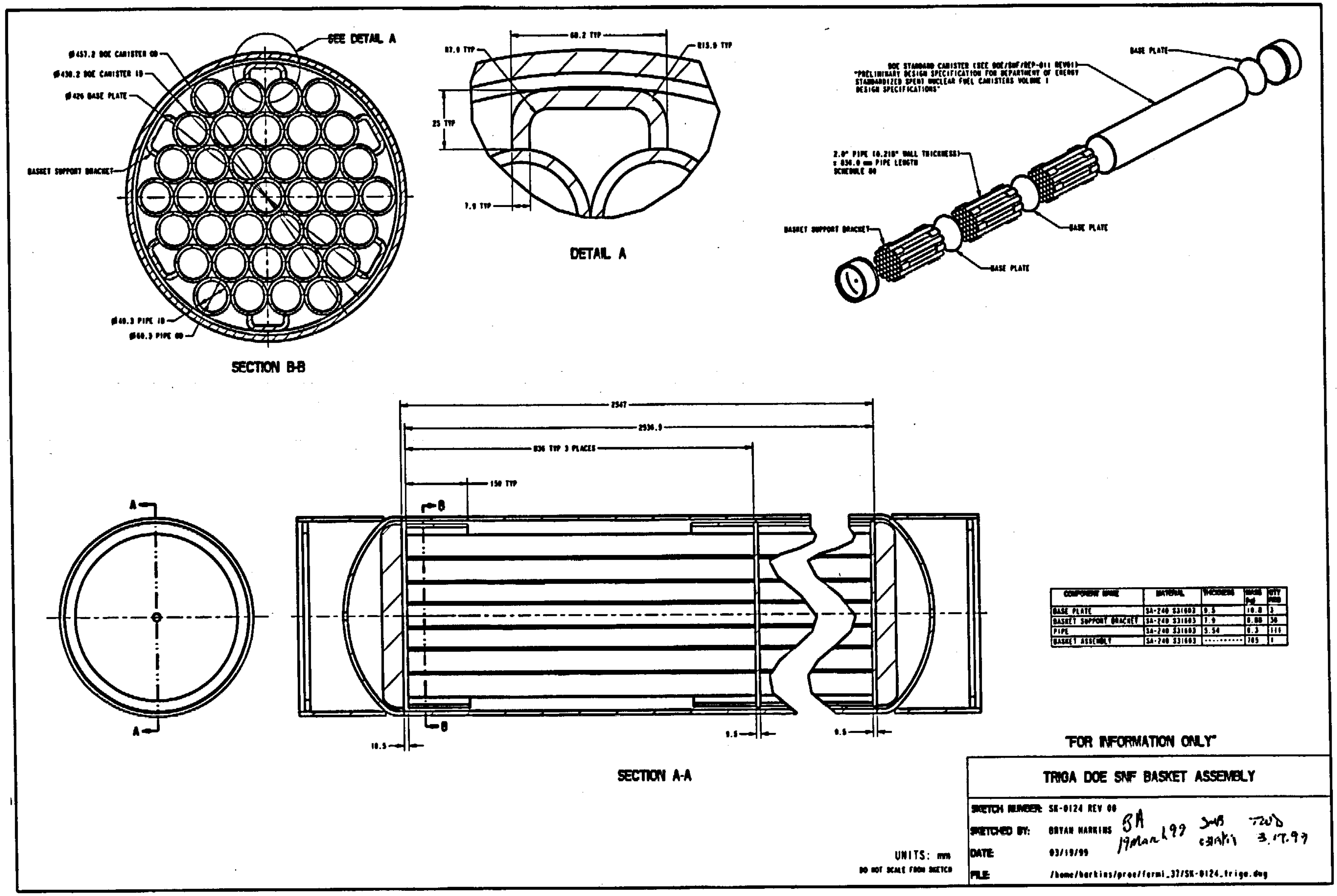
DOE STANDARD CANISTER (SHORT)

SKETCH NUMBER: SK-0129 REV 00

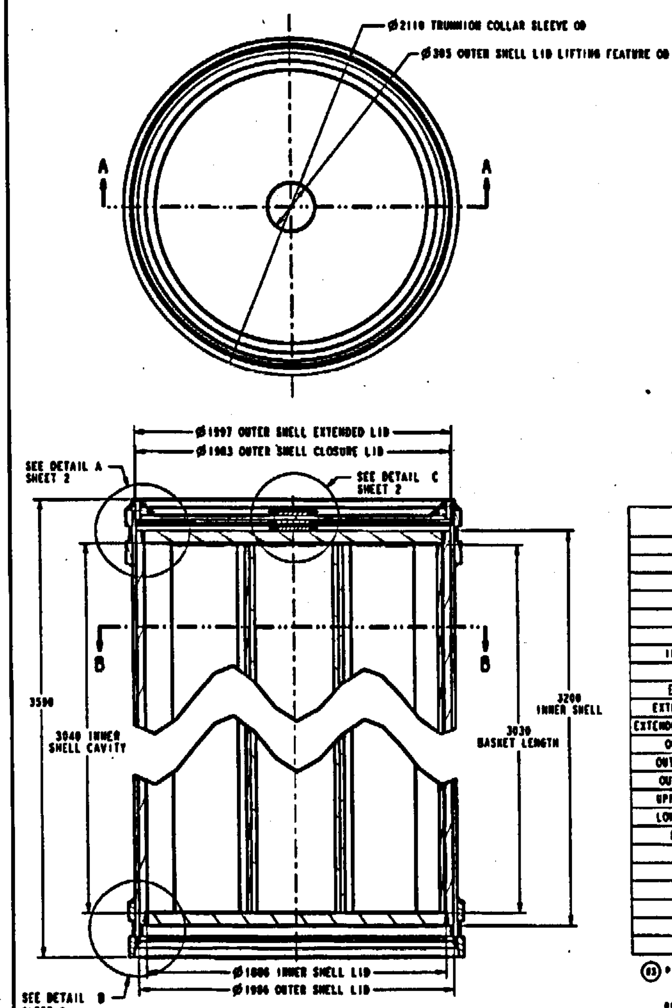
SKETCHED BY: GENE CONNELL

DATE: 03/16/99

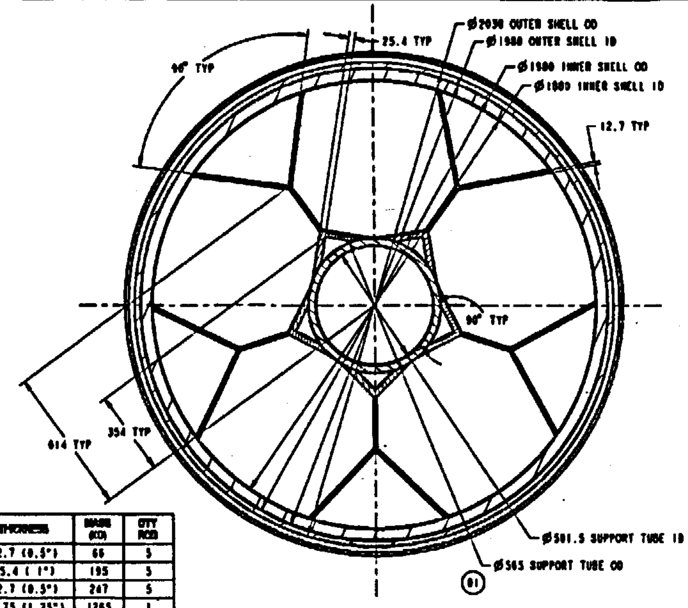
FILE: /home/pro_library/checkout/sketches/forms_fuel_home/short/SK-0129.dwg



COMPONENT NAME	MATERIAL	THICKNESS	MASS (kg)	QTY REQD
BASE PLATE	SA-240 S31603	9.5	10.8	3
BASKET SUPPORT BRACKET	SA-240 S31603	7.9	0.08	30
PIPE	SA-240 S31603	5.54	0.3	111
BASKET ASSEMBLY	SA-240 S31603	-----------	705	1



SECTION A-A



SECTION B-B

COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY REQ'D
DIVIDER PLATE	SA-516 K02700	12.7 (0.5")	66	5
INNER BRACKET	SA-516 K02700	25.4 (1")	195	5
OUTER BRACKET	SA-516 K02700	12.7 (0.5")	247	5
SUPPORT TUBE	SA-516 K02700	31.75 (1.25")	1265	1
INNER SHELL	SA-240 S31600	50	7621	1
INNER SHELL LID	SA-240 S31600	80	1765	2
INNER LID LIFTING FEATURE	SA-240 S31600	27	12	1
OUTER SHELL	SB-575 N06022	25	4692	1
EXTENDED OUTER SHELL LID	SB-575 N06022	25	172	1
EXTENDED OUTER SHELL LID BASE	SB-575 N06022	25	629	1
EXTENDED OUTER LID REINFORCING RING	SB-575 N06022	50	129	1
OUTER LID LIFTING FEATURE	SB-575 N06022	27	13	2
OUTER SHELL FLAT CLOSURE LID	SB-575 N06022	10	268	1
OUTER SHELL FLAT BOTTOM LID	SB-575 N06022	25	669	1
UPPER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	655	1
LOWER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	642	1
INNER SHELL SUPPORT RING	SB-575 N06022	20	53	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	325	***
TOTAL 316 WELDS	SFA-5.9 S31680	-	133	***
WASTE PACKAGE ASSEMBLY	-	-	23360	1
HLW GLASS ASSEMBLY	-	-	2500*	5
18" CANISTER SHORT	-	-	2270**	1
WP ASSEMBLY WITH SNF	-	-	38130	-

(03) * WASTE ACCEPTANCE SYSTEM REQUIREMENTS DOCUMENT. E00000000-00811-1708-00001 REV 03, DOE/RW-0351. ACC: MOO.19990226.0001. PAGE 10, SECTION 4.2.3.1.A.4.

** UNITED STATES DEPARTMENT OF ENERGY 1998. DESIGN SPECIFICATION FOR DEPARTMENT OF ENERGY STANDARDIZED SPENT NUCLEAR FUEL CANISTERS, VOLUME 1, DESIGN SPECIFICATION, REV 01, WASHINGTON D.C.: UNITED STATES DEPARTMENT OF ENERGY. TIC: 241528

*** SEE SK-0197 FOR WELD CONFIGURATION AND MASSES

UNITS: mm

DO NOT SCALE FROM SKETCH

REVISIONS			
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01	IN SECTION B-B Ø 565 SUPPORT TUBE OD "WAS" ID	DGN	4/21/00
02	"MODIFIED" REVISION TABLE, "ADDED" DIMENSION 4 TO DETAIL A, "MODIFIED" CROSS HATCHING ON DETAIL A	BH	4/25/00
03	IN NOTE **, DOE/RW-0351 "WAS" DOE/RW-315P, IN REVISION BLOCK REV 00, 1/20/00 "WAS" 1/25/00, "ADDED" REVISION BALLOONS TO SECTION B-B AND DETAIL "A"	EJC	6/5/00

"FOR INFORMATION ONLY"

5 DHLW/DOE SNF - SHORT WP ASSSEMBLY CONFIGURATION FOR SITE RECOMENDATION

SKETCH NUMBER:	SK-0196 REV 03	SHEET 1 OF 2
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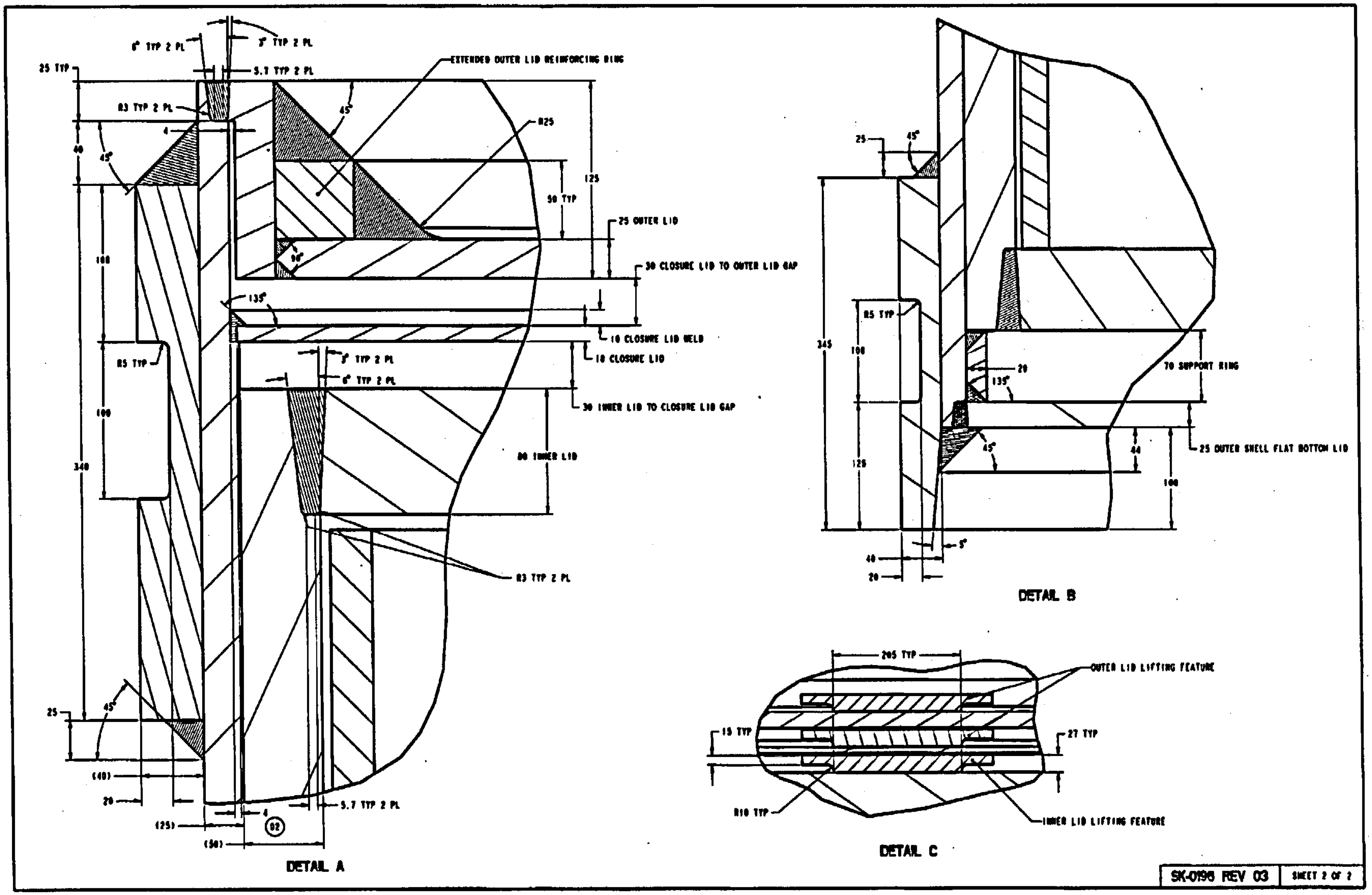
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3° TYP 2 PL
25 TYP
5.7 TYP 2 PL
EXTENDED OUTER LID REINFORCING RING
R3 TYP 2 PL
45°
R25
125
50 TYP
25 OUTER LID
90°
30 CLOSURE LID TO OUTER LID GAP
135°
10 CLOSURE LID WELD
10 CLOSURE LID
R5 TYP
30 INNER LID TO CLOSURE LID GAP
80 INNER LID
340
R3 TYP 2 PL
(40)
(25)
(50)
DETAIL A
345
70 SUPPORT RING
25 OUTER SHELL FLAT BOTTOM LID
5°
DETAIL B
205 TYP
OUTER LID LIFTING FEATURE
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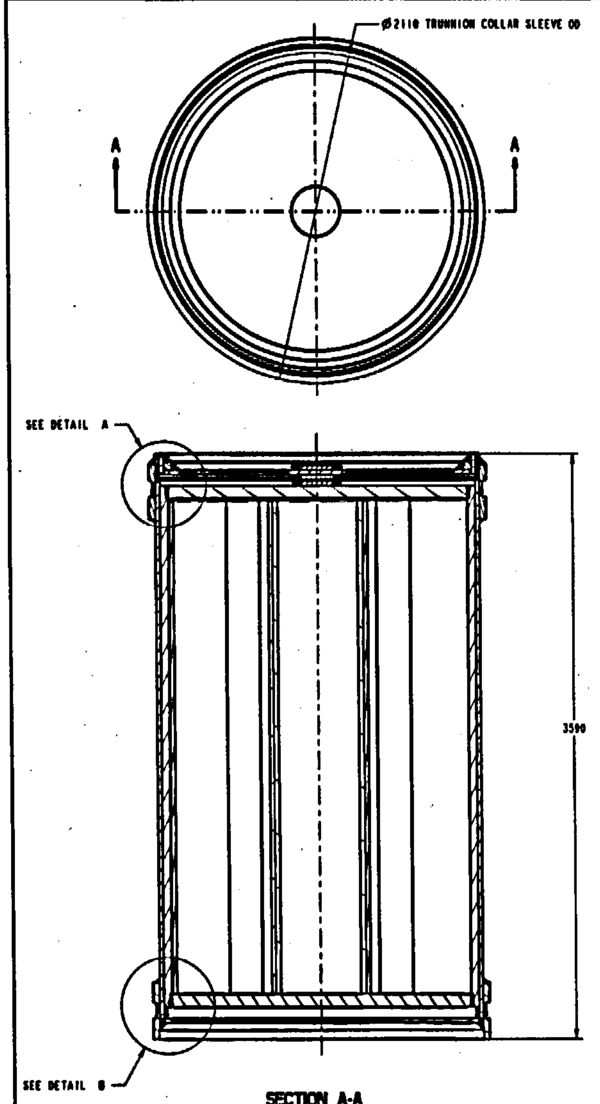
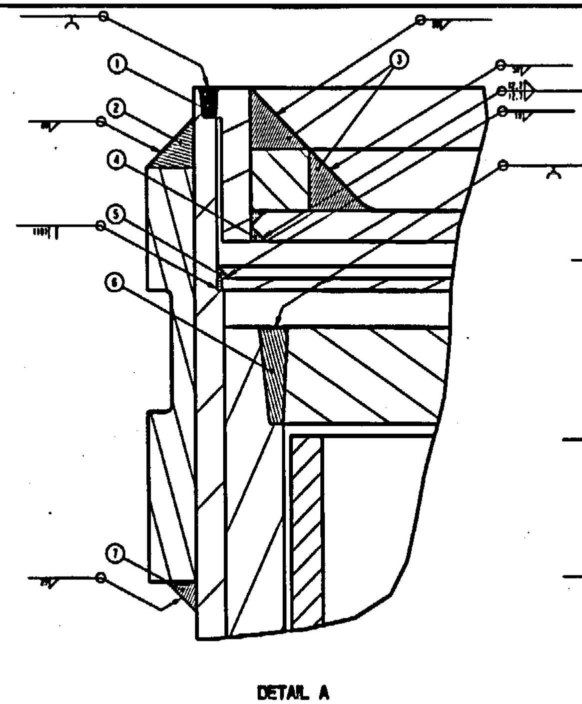
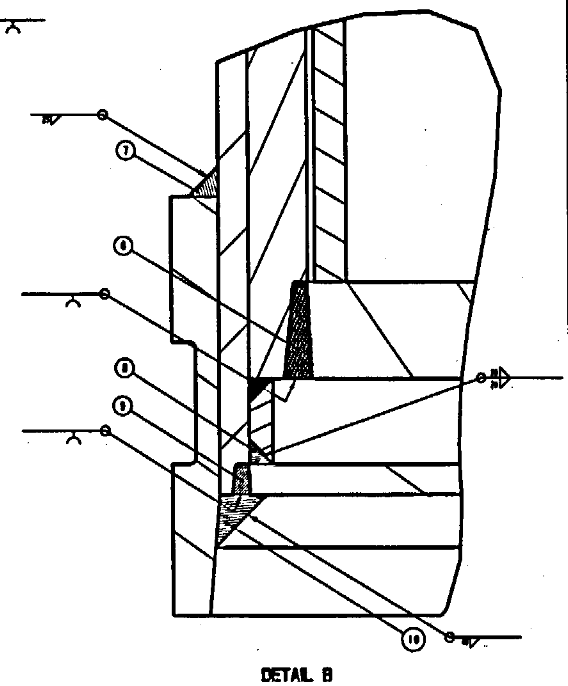
INNER LID LIFTING FEATURE
DETAIL C
SK-0196 REV 03
SHEET 2 OF 2



SECTION A-A



DETAIL A



DETAIL B

WELD	MATERIAL	MASS (KG)	QTY REQ
1	SFA-5.14 N06022	18	1
2	SFA-5.14 N06022	45	1
3	SFA-5.14 N06022	127	1
4	SFA-5.14 N06022	4.1	2
5	SFA-5.14 N06022	4.9	1
6	SFA-5.9 S31680	67	2
7	SFA-5.14 N06022	17	2
8	SFA-5.14 N06022	11	2
9	SFA-5.14 N06022	18	1
10	SFA-5.14 N06022	40	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	325	-
TOTAL 316 WELDS	SFA-5.9 S31680	133	-

UNITS: mm

DO NOT SCALE FROM SKETCH

REVISIONS			
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"FOR INFORMATION ONLY"

5-DHLW/DOE SNF - SHORT WELD CONFIGURATION

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SMB 03/13/00

DATE: 03/10/00

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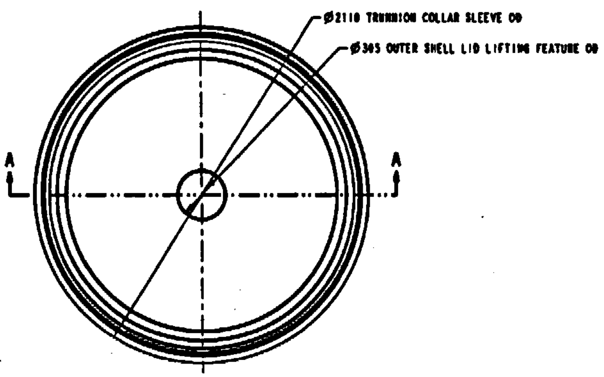
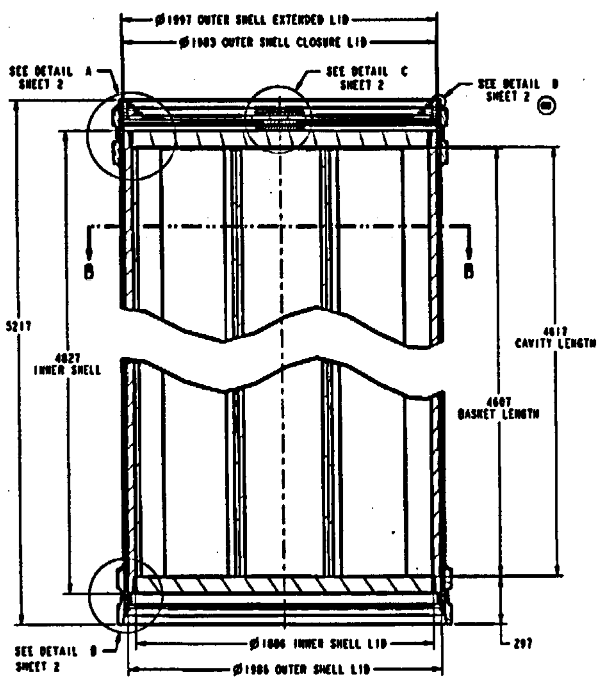
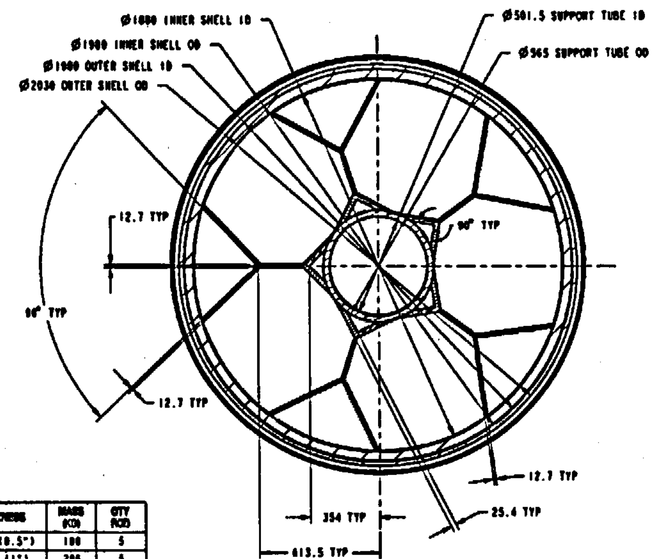




SECTION A-A



SECTION B-B

COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY REQ
DIVIDED PLATE	SA-516 K02700	12.7 (0.5")	100	5
INNER BRACKET	SA-516 K02700	25.4 (1")	296	5
OUTER BRACKET	SA-516 K02700	12.7 (0.5")	375	5
SUPPORT TUBE	SA-516 K02700	31.75 (1.25")	1924	1
INNER SHELL	SA-240 S31600	50	11507	1
INNER SHELL LID	SA-240 S31600	105 (01)	2314	2
INNER LID LIFTING FEATURE	SA-240 S31600	27	12	1
OUTER SHELL	SB-575 N06022	25 (02)	6910	1
EXTENDED OUTER SHELL LID	SB-575 N06022	25	172	1
EXTENDED OUTER SHELL LID BASE	SB-575 N06022	25	629	1
EXTENDED LID REINFORCEMENT RING	SB-575 N06022	50	129	1
OUTER LID LIFTING FEATURE	SB-575 N06022	27	13	2
OUTER SHELL FLAT CLOSURE LID	SB-575 N06022	10	268	1
OUTER SHELL FLAT BOTTOM LID	SB-575 N06022	25	669	1
UPPER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	655	1
LOWER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	642	1
INNER SHELL SUPPORT RING	SB-575 N06022	20	53	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	325	***
TOTAL 316 WELDS	SFA-5.9 S31680	-	194	***
WASTE PACKAGE ASSEMBLY	-	-	32610	1
HLW GLASS ASSEMBLY	-	-	4200**	5
18" CANISTER LONG	-	-	2721*	1
WP ASSEMBLY WITH SNF	-	-	56331	-

* UNITED STATES DEPARTMENT OF ENERGY 1998. DESIGN SPECIFICATION FOR DEPARTMENT OF ENERGY STANDARDIZED SPENT NUCLEAR FUEL CANISTERS, VOLUME 1, DESIGN SPECIFICATION, REV 01 WASHINGTON D.C.: UNITED STATES DEPARTMENT OF ENERGY. TIC: 241528

(04) ** WASTE ACCEPTANCE SYSTEM REQUIREMENTS DOCUMENT. E00000000-00811-1708-00001 REV 03, DOE/RW-0351. ACC: MOO.19990226.0001, PAGE 18, SECTION 4.2.3.1.A.4.

*** SEE SK-0201 FOR WELD CONFIGURATION AND MASSES

UNITS: mm

DO NOT SCALE FROM SKETCH

REVISIONS			
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02	OUTER SHELL THICKNESS 25 "WAS" 20 IN TABLE	DGN	2/9/00
03	SKETCHED BY "WAS" ORIGINATOR, "REDESIGNED" REVISION BLOCK, 5DHLW_LONG "WAS" NEW_LONG, "ADDED" VIEW "D" TO SHEET 2	EJC	3/2/00
04	IN NOTE **, DOE/RW-0351 "WAS" DOE/RW-315P	EJC	6/5/00

"FOR INFORMATION ONLY"

5 DHLW/DOE SNF - LONG WASTE PACKAGE CONFIGURATION FOR SITE RECOMMENDATION

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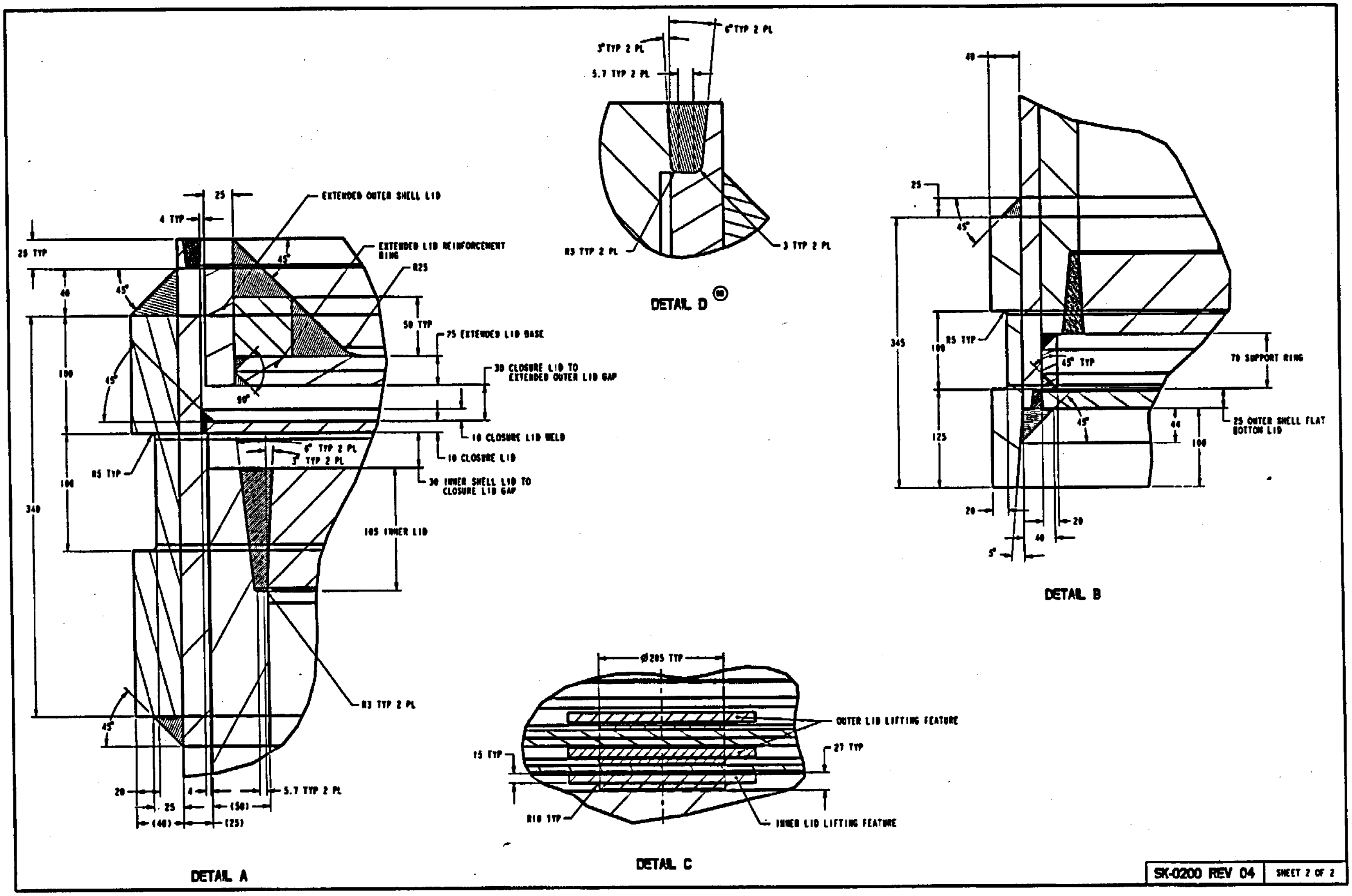
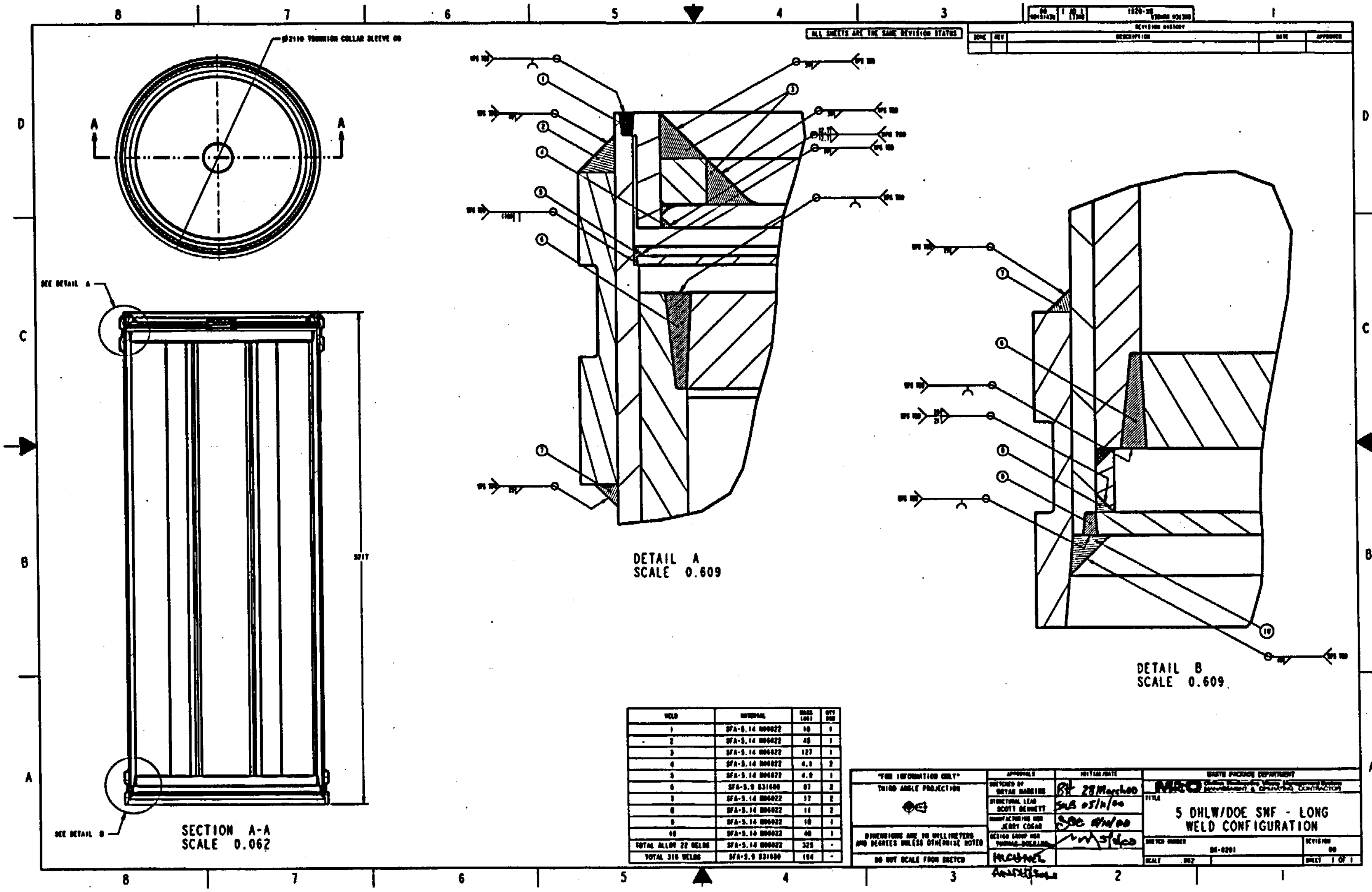
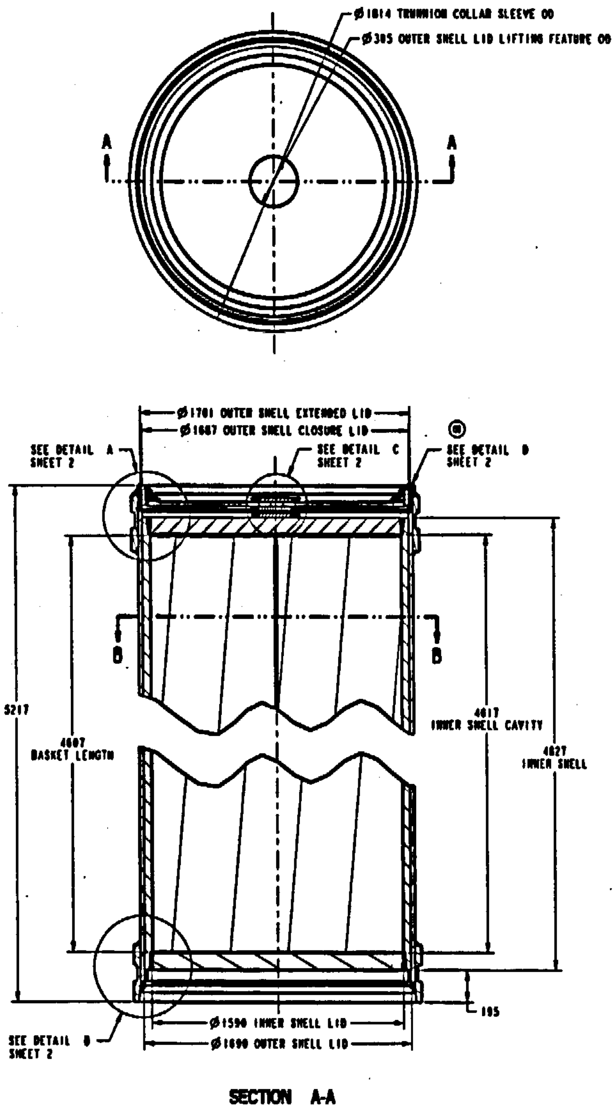
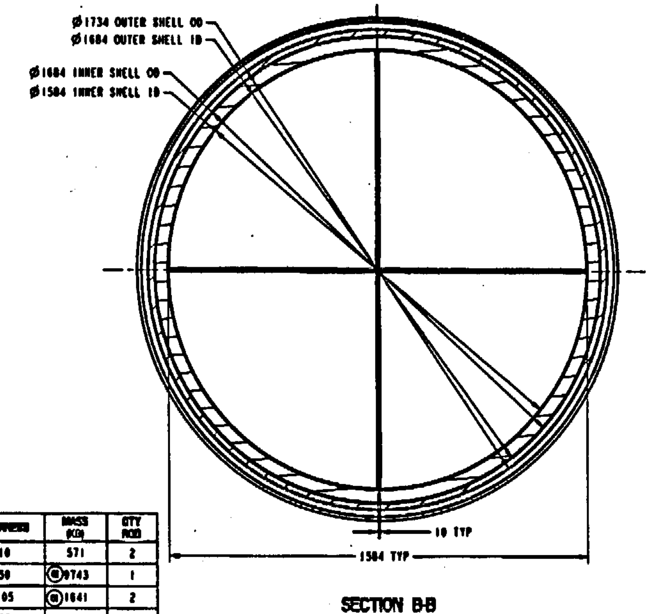


DETAIL A
DETAIL B
DETAIL C
DETAIL D
EXTENDED OUTER SHELL LID
EXTENDED LID REINFORCEMENT RING
75 EXTENDED LID BASE
30 CLOSURE LID TO EXTENDED OUTER LID GAP
10 CLOSURE LID WELD
10 CLOSURE LID
30 INNER SHELL LID TO CLOSURE LID GAP
105 INNER LID
70 SUPPORT RING
25 OUTER SHELL FLAT BOTTOM LID
OUTER LID LIFTING FEATURE
INNER LID LIFTING FEATURE
SK-0200 REV 04
SHEET 2 OF 2



WELD	MATERIAL	MASS (kg)	QTY REQ
1	SFA-5.14 N06022	10	1
2	SFA-5.14 N06022	45	1
3	SFA-5.14 N06022	127	1
4	SFA-5.14 N06022	4.1	2
5	SFA-5.14 N06022	4.9	1
6	SFA-5.9 S31600	87	2
7	SFA-5.14 N06022	17	2
8	SFA-5.14 N06022	11	2
9	SFA-5.14 N06022	10	1
10	SFA-5.14 N06022	40	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	325	-
TOTAL 316 WELDS	SFA-5.9 S31600	184	-





COMPONENT NAME	MATERIAL	THICKNESS	MASS (KG)	QTY REQ
A-PLATE	SA-516 K02700	10	571	2
INNER SHELL	SA-240 S31600	50	9743	1
INNER SHELL LID	SA-240 S31600	105	1641	2
INNER LID LIFTING FEATURE	SA-240 S31600	27	12	1
OUTER SHELL	SB-575 N06022	25	5897	1
EXTENDED OUTER SHELL LID	SB-575 N06022	25	146	1
EXTENDED OUTER SHELL LID BASE	SB-575 N06022	25	450	1
EXTENDED OUTER LID REINFORCING RING	SB-575 N06022	50	100	1
OUTER LID LIFTING FEATURE	SB-575 N06022	27	13	2
OUTER SHELL FLAT CLOSURE LID	SB-575 N06022	10	194	1
OUTER SHELL FLAT BOTTOM LID	SB-575 N06022	25	484	1
UPPER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	561	1
LOWER TRUNNION COLLAR SLEEVE	SB-575 N06022	40	550	1
INNER SHELL SUPPORT RING	SB-575 N06022	20	45	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	-	276	***
TOTAL 316 WELDS	SFA-5.9 S31680	-	184	***
WASTE PACKAGE ASSEMBLY	-	-	23081	1
HLW GLASS ASSEMBLY	-	-	4200*	2
MCO	-	-	8909.6**	2
WP ASSEMBLY WITH SNF	-	-	49300	1

* WASTE ACCEPTANCE SYSTEM REQUIREMENTS DOCUMENT. E00000000-00811-1708-00001 REV 03, DOE/RW-0351P. ACC: MOO.19990226.0001, PAGE 10, SECTION 4.2.3.1.A.4.

** DES HANFORD 1997. MULTI-CANISTER OVERPACK DESIGN REPORT. HNF-SD-SNF-DR-003 REV 0. JUNE 9, 1997, RICHLAND, WASHINGTON: U.S. DEPARTMENT OF ENERGY, RICHLAND OPERATIONS OFFICE, DUKE ENGINEERING SERVICES HANFORD, INC. ACC: MOL.19980825.0219.

*** SEE SK-0199 FOR WELD CONFIGURATION AND MASSES.

UNITS: mm

DO NOT SCALE FROM SKETCH

REVISIONS

"FOR INFORMATION ONLY"

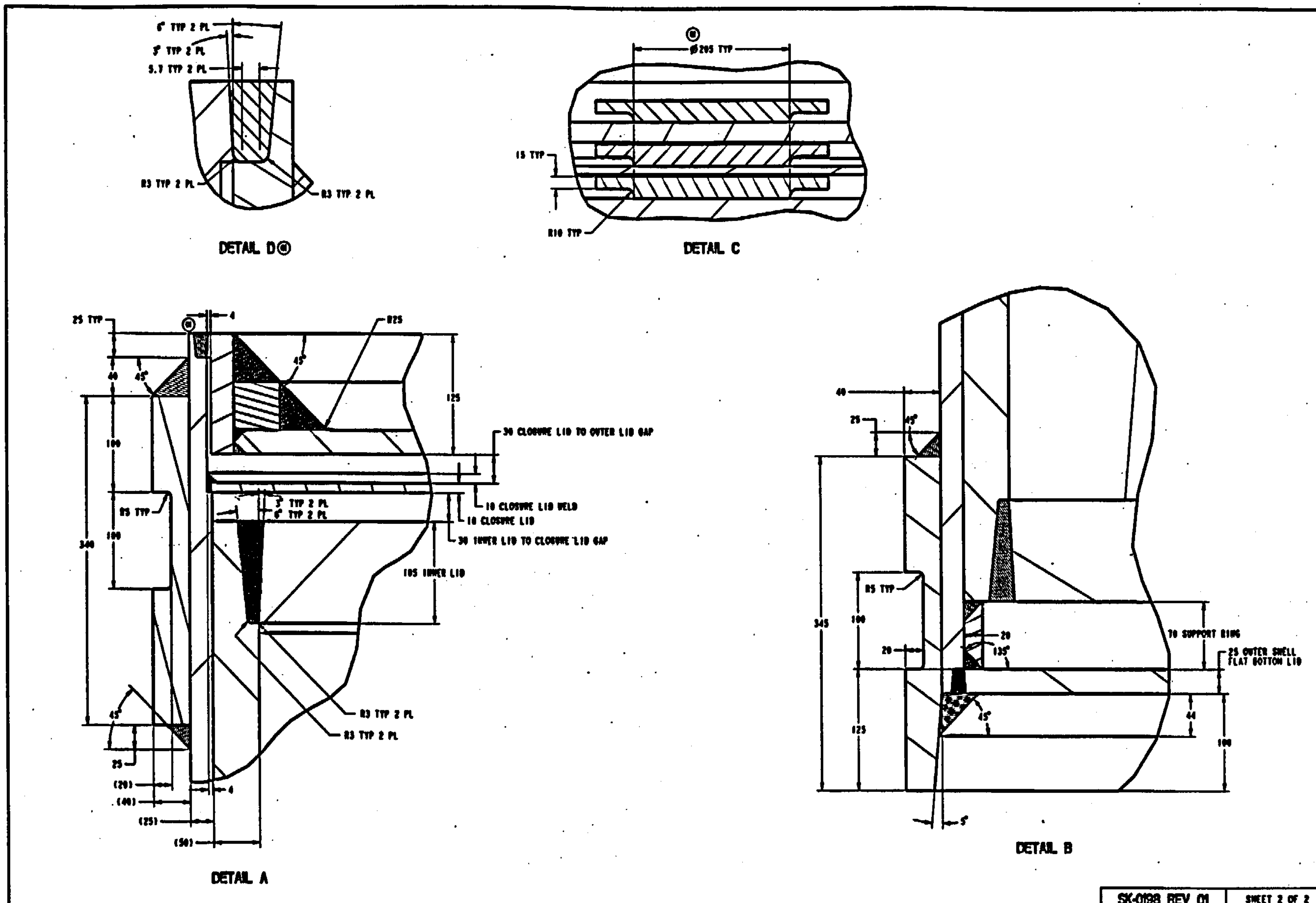
2-MCO / 2-DHLW WASTE PACKAGE CONFIGURATION FOR SITE RECOMMENDATION

SKETCH NUMBER: SK-0198 REV 01 SHEET 1 OF 2

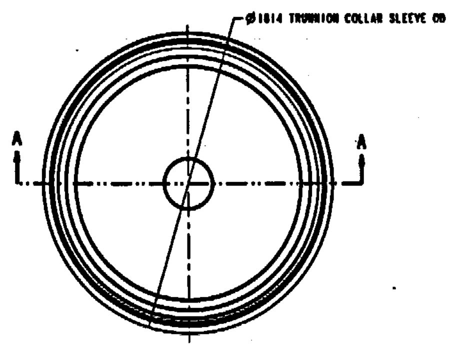
SKETCHED BY: BRYAN HARKINS BH 09 march 00 SMG 03/13/00 3/14/00

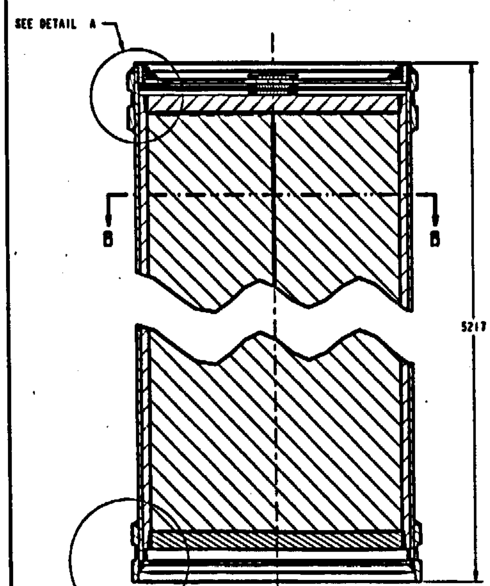
DATE: 03/09/00

FILE: /home/pro_library/checkout/sketches/2mco_2dhlw/sk-0198rev01.dwg

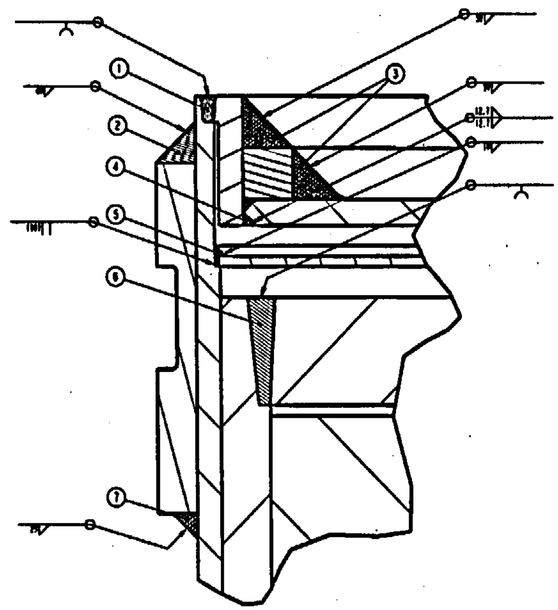


6° TYP 2 PL
3° TYP 2 PL
5.7 TYP 2 PL
R3 TYP 2 PL
R3 TYP 2 PL
DETAIL D
ø205 TYP
15 TYP
R10 TYP
DETAIL C
25 TYP
4
R25
45°
40
45°
125
30 CLOSURE LID TO OUTER LID GAP
100
10 CLOSURE LID WELD
3° TYP 2 PL
6° TYP 2 PL
10 CLOSURE LID
30 INNER LID TO CLOSURE LID GAP
R5 TYP
340
100
105 INNER LID
R3 TYP 2 PL
R3 TYP 2 PL
45°
25
(20)
(40)
4
(25)
(50)
DETAIL A
40
25
45°
R5 TYP
345
100
20
20
135°
TO SUPPORT RING
25 OUTER SHELL FLAT BOTTOM LID
45°
44
125
100
5°
DETAIL B
SK-0198 REV 01
SHEET 2 OF 2

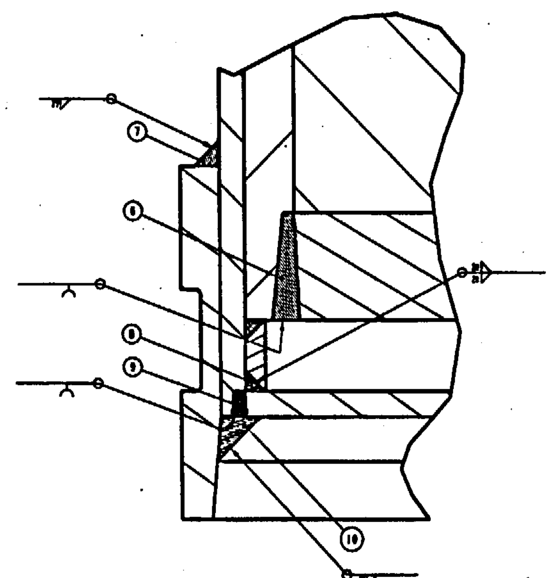




SECTION A-A



DETAIL A



DETAIL B

WELD	MATERIAL	MASS (KG)	QTY REQ
1	SFA-5.14 N06022	15	1
2	SFA-5.14 N06022	38	1
3	SFA-5.14 N06022	107	1
4	SFA-5.14 N06022	3.5	2
5	SFA-5.14 N06022	4.2	1
6	SFA-5.9 S31600	82	2
7	SFA-5.14 N06022	15	2
8	SFA-5.14 N06022	9.1	2
9	SFA-5.14 N06022	15	1
10	SFA-5.14 N06022	41	1
TOTAL ALLOY 22 WELDS	SFA-5.14 N06022	270	-
TOTAL 316 WELDS	SFA-5.9 S31600	164	-

REVISIONS

REV	DESCRIPTION	APPD BY	DATE
00	ISSUED APPROVED	BH	03/08/00

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UNITS: mm

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2-MCO / 2-DHLW WASTE PACKAGE WELD CONFIGURATION

SKETCH NUMBER: SK-0199 REV 00
SKETCHED BY: BRYAN HARKINS BH 13 March 00 SMB 3/13/00
DATE: 03/08/00
FILE: /home/pro_library/checkout/sketches/2mco_2dhlw/sk-0199rev00.dwg