1. QA: QA

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
INPUT TRANSMITTAL

TO:

2. INPUT TRACKING NO.
00422.T

3. REQUESTER/RECIPIENT NAME	3a. ADDITIONAL USERS
Robert MacKinnon	Nicholas Francis, E. James Nowak, Robert Rechard, Ernest Hardin, Bo Bodvarsson, Al Eddebbarh, Jerry McNeish, Cliff Ho, Michael Sauer, Peter Swift, Jeff Ryman, Mike Anderson, Kevin Mon, Dan McKenzie III, Patrick Mattie, Fei Duan, Dwayne Kicker, Hemi Kalia, Rob Howard, Scott Bennett
4. REQUESTER/RECIPIENT ORGANIZATION	**5. REQUESTER/RECIPIENT ADDRESS**
Performance Assessment	Sandia National Lab, Albuquerque

MOL.20010410.0256

6. TITLE OF TRANSMITTAL

Design Input for the Engineered Barrier System Environment and Barriers

ATTACHED ARE THE INPUT DESCRIBED BELOW: | **INPUT STATUS**

7. ITEM NO.	8. DESCRIPTION (Including document number/identifier, if applicable)	9. REVISION	10. DATE	11. NEEDS FURTHER CONFIRMATION Y/N
1	Repository Footprint and Plane Coordinates	0	01/29/01	Y
2	MGR Project Description Document – Low Temperature Requirements Redline of Section 5, Technical Requirements	0	January 2001	Y
3	Waste Package Design Information supporting a "Cool" Repository Design Information for Performance Assessment.	0	02/08/01	Y
4	Hydrologic and Thermal Properties of the Invert (from *Water Distribution and Removal Model*, ANL-EBS-MD-000032 REV 01, Attachment XIV. MOL Pending).	0	November 2000	Y
5	Draft evaluation of the range of properties for crushed tuff.	0	02/08/2001	Y
6	Draft version of *Committed Materials in Repository Drifts*, CAL-GCS-GE-000002 REV 00A (in checking).	0	January 2001	Y

12. SPECIAL INSTRUCTIONS/COMMENTS:

Yes	No	
☒	☐	Identified input is latest version
☒	☐	Identified input will be placed in a controlled source
☒	☐	Some input provided differs from the current baselined. It is anticipated that the baseline design will be updated as the information is further developed and finalized.

This input has been identified with TBV - ______________________ .

WM-11
NMSS07

NOTE: The attached information pertains to anticipated design changes corresponding to a representative low temperature repository operating mode. This information is to be used for comparative evaluations only. While information pertaining to these evaluations is being controlled in accordance with QA procedural requirements, adjustments to the baseline as a result of these evaluations is not contemplated at this time. If and when such adjustments are pursued, appropriate baseline impact evaluations will be required.

The attached spreadsheet contains a more complete listing of input transmittal responses to specific items requested by Input Request 00422.R. Items are subdivided as follows:

1. Repository Footprint
2. Operational Plans
3. Repository Closure
4. Emplacement Drift Environment
5. Engineered Barriers
6. Waste Form and Heat Output
7. Composition and Quantities of EBS Materials
8. Mechanical Response of EBS Elements to Postclosure Ground Motion and Fault Displacement
9. Thermal Response of Drip Shield
10. Mechanical Response of the Emplacement Pallet
11. Properties of Corroded Waste Package Materials

Transmitted input will be used to control information and assumptions to be used in evaluating a representative low temperature design. Transmitted input consists of those programmatic assumptions or requirements, system environments, and design concepts, configurations, and assumptions pertinent to the performance modeling and total system performance assessment of the repository system. Information will be used in design analyses, integrated analysis model reports, and the low temperature total system performance assessment. The transmittal has been pre-coordinated with potential users.

This input transmittal is substantially complete with respect to the specific requested information. Information not contained in this transmittal will be addressed by a subsequent transmittal as indicated in the attached spreadsheet. Subsequent transmittals are planned for 3/20/01 and 4/20/01.

Where appropriate, the attached spreadsheet provides specific references to information already contained in existing approved or baseline documentation.

This transmittal will be superceded by formal analyses, calculations, or reports yet to be completed. The anticipated date for completion of controlled documentation is 5/31/2001.

13. APPROVED BY: (Including authorization to release information that needs further confirmation) RESPONSIBLE MANAGER NAME/SIGNATURE/DATE	SYSTEMS ENGINEERING DEPARTMENT MANAGER CONCURRENCE (Print Name/Signature/Date)
Mark Sellers [signature] 02/09/2001	E. P. "Woody" Stroupe 02/09/2001 [signature]
14. TRANSMITTING ORGANIZATION: Systems Engineering Department	15. ADDRESS: 1180 Town Center Drive, Mail Stop SUM1/423, Las Vegas, NV 89144
16. RETURN TRANSMITTAL BY (DATE) 02/23/2001	

REQUESTER/RECIPIENT ACKNOWLEDGMENT

17. TRANSMITTED DATA:

- [x] Correct Input
- [ ] Incomplete Input (Include explanation)
- [ ] Incorrect Input (Include explanation)
- [ ] Unsolicited Input, Receipt Acknowledged
- [ ] Unsolicited Input, Not Needed (Remove from tracking)

18. REQUESTER/RECIPIENT NAME	REQUESTER/RECIPIENT SIGNATURE	DATE
Robert MacKinnon	[signature]	04/10/01
19. REQUESTER/RECIPIENT NON-ACKNOWLEDGMENT RESPONSIBLE MANAGER SIGNATURE		DATE

Design Input Transmittal Spreadsheet

Design Input Transmittal

Item	Description	Comments	Anticipated Interim Transmittal Date	Anticipated Final Transmittal Date	Responsible Organization	Responsible Individual	Notes	Users	Included in Transmittal	Reference (if any)
I.	**Repository Footprint**									
1	Coordinate locations in easting and northing of the loaded repository area and any contingency areas. Clearly mark loaded and unloaded drift areas.	Need #'s of waste packages from WP. Depends on PDD quantities - anticipated to be unchanged from those used in high temp design		Final transmittal contained in approved Lay-out analysis		McKenzie, Linden, Krug	Needed for TH, UZ Flow, SZ flow. 70,000 MTU, EIS, and TSLCC Cases desired	Bodvarsson, Eddebbarh, Francis, Hardin, MacKinnon, McNeish, Mattie, Ho, Sauer, Swift	Yes	Attached to Transmittal (Item 1)
a.	Repository elevation at each node		02/01/2001	05/31/2001	Subsurface Design	See above		Bodvarsson, Eddebbarh, Francis, Hardin, MacKinnon, McNeish, Mattie, Ho, Sauer, Swift	Yes	Attached to Transmittal (Item1)
b.	Emplacement Drift Spacing		02/01/2001	05/31/2001	Subsurface Design	See above		Bodvarsson, Eddebbarh, Francis, Hardin, MacKinnon, McNeish, Mattie, Ho, Sauer, Swift	Yes	Attached to Transmittal (Item1)
c.	Emplacement drift orientation		02/01/2001	05/31/2001	Subsurface Design	See above		Bodvarsson, Eddebbarh, Francis, Hardin, MacKinnon, McNeish, Mattie, Ho, Sauer, Swift	Yes	Attached to Transmittal (Item 1)
d.	Approximate number of total drifts		02/01/2001	05/31/2001	Subsurface Design	See above		Bodvarsson, Eddebbarh, Francis, Hardin, MacKinnon, McNeish, Mattie, Ho, Sauer, Swift	Yes	Attached to Transmittal (Item1)
e.	% of Repository in each host unit		02/01/2001	05/31/2001	Subsurface Design	See above		Bodvarsson, Eddebbarh, Francis, Hardin, MacKinnon, McNeish, Mattie, Ho, Sauer, Swift	Yes	Attached to Transmittal (Item 1)
f.	Repository Design Input from PDD needed regarding total number of waste packages	Nominal numbers versus numbers with margin	02/01/2001	From PDD	Systems Engineering	Rhodes	Column added to Table 5-5 in PDD to indicate nominal waste package numbers.	McKenzie, Ryman, Anderson	Yes	Attached to Transmittal (Item 2, Table 5-5)
g.	Quantity of wastes to be considered for each case		02/01/2001	From PDD	Systems Engineering	Hastings	No change	McKenzie, Ryman, Anderson	Yes	Attached to Transmittal (Item 2, 5.1.4.1 & 5.1.4.2)
II.	**Operational Plans**									
1	Duration of Emplacement Period	24 years	02/01/2001	05/31/2001	Systems Engineering	Hastings	Assume no additional blending	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 2, Table 5-1)
2	Duration of Ventilation Period									
a.	Forced Ventilation Period		02/01/2001	From PDD	Systems Engineering	Hastings		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 2, 5.1.3.1)
b.	Natural Ventilation Period		02/01/2001	From PDD	Systems Engineering	Hastings		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 2, 5.1.3.1)
3	Heat removal efficiency for each ventilation period with time histories for heat removal efficiency if not constant values	Example: 70% Heat Removal for forced ventilation								
a.	Forced Ventilation Period		02/06/2001	05/31/2001	Subsurface/EBS	Krug, Sun		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	ANSYS Calculations in Support of Natural Ventilation Parametric Study for SR, CAL-SVS HV-000003 REV 00, MOL.20001117.0051. Table XVII-5, p. XVII-8 and Figure XVII-6, p. XVII-9.
b.	Natural Ventilation Period		02/06/2001	05/31/2001	Subsurface/EBS	Krug, Sun		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	ANSYS Calculations in Support of Natural Ventilation Parametric Study for SR, CAL-SVS HV-000003 REV 00, MOL.20001117.0051. Table XVII-5, p. XVII-8 and Figure XVII-6, p. XVII-9.
4	Water removal rate and temperature gradients along a typical drift, mass flow rates, and average relative humidity along a typical drift for both forced and natural ventilation periods	There is no coupling of ventilation with the moisture removal rate in current models	03/30/2001		Subsurface/EBS	Yang	Uses Multi-flux model. Calculations will take 2 weeks for forced ventilation and another 2 weeks for natural ventilation assuming an air flow rate is provided for natural ventilation (will use the same as Yiming Sun). Results include water removal rate, temperature gradients, and average relative humidity along the length of a typical drift (axial direction only). More definition is needed to understand what is needed to satisfy "mass flow rate" request. Work is currently outprioritized by Ventilation AMR completion scheduled to go into check by end of Feb.	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	No	
5	Waste Package spacing - variable spacing with a two meter average and average loading of 1 kW/m	The 1 kW/m may be too constraining - may go with 85°C thermal limit for waste package temperature instead; line load is whatever is necessary to maintain the 85°C thermal limit	PDD - 02/01/2001 WP - 02/06/2001	From PDD	Systems Engineering	Hastings		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 2, 5.2.10); Also see Item 3 provided by Waste Package, Section 2.1, Worksheet 4)
6	Number of waste packages in a typical drift		02/01/2001	05/31/2001	Subsurface Design	Linden		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 1)
7	Distance from the last waste package in the drift to the bulkhead	Unchanged	02/01/2001	05/31/2001	Subsurface Design	Linden		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 1)

8	Development of a typical drift or drift segment for use in 3-D drift-scale models	Example: 7-waste package model with proportional number of packages and waste package spacings relevant for the corresponding waste package quantities; Dunlap may have initial version already	02/08/2001	05/31/2001	Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 3, Section 2.2)
III	Repository Closure									
1	Time at repository closure	From PDD	02/01/2001		Systems Engineering	Hastings		Swift	Yes	Attached to Transmittal (Item 1, 5.1.1.1)
2	Specify backfilling and/or sealing of access drifts (ramps and mains),ventilation shafts, and turn-outs	No change	02/15/2001		Subsurface Design?	Saunders?		Swift	No	
3	Policy on sealing surface boreholes	No change?	02/15/2001		Subsurface Design?	?	Surface-based testing requirement?	Swift	No	
IV	Emplacement Drift Environment	Thermal & hydrologic properties, variability, and uncertainty								
1	Drift diameter	5.5 m	02/05/2001		Systems Engineering	Hastings		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 1, 5.2.5)
2	Ground support material specifications	No change	02/05/2001		Subsurface Design	Duan		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	(1) Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 REV 00, MOL.20000414.0875. Section 4.1.8 and Table 4-8, Section 4.1.10 and Table 4-10. (2) Longevity of Emplacement Drift Ground Support Materials, ANL-EBS-GE-000003 REV 01, MOL.20000414.0874. Section 6.2.3.
a.	thermal properties	No change	02/05/2001		Subsurface Design	Duan		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Same
	thermal conductivity	No change	02/05/2001		Subsurface Design	Duan		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Same
	specific heat	No change	02/05/2001		Subsurface Design	Duan		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Same
	density	No change	02/05/2001		Subsurface Design	Duan		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Same
	emissivity	No change	02/05/2001		Subsurface Design	Duan		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Same
b.	possible ranges in thermal properties	Example: Thermal conductivity k_m plus or minus *x*	TBD		Subsurface Design	Duan	Probably not available. Need to check source	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	No	
c.	anisotropy in thermal properties, if important	No change	TBD		Subsurface Design	Duan	Probably not available. Need to check source	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	No	
3	Invert height	Ensure invert elevation is the same on subsurface and waste package illustrations (i.e., for a "typical" drift, invert depth is 80.6 cm)	02/06/2001		Subsurface Design	Stanley (M. Taylor)		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	EMPLACEMENT DRIFT INVERT-LOW STEEL EVALUATION, TDR-EDS-ST-000002, REVISION 00. Page 20, Figure 1. MOL.20001011.0001.
4	Invert material thermal properties									
a.	thermal conductivity	[Dry: Nominal: 0.15 W/m°K; Range for Dry: 0.122 to 0.163 W/m°K]; [Wet: Nominal: 1.03 W/m°K; Range for Wet: 0.737 to 1.06 W/m°K]	02/06/2001		Subsurface Design	Hardin	Assumption: Crushed tuff for invert comes from lower lithophysal region of repository horizon	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Table XIV-3 and page XIV-12. MOL Pending. See Item 4 attached to transmittal.
b.	grain specific heat	948 J/kg °K	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-10. MOL Pending. See Item 4 attached to transmittal.
c.	grain density	2.53 gm/cm^3	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-2. MOL Pending.
d.	emissivity	0.83	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-10. MOL Pending. See Item 4 attached to transmittal.
e.	possible ranges in thermal properties		02/07/2001 (partial)		Subsurface Design	Hardin	To be provided initially for K_{sat}, porosity, and thermal conductivity	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 5)
f.	heterogeneity and/or anisotropy in thermal properties, if important		TBD		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift		
5	Invert material hydrologic properties for a separate "fracture" and "matrix" continuum representation (fracture and matrix representations of each)									
a.	saturated intrinsic permeability	Nominal: 6.0 x 10^{-5} cm^2; Range: 9.4 x 10^{-10} m^2 to 3.8 x 10^{-9} m^2; Saturated Hydraulic Conductivity range: 1.8 to 7.5 cm/s	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-7. MOL Pending. See Item 4 attached to transmittal.

b.	porosity	[Total Porosity: Nominal: 0.55; Range: 0.36 to 0.56]; [Intergranular porosity: nominal: 0.35; Range: 0.28 to 0.42] - Crushed tuff values may change in early March	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-5. MOL Pending. See Item 4 attached to transmittal.
c.	residual liquid saturation	0.05	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-6. MOL Pending. See Item 4 attached to transmittal.
d.	van Genuchten alpha	0.12 cm^{-1}	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-6. MOL Pending. See Item 4 attached to transmittal.
e.	van Genuchten n	2.75	02/06/2001		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Water Distribution and Removal Model, ANL-EBS-MD-000032 REV 01, Attachment XIV, Page XIV-6. MOL Pending. See Item 4 attached to transmittal.
f.	possible ranges in each of the hydrologic properties	Example: log intrinsic permeability log K plus or minus *x*	02/07/2001 (partial)		Subsurface Design	Hardin	To be provided initially for K_{sat}, porosity, and thermal conductivity	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 5)
g.	anisotropy in hydrologic properties, if important	No change	TBD		Subsurface Design	Hardin		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift		
h.	size distribution/grading of the fill material	Determine whether PA feedback through requirements to design is appropriate at this time	02/05/2001		Subsurface Design	Stanley (M. Taylor)	Crushed tuff balast uniform graded crushed to fine.	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	EMPLACEMENT DRIFT INVERT-LOW STEEL EVALUATION, TDR-EDS-ST-000002, REVISION 00. Page 33. MOL.20001011.0001.
6	Emplacement drift wall emissivity	No change	02/05/2001		Subsurface Design	Sun	Will probably need to get this from someone else. May want to check what Waste Package uses	Francis, Hardin	Yes	ANSYS Calculations in Support of Natural Ventilation Parametric Study for SR, CAL-SVS-HV-000003 REV 00, MOL.20001117.0051. Section 6.1.4, p. 31. This information was based on Incropera, F.P. and DeWitt, D.P. 1985. Fundamentals of Heat and Mass Transfer. New York, New York: John Wiley & Sons. TIC: 208420. p. 780.
7	Quantity/location of cement for rock bolts and rough estimated fraction of drift needing rock bolts in each hydrologic host unit	Look at any potential changes to the rock bolt spacing	02/05/2001		Subsurface Design	Tang		Bodvarsson, Francis, Hardin, MacKinnon, McNeish	Yes	(1) Longevity of Emplacement Drift Ground Support Materials, ANL-EBS-GE-000003 REV 01, MOL.20000414.0874. Sections 6.2.1, 6.2.3, and 6.4.1. (2) Committed Materials in Repository Drifts, CAL-GCS-GE-000002 REV 00A (in checking). See Item 6 attached to transmittal.
V	Engineered Barriers									
1	Drip shield geometry									
a.	for a mailbox type & stand-alone		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2001	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
	inside radius		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2002	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
	thickness		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2003	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
	height above invert		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2004	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
b.	if not mailbox type, provide all critical dimensions		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2005	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
c.	spacing/configuration for adjacent drip shields		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2006	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
d.	dimensions and thickness of plates		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2007	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
e.	Locations and thickness of reinforcing bars		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2008	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1)
f.	Dimensions, overlaps, and clearances between adjacent components (if any)		02/15/2001	03/30/2001	Waste Package Design	Anderson	Current Design: 02/01/2001; Stand-Alone Design: 2/15/2009	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes (partial)	Attached to Transmittal (Item 3, Section 3.1 and Figure 2)
g.	Time of drift shield emplacement	Ensure proper coupling of drip shield emplacement timing with assumed/ proposed drift maintenance schedule & costs	02/01/2001	From PDD	Systems Engineering for requirement, Subsurface for coupling with maintenance schedule	Hastings		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Drip shield emplacement at closure. See Item 1, 5.1.1.1
2	Drip shield thermal properties									
a.	thermal conductivity	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 3, Section 3.2)
b.	specific heat	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 3, Section 3.2)
c.	density	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 3, Section 3.2)
d.	emissivity	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 3, Section 3.2)
e.	possible ranges in thermal properties	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift	Yes	Attached to Transmittal (Item 3, Section 3.2)

3	Waste package geometry for each of the 5 main types of packages (21 PWR, 44 BWR, 5 HLW/DOE SNF, 2 MCO/2 HLW, Naval SNF									
a.	diameters (for different wastepackage types and for different layers)	No change	02/06/2001		Waste Package Design	Anderson	.	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift, Mon	Yes	Attached to Transmittal (Item 3, Section 3.3, Table 8)
b.	lengths	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift, Mon	Yes	Attached to Transmittal (Item 3, Section 3.3, Table 8)
c.	minimum gap between the bottom waste package surface and the top of the invert	No change	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift, Mon	Yes	Attached to Transmittal (Item 3, Section 3.3, Table 9 & Figure 1)
d.	Initial waste package internal surface area	No change	TBD		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift, Mon	No	
e.	Initial waste package void volume & porosity	No change	TBD		Waste Package Design	Anderson	PA to coordinate the content of the response	Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift, Mon	No	
f.	Impact of ventilation on buildup of dust and hygroscopic salts on WPs	No change - but depends on Pasu	TBD		Waste Package Materials	J. Lee?	May be Subsurface Design?	Hardin, MacKinnon	No	
g.	Emplacement drawings for these packages	No change	02/07/2001		Waste Package Design	Anderson	Ensure consistency between Waste Package Design and Subsurface Design illustrations	Francis, Hardin, MacKinnon, Mon	Yes	Attached to Transmittal (Item 3, Section 3.3)
	Separation between top of WP and underside of drip shield	Check w/Scott Bennett	TBD		Waste Package Design	Anderson	Ensure consistency between Waste Package Design and Subsurface Design illustrations	Francis, Hardin, MacKinnon, Mon	No	Need to check reference
	Separation between bottom of the waste package and the top of the invert		02/06/2001		Waste Package Design	Anderson	Ensure consistency between Waste Package Design and Subsurface Design illustrations	Francis, Hardin, MacKinnon, Mon	Yes	Attached to Transmittal (Item 3, Section 3.3, Table 9 & Figure 1)
	Uncertainty in separation between the waste package and the drip shield or invert	Early transmittal of existing information. Transmittal for stand-alone will take longer	TBD		Waste Package Design	Anderson	Ensure consistency between Waste Package Design and Subsurface Design illustrations	Francis, Hardin, MacKinnon, Mon	No	
	Clearance between the drip shield and the drift wall		TBD		Waste Package Design	Anderson	Ensure consistency between Waste Package Design and Subsurface Design illustrations	Francis, Hardin, MacKinnon, Mon	No	
4	Waste Package Thermal Properties (by component) - effective and bulk									
a.	thermal conductivity		02/06/2001		Waste Package Design	Anderson		Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 3.4, Tables 11, 13, & 14)
b.	specific heat		02/06/2001		Waste Package Design	Anderson		Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 3.4, Tables 11, 13, 14, & 15)
c.	density		02/06/2001		Waste Package Design	Anderson		Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 3.4, Tables 10, 12, & 14)
d.	emissivity		02/06/2001		Waste Package Design	Anderson		Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 3.4, Tables 10 & 12)
e.	possible ranges in thermal properties		02/06/2001		Waste Package Design	Anderson		Francis, Hardin	Yes (partial)	Attached to Transmittal (Item 3, Section 3.4, Tables 11, 13, & 16)
5	Emplacement Pallet material and dimensions	Not changing	02/06/2001		Waste Package Design	Anderson		Hardin, MacKinnon, Mon	Yes	Attached to Transmittal (Item 3, Section 3.5)
a.	Material, dimensions, and thicknesses of plates	Not changing	02/06/2001		Waste Package Design	Anderson		Hardin, MacKinnon, Mon	Yes	Attached to Transmittal (Item 3, Section 3.5)
b.	Material, locations, dimensions, and thicknesses of reinforcing bars	Not changing	02/06/2001		Waste Package Design	Anderson		Hardin, MacKinnon, Mon	Yes	Attached to Transmittal (Item 3, Section 3.5)
VI	Waste Form and Heat Output									
1	Heat decay curves in kW as a function of time for each (averaged) representative waste type - out to 1 million years	Needed for 21-PWR, 44-BWR, 5-DHLW, Naval SNF, etc.	02/06/2001		Waste Package Design	Anderson	Values used by PA have not been updated since VA	Bodvarsson, Francis, Hardin, MacKinnon, Rechard	Yes	Attached to Transmittal (Item 3, Section 4.1, Tables 16, 17, & 18)
2	Number of each type of waste package including all commercial and non-commercial packages	See Item I.f.	02/06/2001		Systems Engineering	Hastings		McKenzie, Ryman, Anderson		
3	Mass loading for each (averaged) representative waste type	No change (waste mass only)	02/06/2001		Waste Package Design	Anderson		Rechard	Yes	Attached to Transmittal (Item 3, Section 4.2, Table 19)
4	Representative lineal heat load time-history in kW/m out to 1 million years		02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 4.3, Table 20)
5	Overall repository-wide averaged heat decay curve in kW as a function of time		02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 4.4, Table 20)
6	Total waste mass including total for commercial and non-commercial waste		TBD		Waste Package Design	Anderson		Rechard, Mattie	No	
7	Waste Package Emplacement Strategy including schedule and where CSNF and DSNF will be located at emplacement	For a "typical" drift only. See Item II.8	02/06/2001		Waste Package Design	Anderson		Bodvarsson, Francis, Hardin, MacKinnon, McNeish, Sauer, Swift		
VII	Composition and Quantities of EBS Materials									
1	Specify the quantities and compositions of rock bolts and associated cementitious grout per unit length of drift	Request includes trace metal information, though none is available currently	02/05/2001		Subsurface Design	Tang	Supply major constituents only using currently available documentation	Hardin, MacKinnon	Yes	(1) Longevity of Emplacement Drift Ground Support Materials, ANL-EBS-GE-000003 REV 01, MOL.20000414.0874. Sections 6.2.1, 6.2.3, and 6.4.1. (2) Committed Materials in Repository Drifts, CAL-GCS-GE-000002 REV 00A (in checking). See Item 6 attached to transmittal.
2	Specify quantities (mass units) and elemental compositions of all non-host rock materials per unit length of drift	Example: rock bolts and grout, drip shields, waste package, pedestal, invert, rails, and other structural invert members	TBD		Subsurface Design	Tang	Needed for corrosion and microbial analyses. Document currently in check.	Hardin, MacKinnon	No	

3	Approximate values for trace metal concentrations (Pb, As, and Hg only) in the structural steels to be used in the EBS		Sometime in 2002		Subsurface Design	Saunders	As available	Hardin, MacKinnon	No	
4	Layout of shafts, stations, and other facilities that will be concrete lined, and where the concrete will remain after closure. Include concrete thickness, permeability at full cure, and type of aggregate (i.e., limestone, tuff, or other materials)	Need to include impacts to PC facilities resulting from low temperature operational mode	Sometime in 2002		Subsurface Design	Linden	Per Ernie Hardin, not needed at this time. Concrete leaching model will not be included in AMRs at this time.	Hardin, MacKinnon	No	
VIII	Mechanical response of EBS elements to postclosure ground motion and fault displacement									
1	10^{-6} Annual frequency ground motion spectrum and 10^{-6} fault displacement	Needed for design to comply with input request	02/21/2001		Risk Engineering	Quittmeyer	Need early start of $45K on Risk Engineering contract to facilitate extending seismic hazard calculations to lower annual frequencies	Anderson, Duan, Kicker	No	
2	Structural response of the drip shield to the 10^{-6} annual frequency ground motion spectrum and 10^{-6} fault displacement	Near term qualitative evaluation only - drip shield will lose function	TBD		Waste Package Design	Anderson	To work with Kevin Mon to develop qualitative reasonable response by end of February	Sauer, Swift, Mon	No	
a.	Provide structural response in as-emplaced condition		TBD		Waste Package Design	Anderson	To work with Kevin Mon to develop qualitative reasonable response by end of February	Sauer, Swift, Mon	No	
b.	Provide structural response in the corroded state	Use "best judgment" to provide reasonable qualitative evaluation of failure probability as a function of time. Drip shield will lose function.	TBD		Waste Package Design	Anderson	To work with Kevin Mon to develop qualitative reasonable response by end of February	Sauer, Swift, Mon	No	
3	Postclosure rockfall (using 10^{-6} annual frequency ground motion spectrum), specifically the block sizes versus frequency of occurrence for various strata	Extend/extrapolate Fei Duan's analysis	03/15/2001		Subsurface Design	Kicker	3 to 4 week turn-around once peak acceleration and velocity received. May initiate analysis without input. Ground motion spectra not available for 10^{-6} until FY02.	Sauer, Swift, Anderson, Bennett	No	
4	Time dependent structural response of the drip shield to rockfalls	Near term qualitative evaluation only - drip shield will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
a.	Permanent deflection of the drip shield due to rockfall	Near term qualitative evaluation only - drip shield will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
b.	Incidence of stress corrosion cracking due to rockfall	Near term qualitative evaluation only - drip shield will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
c.	Unceraintv range in permanent deflection and number of stress corrosion cracks	Near term qualitative evaluation only - drip shield will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
d.	Provide structural response in both as-emplaced and corroded states	Near term qualitative evaluation only - drip shield will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
5	Structural response of the emplacement pallet to the 10^{-6} annual frequency ground motion spectrum and 10^{-6} fault displacement	Near term qualitative evaluation only - pallet will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
a.	Provide structural response in as-emplaced state	Near term qualitative evaluation only - pallet will lose function	TBD		Waste Package Design	Anderson		Sauer, Swift, Mon	No	
b.	Provide structural response in a corroded state; lifetime function indicating pallet failure over time	Failure probability as a function of time - pallet function expected to fail under this magnitude of event.	03/15/2001		Waste Package Design	Anderson	Provide a time history for the emplacement pallet. Indicate whether corrosion is the same as for waste packages (This part is independent of seismic events). State in the transmittal what happens to the emplacement pallet when it fails.	Sauer, Swift, Mon	No	
6	Structural response of the waste package to the 10^{-6} annual frequency ground motion spectrum and 10^{-6} fault displacement		04/20/2001		Waste Package Design	Anderson	To work with Kevin Mon to develop qualitative reasonable response by end of February	Sauer, Swift, Mon	No	
a.	Provide structural response in as-emplaced state		04/20/2001		Waste Package Design	Anderson	To work with Kevin Mon to develop qualitative reasonable response by end of February	Sauer, Swift, Mon	No	
b.	Provide structural response in a corroded state	Failure probability as a function of time	04/20/2001		Waste Package Design	Anderson	To work with Kevin Mon to develop qualitative reasonable response by end of February	Sauer, Swift, Mon	No	
7	Drift displacement due to floor heave									
a.	Displacement of the floor of the drift under *ambient conditions, thermal loading, and* seismic effects	fault displacement or normal stress relief	02/08/2001		Subsurface Design	Duan		Sauer, Swift	Yes	Ground Control for Emplacement Drifts for SR, ANL-EBS-GE-000002 REV 00, MOL.20000414.0875. Figures 6-15a and 6-15b for in-situ and thermal loads and Section 6.5.1.3 for seismic load.
b.	Uncertainty range for the displacement of the floor of the drift	rise in meter of drift per meter of drift length	TBD		Subsurface Design	Duan	Take the preclosure number and provide a qualitative analysis for extrapolating/extending the number for postclosure	Sauer, Swift	No	

IX	Thermal Response of Drip Shield	Geometric changes of elements to each other and effects over time								
1	Physical dimensions of the drip shield, particularly clearances between adjacent segments of drip shield	See Item V.1	02/15/2001	03/30/2001	Waste Package Design	Anderson		Francis, Hardin	Yes (partial)	See Item V.1
2	Maximum temperature of the drip shield for various waste package types, waste package spacings, and ventilation histories		02/07/2001		Waste Package Design	Anderson	Will likely just use WP temperatures.	Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 6.2)
3	Thermal expansion coefficient of Titanium or the drip shield material	No change	02/06/2001		Waste Package Design	Anderson		Francis, Hardin	Yes	Attached to Transmittal (Item 3, Section 6.3)
4	Uncertainties in maximum temperature and thermal expansion coefficients		TBD		Waste Package Design	Anderson	May need to extract this from the code.	Francis, Hardin	No	
X	Mechanical Response of the Emplacement Pallet									
1	Physical dimensions of the emplacement pallet	Already covered in V.5								
2	Structural response of emplacement pallet and waste package design to 10^{-6} ground motion event	Combined into Item VIII								
XI	Properties of corroded waste package materials									
1	Porosity and permeability of in-package corrosion products		02/16/2001		Waste Package Materials	J. Lee	Will need to make an assumption.	MacKinnon, Rechard	No	
2	Porosity and permeability of ex-package corrosion products for Titanium		TBD		Waste Package Materials	J. Lee		MacKinnon, Rechard	No	
3	Adsorption isotherm for Tc, I, Pu, and Np in the in-package corrosion products		TBD		Waste Package Materials	Stockman	Los Alamos Kd work? Point to AMR? Should be same as #4	MacKinnon, Rechard	No	
4	Adsorption isotherm for TC, I, Pu, and Np in the ex-package corrosion products		TBD		Subsurface/EBS	Hardin?	Point to AMR?	MacKinnon, Rechard	No	
5	Porosity and permeability of corrosion products, particularly in stress corrosion products		TBD		Waste Package Materials	Stockman	Point to AMR?	MacKinnon, Rechard	No	
6	Potential for chemical processes, such as calcite precipitation, to plug a crack in the waste package		TBD		Waste Package Materials	J. Lee	Point to AMR?	MacKinnon, Rechard	No	
7	Uncertainty estimates for the above transport properties		TBD		Waste Package Materials	Stockman	Point to AMR?	MacKinnon, Rechard	No	
8	Thickness of corrosion products on the Alloy-22 surface as a function of time or as a function of general corrosion extent		TBD		Waste Package Materials	J. Lee	Point to AMR?	MacKinnon, Rechard	No	

Item 1

Repository Footprint and Plane Coordinates

Christine Linden
01/29/2001 08:09 AM

To: Bo Bodvarsson/YM/RWDOE@CRWMS, Al Eddebbarh/YM/RWDOE@CRWMS
cc: Mark Sellers/YM/RWDOE@CRWMS, Alan Krug/YM/RWDOE@CRWMS, Robert Saunders/YM/RWDOE@CRWMS

Subject: Transmittal Information for Performance Assessment

QA:N/A Exclusionary

Find attached the electronic file that contains the information required for the Performance Assessment transmittal. This electronic file includes the footprint information requested in Item I, the emplacement drift coordinates, drift orientation, etc. Let me know if anything is missing.

Transmittal of Input to PA.d

Christine
5-4988

I. REPOSITORY FOOTPRINT AND PLANE COORDINATES

This footprint, plane coordinates, and elevation information is preliminary and will be placed in a controlled source, a design analysis, which is scheduled for approval in May 2001.

The 70,000 MTHM layout for the cooler repository design is based on a linear thermal density of 1.0 kW/m and results in an average end-to-end waste package spacing of 2.1 meters.

Figure 1 illustrates the preliminary layout for accommodating 70,000 MTHM of waste. This layout is preliminary in nature, and although the emplacement drifts are not anticipated to change, the location and gradients of the access mains and ancillary openings may change. The 70,000 MTHM layout for the cooler repository design will require 91 excavated emplacement drifts spaced at 81 meters from center-to-center. The emplacement drifts will be excavated with an orientation of 252°. Emplacement Drifts 1 through 85 are required for emplacement of the nominal waste package inventory (11,184 waste packages). In addition, Emplacement Drifts 86 through 91 are also required to allow emplacement of the nominal waste package quantities plus 5 percent (11,734 waste packages).

If the waste emplacement encompasses all 91 emplacement drifts, the loaded repository will occupy approximately 1,675 acres, and will result in an areal mass loading of approximately 38 MTHM/acre. If the waste emplacement encompasses only 85 emplacement drifts, the loaded repository will only occupy approximately 1,600 acres, and will result in an areal mass loading of approximately 40 MTHM/acre.

The emplacement area for the layouts is bounded by a set of coordinates that represent the theoretically last emplaced waste package in the drift. The last emplaced waste package in the emplacement drift is assumed to be 1.5 meters from the start of the emplacement drift (i.e., the distance from the last waste package in the drift to the bulkhead). The elevation is that of the drift centerline, on the bottom of the invert. Table 1 lists the boundary coordinates for the emplacement area. Please note that the first drift listed in Table 1 is a performance confirmation postclosure test drift and is not included in the count of emplacement drifts. The input contained in Table 1 defines the boundary coordinates for the emplacement area for the cooler repository design.

In an average 600 meter long emplacement drift split, approximately 83 waste packages can be accommodated. This calculation is based on an average waste package length of 5.037 meters and an average waste package spacing of 2.1 meters.

The excavation percentages of the potential repository in each of the geologic units are 6.5 % in the tptpmn, 73.3% in the tptpll, and 20.1% in the tptpln.

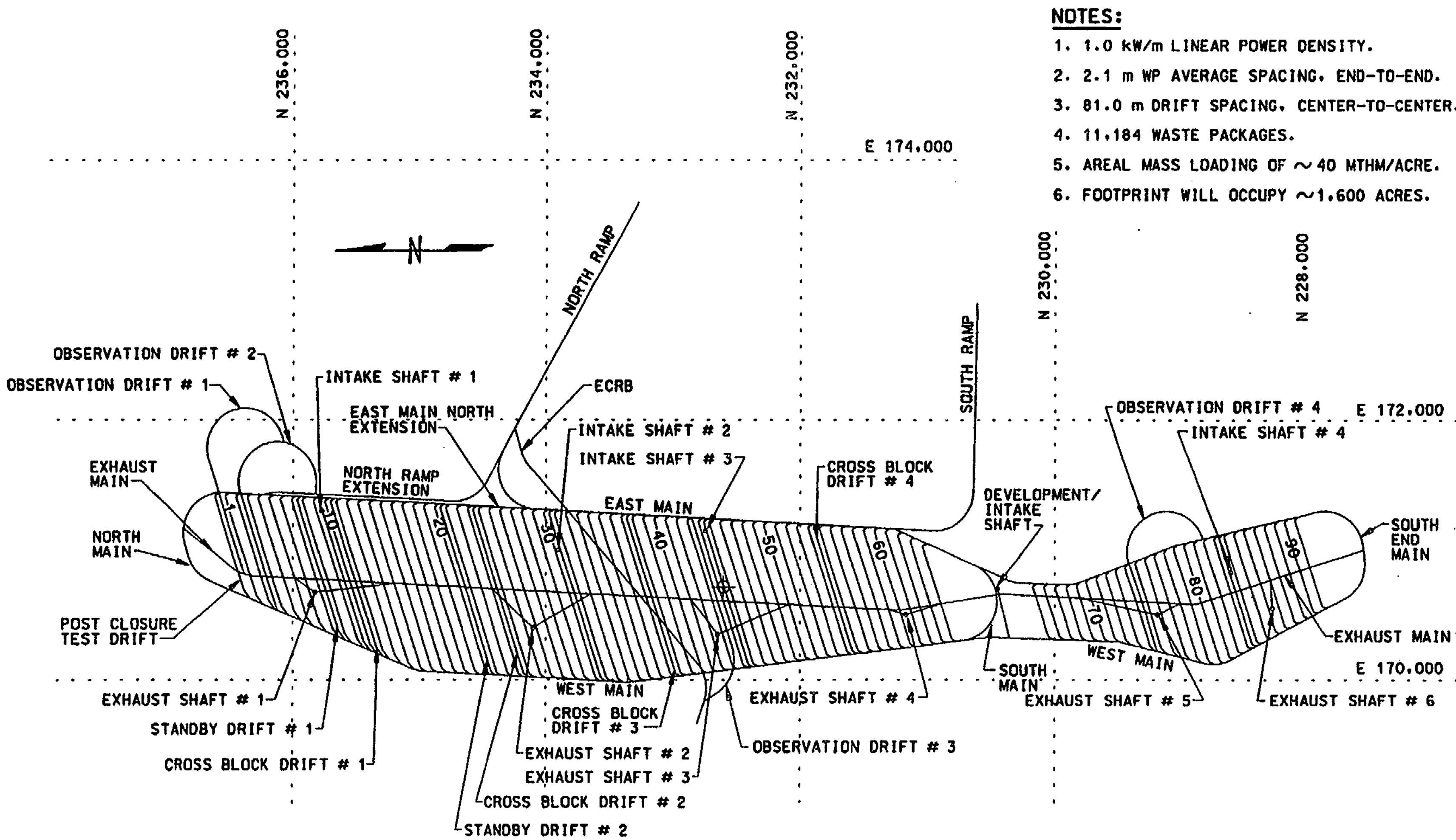

Figure 1. Preliminary 70,000 MTHM Layout for the Cooler Repository Design Concept

Table 1. Bounding Coordinates for the Emplacement Area

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
PC1	236,606.073	171,378.875	1,032.437	236,391.550	170,718.641	1,032.437
1	236,521.040	171,379.292	1,033.659	236,292.756	170,676.706	1,033.659
2	236,434.396	171,374.751	1,034.831	236,193.962	170,634.770	1,034.831
3	236,347.752	171,370.210	1,036.002	236,095.168	170,592.834	1,036.002
4	236,261.109	171,365.669	1,037.173	235,996.374	170,550.899	1,037.173
5	236,174.465	171,361.129	1,038.345	235,897.579	170,508.963	1,038.345
6	236,087.821	171,356.588	1,039.516	235,798.785	170,467.027	1,039.516
7	236,001.177	171,352.047	1,040.687	235,699.991	170,425.092	1,040.687
8	235,914.533	171,347.506	1,041.858	235,601.197	170,383.156	1,041.858
9	235,827.889	171,342.965	1,043.030	235,502.403	170,341.221	1,043.030
10	235,741.245	171,338.424	1,044.201	235,403.608	170,299.285	1,044.201
11	235,654.601	171,333.884	1,045.372	235,304.814	170,257.349	1,045.372
12	235,567.957	171,329.343	1,046.544	235,206.020	170,215.414	1,046.544
13	235,481.314	171,324.802	1,047.715	235,102.137	170,157.816	1,047.715
14	235,394.670	171,320.261	1,048.886	235,005.154	170,121.454	1,048.886
15	235,308.026	171,315.720	1,050.058	234,918.510	170,116.913	1,050.058
16	235,221.382	171,311.180	1,051.229	234,831.866	170,112.372	1,051.229
17	235,134.738	171,306.639	1,052.400	234,745.222	170,107.831	1,052.400
18	235,048.094	171,302.098	1,053.571	234,658.578	170,103.290	1,053.571
19	234,961.450	171,297.557	1,054.743	234,571.935	170,098.749	1,054.743
20	234,874.806	171,293.016	1,055.914	234,485.291	170,094.209	1,055.914
21	234,788.163	171,288.475	1,057.085	234,398.647	170,089.668	1,057.085
22	234,701.519	171,283.935	1,058.257	234,312.003	170,085.127	1,058.257
23	234,614.875	171,279.394	1,059.428	234,225.359	170,080.586	1,059.428
24	234,528.231	171,274.853	1,060.599	234,138.715	170,076.045	1,060.599
25	234,441.587	171,270.312	1,061.770	234,052.071	170,071.505	1,061.770
26	234,354.943	171,265.771	1,062.942	233,965.427	170,066.964	1,062.942
27	234,268.299	171,261.231	1,064.113	233,878.784	170,062.423	1,064.113
28	234,181.655	171,256.690	1,065.284	233,792.140	170,057.882	1,065.284
29	234,095.012	171,252.149	1,066.456	233,705.496	170,053.341	1,066.456
30	234,008.368	171,247.608	1,067.627	233,618.852	170,048.801	1,067.627
31	233,921.724	171,243.067	1,068.798	233,532.208	170,044.260	1,068.798

Table 1. Bounding Coordinates for the Emplacement Area (Continued)

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
32	233,835.080	171,238.527	1,069.969	233,445.564	170,039.719	1,069.969
33	233,748.436	171,233.986	1,071.141	233,358.817	170,034.860	1,071.141
34	233,661.792	171,229.445	1,072.312	233,276.916	170,044.916	1,072.312
35	233,575.148	171,224.904	1,073.483	233,195.015	170,054.972	1,073.483
36	233,488.504	171,220.363	1,074.655	233,113.114	170,065.029	1,074.655
37	233,401.861	171,215.822	1,075.826	233,031.213	170,075.085	1,075.826
38	233,315.217	171,211.282	1,076.997	232,949.312	170,085.141	1,076.997
39	233,228.573	171,206.741	1,078.169	232,867.411	170,095.197	1,078.169
40	233,141.929	171,202.200	1,079.340	232,785.510	170,105.253	1,079.340
41	233,055.285	171,197.659	1,080.511	232,703.609	170,115.309	1,080.511
42	232,968.641	171,193.118	1,081.682	232,621.708	170,125.366	1,081.682
43	232,881.997	171,188.578	1,082.854	232,539.807	170,135.422	1,082.854
44	232,795.353	171,184.037	1,084.025	232,457.906	170,145.478	1,084.025
45	232,708.710	171,179.496	1,085.196	232,376.005	170,155.534	1,085.196
46	232,622.066	171,174.955	1,086.368	232,294.104	170,165.590	1,086.368
47	232,535.422	171,170.414	1,087.539	232,212.203	170,175.647	1,087.539
48	232,448.778	171,165.874	1,088.710	232,130.301	170,185.703	1,088.710
49	232,362.134	171,161.333	1,089.881	232,048.400	170,195.759	1,089.881
50	232,275.490	171,156.792	1,091.053	231,966.499	170,205.815	1,091.053
51	232,188.846	171,152.251	1,092.224	231,884.598	170,215.871	1,092.224
52	232,102.202	171,147.710	1,093.395	231,802.697	170,225.927	1,093.395
53	232,015.558	171,143.169	1,094.567	231,720.796	170,235.984	1,094.567
54	231,928.915	171,138.629	1,095.738	231,638.895	170,246.040	1,095.738
55	231,842.271	171,134.088	1,096.909	231,556.994	170,256.096	1,096.909
56	231,755.627	171,129.547	1,098.081	231,475.093	170,266.152	1,098.081
57	231,668.983	171,125.006	1,099.252	231,393.192	170,276.208	1,099.252
58	231,582.339	171,120.465	1,100.423	231,311.291	170,286.265	1,100.423
59	231,495.695	171,115.925	1,101.594	231,229.390	170,296.321	1,101.594
60	231,409.051	171,111.384	1,102.766	231,147.489	170,306.377	1,102.766
61	231,322.407	171,106.843	1,103.937	231,065.588	170,316.433	1,103.937

Table 1. Bounding Coordinates for the Emplacement Area (Continued)

Drift Number	East Side of Emplacement Drift			West Side of Emplacement Drift		
	Northing (m)	Easting (m)	Elevation (m)	Northing (m)	Easting (m)	Elevation (m)
62	231,228.794	171,080.845	1,105.126	230,983.689	170,326.489	1,105.126
63	231,129.221	171,036.512	1,106.128	230,901.788	170,336.545	1,106.128
64	231,029.648	170,992.179	1,107.130	230,819.887	170,346.601	1,107.130
65	230,161.806	170,680.331	1,112.032	230,059.664	170,365.970	1,112.032
66	230,075.660	170,677.322	1,112.463	229,973.518	170,362.962	1,112.463
67	229,989.514	170,674.314	1,112.894	229,887.373	170,359.954	1,112.894
68	229,903.957	170,673.116	1,113.279	229,801.227	170,356.946	1,113.279
69	229,823.182	170,686.637	1,113.667	229,715.081	170,353.937	1,113.667
70	229,746.888	170,713.951	1,114.115	229,628.935	170,350.929	1,114.115
71	229,671.164	170,743.018	1,114.549	229,543.716	170,350.774	1,114.549
72	229,595.440	170,772.086	1,115.001	229,454.670	170,338.840	1,115.001
73	229,519.716	170,801.154	1,115.479	229,361.994	170,315.734	1,115.479
74	229,443.993	170,830.221	1,115.957	229,269.318	170,292.627	1,115.957
75	229,368.269	170,859.289	1,116.434	229,176.641	170,269.520	1,116.434
76	229,292.545	170,888.357	1,116.912	229,083.965	170,246.413	1,116.912
77	229,216.821	170,917.424	1,117.389	228,991.289	170,223.306	1,117.389
78	229,141.098	170,946.492	1,117.275	228,898.612	170,200.200	1,117.275
79	229,065.285	170,975.285	1,116.251	228,804.965	170,174.104	1,116.251
80	228,986.633	170,995.342	1,115.190	228,721.372	170,178.952	1,115.190
81	228,907.407	171,013.632	1,114.059	228,646.270	170,209.934	1,114.059
82	228,828.182	171,031.923	1,112.851	228,573.648	170,248.548	1,112.851
83	228,748.957	171,050.214	1,111.535	228,501.026	170,287.162	1,111.535
84	228,669.731	171,068.504	1,110.219	228,428.404	170,325.776	1,110.219
85	228,590.506	171,086.795	1,108.903	228,355.782	170,364.389	1,108.903
86	228,511.280	171,105.085	1,107.587	228,283.160	170,403.003	1,107.587
87	228,432.055	171,123.376	1,106.271	228,210.538	170,441.617	1,106.271
88	228,352.829	171,141.667	1,104.955	228,137.916	170,480.231	1,104.955
89	228,273.604	171,159.957	1,103.663	228,065.294	170,518.845	1,103.663
90	228,194.378	171,178.248	1,102.370	227,992.672	170,557.459	1,102.370
91	228,115.153	171,196.539	1,101.078	227,920.050	170,596.072	1,101.078

Item 2

MGR Project Description Document – Low Temperature Requirements Redline of Section 5, Technical Requirements

5. TECHNICAL REQUIREMENTS

The elements of the technical requirements in Sections 5.1, 5.2, 5.3, and 5.4 are established to implement the current repository design concept as described in Section 2. These requirements, criteria, and constraints~~, and goals~~ are considered part of the technical baseline and, in addition to the items shown in Table 1-1, address the technical requirements in the MGR RD (YMP 2000a). In conjunction with those requirements, these things compose the engineering design basis for the detailed design process as captured in the SDDs. All requirements, criteria, and constraints below, that are not referenced to another document, will be treated as management edicts once this document is baselined and, consequently, are not referenced to other management directives. Any technical requirement in this section that cites an unqualified, unconfirmed, or uncontrolled reference is not considered "to be verified" (TBV) for the purposes of the design process. The cited document is TBV with regard to its content; however, the requirements criterion or constraint resolves this TBV status for design purposes. Each technical requirement element is allocated to one or more architectural elements, and an allocation arrangement is shown in Section 5.5.

The requirements, criteria, and constraints~~, and goals~~ in this section are assigned unique paragraph numbers for ease of reference.

5.1 DESIGN PERFORMANCE

The requirements and criteria below reflect the current design strategy. ~~The performance goals in Section 5.1.5 represent those design attributes that the current design effort is not required to achieve. These goals may be achieved through further refinements of the design, if so directed.~~

5.1.1 Performance Requirements

5.1.1.1 ~~The MGR design shall allow the repository to be closed as early as 30 years after emplacement of the last WP contingent upon meeting the remainder of the thermal requirements, and be kept open, with routine maintenance, for at least 100 years after the first WP emplacement.~~ The MGR design ~~shall include provisions that support a deferral of closure for up to~~allow closure of the repository 300 years from ~~initiation of~~final waste emplacement~~, with appropriate monitoring and maintenance~~ (YMP 2000a, 3.2.H; and Stroupe 2000).

5.1.1.2 The MGR design under preclosure and postclosure normal operating conditions shall maintain the zirconium-alloy cladding of the CSNF at temperatures that will preserve and not accelerate the degradation of the performance of the cladding as received at the repository (DOE 2000b, 3.4F).

5.1.1.3 Uncertainty in the postclosure effects of elevated rock temperatures on the near field environment shall be mitigated in accordance with the CRD (DOE 2000b, 3.4.E). Following closure, the repository shall avoid long-term accumulation of water in the rock above the emplacement drifts by controlling the rock temperatures so that there is free drainage between the emplacement drifts (YMP 2000a, 3.2.M, 3.2.N; DOE 2000b, 3.4.E).

5.1.1.4 The MGR shall limit the change in temperature of the soil near the surface above the repository in accordance with the MGR RD (YMP 2000a, 3.2.F).

5.1.1.5 The MGR shall have the capability to retrieve all emplaced WPs in accordance with the MGR RD (YMP 2000a, 3.2.J).

5.1.1.6 The expected annual dose to the average member of the critical group shall be in accordance with the MGR RD (YMP 2000a, 3.2.P).

5.1.1.7 The MGR shall only accept for disposal, SNF or HLW that is not subject to regulation as hazardous waste in accordance with the CRD (DOE 2000b, 3.2.1.D).

5.1.2 Regulatory Requirements

The "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada" (Dyer 1999) is the controlling regulatory requirement for the MGR. The MGR shall comply with this guidance in accordance with the MGR RD (YMP 2000a, 3.1.C). An allocation of the regulatory requirements contained within this guidance is correlated to the MGR Level 5 systems that support SR as shown in Table 5-8. A comprehensive allocation of this guidance and additional regulatory requirements will be provided in a later revision of this document.

5.1.2.1 The MGR shall comply with the applicable provisions of the Nuclear Waste Policy Act of 1982 in accordance with the CRD (DOE 2000b, 3.1.1.A).

5.1.2.2 The MGR shall comply with the applicable provisions of 10 CFR 20, "Standards for Protection Against Radiation," in accordance with the CRD (DOE 2000b, 3.1.1.B).

5.1.2.3 The MGR shall comply with the applicable provisions of 10 CFR 73, "Physical Protection of Plants and Materials," in accordance with the CRD (DOE 2000b, 3.1.1.G).

5.1.2.4 The MGR shall comply with the applicable provisions of 29 CFR 1910, "Occupational Safety and Health Standards," in accordance with the CRD (DOE 2000b, 3.1.1.I).

5.1.2.5 The MGR shall comply with the applicable provisions of 29 CFR 1926, "Safety and Health Regulations for Construction," in accordance with the MGR RD (YMP 2000a, 3.1.F).

5.1.2.6 The MGR shall comply with laws, statutes, U.S. Code, treaties, Codes of Federal Regulations, Executive Orders, NUREGs, state and local codes and regulations, DOE Orders, and other directives identified through analysis, as identified in the MGR RD (YMP 2000a, 3.1.G).

5.1.2.7 The MGR shall comply with the applicable provisions of 10 CFR 75, "Safeguards on Nuclear Materials-Implementation of U.S./IAEA Agreement," in accordance with the CRD (DOE 2000b, 3.1.1.J).

5.1.3 Performance Criteria

5.1.3.1 ~~At least 70 percent of the total heat generated by the WPs within the emplacement drifts during the first 50 years of the preclosure period shall be removed by ventilation (Wilkins and Heath 1999, Enclosure 2, A-12.0). In combination with other criteria and constraints, this will ensure that the majority of the pillar space between the emplacement drifts will remain below the boiling temperature of water at the repository altitude, following repository closure (Stroupe 2000).~~ The ventilation period shall begin upon emplacement of the first waste package and end 300 years after emplacement of the last waste package. Forced ventilation shall be used during the period from initial waste emplacement until 50 years after last emplacement. Natural ventilation shall be used for the remaining 250 years.

5.1.3.2 Two annual hazard frequencies of exceedance shall be considered for seismic events during the preclosure period: one occurrence per 1,000 years (Frequency Category 1) and one occurrence per 10,000 years (Frequency Category 2) (taken from Dyer 1999, Section 2). There are also two design input earthquakes, one referred to as the 1 to 2 Hz earthquake, and the other referred to as the 5 to 10 Hz earthquake. Vibratory ground motions corresponding to both earthquakes for both categories shall be considered in the design of SSCs. Additional seismic design criteria will be provided in future revisions of this document.

5.1.3.3 All subsurface portions of the Waste Isolation System within the perimeter drifts on the emplacement level shall be situated in accordance with the MGR RD (YMP 2000a, 3.3.C).

5.1.3.4 The MGR surface facilities shall be capable of accommodating a range of storage and transportation technologies in accordance with the CRD (DOE 2000b, 3.2.1.E).

5.1.3.5 The MGR facilities shall be capable of opening sealed storage/transportable commercial canisters, handling SNF, and managing site-generated waste in accordance with the CRD (DOE 2000b, 3.2.1.F).

5.1.3.6 The MGR shall maintain the separation of site-generated wastes in accordance with the CRD (DOE 2000b, 3.2.2.A).

5.1.3.7 Site-generated hazardous, low-level radioactive, and mixed waste shall be transported to government-approved off-site facilities for disposal in accordance with the CRD (DOE 2000b, 3.2.2.B).

5.1.3.8 Physical barriers to human intrusion shall be provided in accordance with the MGR RD (YMP 2000a, 3.3.M).

5.1.4 Interface Criteria

5.1.4.1 The MGR shall accommodate up to 70,000 MTHM or equivalent, including 63,000 MTHM of CSNF, 640 MTHM of commercial HLW, 4,027 MTHM of

DHLW, and 2,333 MTHM of DOE SNF (which includes 65 MTHM of Naval SNF) in the primary area of the first repository (YMP 2000a, 3.2.A).

5.1.4.2 The MGR shall not preclude the capability (by adding additional components and features) of accommodating a full inventory, including 83,800 MTHM of CSNF, 2,500 MTHM of DOE SNF (which includes 65 MTHM of Naval SNF), 10,923 MTHM of DHLW, and 640 MTHM of commercial HLW (DOE 2000c).

The MGR shall also not preclude the capability of accommodating the maximum inventory analyzed in the Environmental Impact Statement (EIS) (as described in Section 2.3).

5.1.4.3 The MGR shall be capable of receiving, packaging, emplacing, and isolating commercial SNF ~~and HLW~~ that arrives via rail, heavy-haul vehicle, and legal-weight truck, in accordance with the MGR RD (YMP 2000a, 3.3.H), accommodating any of the CSNF annual arrival scenarios depicted in Tables 5-1, 5-2, and 5-3 (YMP 2000a, 3.2.C).

There are three annual arrival scenarios for the CSNF each with a nominal 3,000 MTHM/year maximum receipt rate. These three scenarios span a broad range of potential arrival possibilities with Scenario 1 (see Table 5-1) assuming a maximum number of truck casks arriving, Scenario 2 (see Table 5-2) assuming a maximum number of single-purpose canister (SPC) rail casks arriving, and Scenario 3 (see Table 5-3) assuming a maximum number of dual-purpose canister (DPC) rail casks arriving each year (CRWMS M&O 2000d, Tables 6, 7, and 8).

Table 5-1. Scenario 1 - Annual CSNF Arrival Assuming Maximum Truck Casks

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Truck	4	16	64	12	48	28	112	32
2010	SPC Rail	24	27	648	20	480	47	1,128	324
	DPC Rail	38	3	114	2	76	5	190	53
	Total		46	826	34	604	80	1,430	409
	Truck	4	25	100	18	72	43	172	49
2011	SPC Rail	24	40	960	30	720	70	1,680	483
	DPC Rail	38	4	152	3	114	7	266	77
	Total		69	1,212	51	906	120	2,118	609
	Truck	4	49	196	37	148	86	344	99
2012	SPC Rail	24	79	1,896	60	1,440	139	3,336	963
	DPC Rail	38	9	342	6	228	15	570	160
	Total		137	2,434	103	1,816	240	4,250	1,221
	Truck	4	80	320	60	240	140	560	161
2013	SPC Rail	24	130	3,120	98	2,352	228	5,472	1,576
	DPC Rail	38	14	532	11	418	25	950	276
	Total		224	3,972	169	3,010	393	6,982	2,013
2014	Truck	4	131	524	99	396	230	920	265
To	SPC Rail	24	215	5,160	162	3,888	377	9,048	2,606
2022	DPC Rail	38	23	874	17	646	40	1,520	436

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Total		369	6,558	278	4,930	647	11,488	3,307
2023	Truck	4	51	204	39	156	90	360	104
To	SPC Rail	24	185	4,440	139	3,336	324	7,776	2,238
2033	DPC Rail	38	50	1,900	38	1,444	88	3,344	965
	Total		286	6,544	216	4,936	502	11,480	3,307

Table 5-1. Scenario 1 - Annual CSNF Arrival Assuming Maximum Truck Casks (Continued)

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
2034	Truck	4	23	92	17	68	40	160	46
To	SPC Rail	24	47	1,128	35	840	82	1,968	565
2041	DPC Rail	38	141	5,358	106	4,028	247	9,386	2,702
	Total		211	6,578	158	4,936	369	11,514	3,313

[1] Average values were used to facilitate the computer modeling for the throughput studies.

Table 5-2. Scenario 2 - Annual CSNF Arrival Assuming Maximum SPC Rail Casks

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Truck	4	12	48	9	36	21	84	24
2010	SPC Rail	24	27	648	20	480	47	1,128	324
	DPC Rail	38	3	114	2	76	5	190	53
	Total		42	810	31	592	73	1,402	401
	Truck	4	18	72	14	56	32	128	37
2011	SPC Rail	24	41	984	31	744	72	1,728	498
	DPC Rail	38	5	190	4	152	9	342	100
	Total		64	1,246	49	952	113	2,198	635
	Truck	4	36	144	27	108	63	252	73
2012	SPC Rail	24	80	1,920	60	1,440	140	3,360	967
	DPC Rail	38	9	342	7	266	16	608	176
	Total		125	2,406	94	1,814	219	4,220	1,216
	Truck	4	58	232	44	176	102	408	118
2013	SPC Rail	24	132	3,168	99	2,376	231	5,544	1,595
	DPC Rail	38	16	608	12	456	28	1,064	306
	Total		206	4,008	155	3,008	361	7,016	2,019
2014	Truck	4	96	384	72	288	168	672	193
To	SPC Rail	24	217	5,208	163	3,912	380	9,120	2,625
2022	DPC Rail	38	26	988	19	722	45	1,710	489
	Total		339	6,580	254	4,922	593	11,502	3,308
2023	Truck	4	18	72	14	56	32	128	37
To	SPC Rail	24	205	4,920	155	3,720	360	8,640	2,490
2033	DPC Rail	38	41	1,558	31	1,178	72	2,736	789
	Total		264	6,550	200	4,954	464	11,504	3,316
2034	Truck	4	3	12	2	8	5	20	6
To	SPC Rail	24	80	1,920	60	1,440	140	3,360	967
2041	DPC Rail	38	122	4,636	92	3,496	214	8,132	2,343
	Total		205	6,568	154	4,944	359	11,512	3,315

[1] Average values were used to facilitate the computer modeling for the throughput studies.

Table 5-3. Scenario 3 - Annual CSNF Arrival Assuming Maximum DPC Rail Casks

Year	Cask Type	Average[1] Assemblies Per Cask	BWR		PWR		Total		
			Casks	Assembly	Cask	Assembly	Cask	Assembly	MTHM
	Truck	4	3	12	2	8	5	20	6
2010	SPC Rail	24	28	672	21	504	49	1,176	338
	DPC Rail	38	4	152	3	114	7	266	77
	Total		35	836	26	626	61	1,462	421
	Truck	4	5	20	3	12	8	32	9
2011	SPC Rail	24	42	1,008	32	768	74	1,776	513
	DPC Rail	38	5	190	4	152	9	342	100
	Total		52	1,218	39	932	91	2,150	621
	Truck	4	9	36	7	28	16	64	19
2012	SPC Rail	24	83	1,992	63	1,512	146	3,504	1,011
	DPC Rail	38	11	418	8	304	19	722	206
	Total		103	2,446	78	1,844	181	4,290	1,236
	Truck	4	15	60	11	44	26	104	30
2013	SPC Rail	24	136	3,264	103	2,472	239	5,736	1,654
	DPC Rail	38	17	646	13	494	30	1,140	329
	Total		168	3,970	127	3,010	295	6,980	2,013
2014	Truck	4	24	96	18	72	42	168	48
To	SPC Rail	24	224	5,376	169	4,056	393	9,432	2,717
2022	DPC Rail	38	29	1,102	22	836	51	1,938	559
	Total		277	6,574	209	4,964	486	11,538	3,325
2023	Truck	4	45	180	34	136	79	316	91
To	SPC Rail	24	166	3,984	125	3,000	291	6,984	2,011
2033	DPC Rail	38	63	2,394	47	1,786	110	4,180	1,201
	Total		274	6,558	206	4,922	480	11,480	3,304
2034	Truck	4	77	308	58	232	135	540	156
To	SPC Rail	24	26	624	19	456	45	1,080	309
2041	DPC Rail	38	148	5,624	112	4,256	260	9,880	2,848
	Total		251	6,556	189	4,944	440	11,500	3,313

[1] Average values were used to facilitate the computer modeling for the throughput studies.

5.1.4.4 The MGR shall ~~accommodate~~be capable of receiving, packaging, emplacing, and isolating the DOE SNF, Naval SNF, IPWF, and HLW per the annual arrival scenario depicted in Table 5-4, in accordance with the MGR RD (YMP 2000a, 3.2.C and 3.4.2.P; CRWMS M&O 2000d, Table 11; and Mowbray 2000).

Table 5-4. Annual Cask Receipt Rate of DOE SNF and HLW

Year	DOE SNF Note 1		Naval SNF		DOE HLW Note 2		Immobilized Plutonium Note 2		Total	
	Casks	Cans.	Casks	Cans.	Casks	Cans.	Casks	Cans	Casks	Cans.
2010	3	15	3	3	33	165	12	60	49	241
2011	6	30	3	3	48	240	12	60	67	331
2012	13	65	6	6	83	415	12	60	111	543
2013	16	80	6	6	98	490	12	60	132	636
2014	19	95	12	12	113	565	12	60	152	728
2015 Until end of receipt	30	150	15 Note 3	15 Note 3	168	840	12	60	224	1064

Notes: 1. Assumes five canisters are shipped in each cask, which represents a 50 to 60 percent efficiency for the casks that can hold nine canisters.
2. Assumes five canisters are shipped in each cask.
3. Derived from the equal distribution of remaining Naval casks/canisters over the remaining emplacement period.

5.1.4.5 The MGR shall be capable of receiving and emplacing commercial PWR SNF assemblies and commercial BWR SNF assemblies in accordance with the MGR RD (YMP 2000a, 3.2.D).

5.1.4.6 The MGR shall be capable of receiving, handling, and emplacing CSNF and DOE SNF, commercial HLW, or DHLW in accordance with the MGR RD (YMP 2000a, 3.2.E).

5.1.4.7 Interfaces shall be documented in accordance with the MGR RD (YMP 2000a, 3.4).

5.1.4.8 The MGR shall interface with external agencies in accordance with the CRD (DOE 2000b, 3.6.2).

5.1.4.9 MGR roads, railways, queuing points, and the site layout shall be compatible in accordance with the CRD (DOE 2000b, 3.6.5.1.A).

5.1.4.10 MGR equipment shall be compatible with transportation equipment in accordance with the MGR RD (YMP 2000a, 3.4.2.B).

5.1.4.11 The MGR operations and facility design shall be consistent with canister containment and internal structure designs in accordance with the MGR RD (YMP 2000a, 3.4.2.C).

5.1.4.12 The MGR shall accommodate waste forms that require remedial processing in accordance with the MGR RD (YMP 2000a, 3.4.2.D).

5.1.4.13 The MGR shall accommodate radiological surveys and security inspections in accordance with the MGR RD (YMP 2000a, 3.4.2.E).

5.1.4.14 The MGR shall address safeguards in accordance with the MGR RD (YMP 2000a, 3.4.2.F).

5.1.4.15 The MGR shall accommodate the visual inspection and testing of transportation casks in accordance with the MGR RD (YMP 2000a, 3.4.2.G).

5.1.4.16 The MGR shall accommodate decontamination of transportation casks in accordance with the MGR RD (YMP 2000a, 3.4.2.H).

5.1.4.17 The MGR and the Waste Acceptance and Transportation interface shall be in accordance with the CRD (DOE 2000b, 3.6.5.1.E).

5.1.4.18 The MGR and the Waste Acceptance and Transportation communications equipment shall be designed to be compatible in accordance with the CRD (DOE 2000b, 3.6.5.1.F).

5.1.4.19 The MGR and the Waste Acceptance and Transportation and MGR information systems shall be designed in accordance with the CRD (DOE 2000b, 3.6.5.1.G).

5.1.4.20 The MGR shall accommodate incidental transportation cask maintenance in accordance with the CRD (DOE 2000b, 3.6.5.1.H).

5.1.4.21 The Waste Acceptance and Transportation and the MGR technical, planning, and operational information exchange shall be designed in accordance with the CRD (DOE 2000b, 3.6.5.1.I).

5.1.4.22 DOE SNF shall be packaged in accordance with the MGR RD (YMP 2000a, 3.4.2.N).

5.1.4.23 The MGR shall not be required to condition DOE SNF, in accordance with the MGR RD (YMP 2000a, 3.4.2.O).

5.1.4.24 Assumptions developed during the design of the MGR shall be in accordance with the CRD (DOE 2000b, 3.6.5).

5.1.5 <u>RESERVED.</u>

5.1.6 Industry Codes and Standards

All MGR SSCs shall be designed and fabricated in accordance with the CRD (DOE 2000b, 3.2.3).

5.2 DESIGN CONSTRAINTS

5.2.1 The nominal emplacement drift spacing shall be 81 m, drift center to center. In combination with other criteria and constraints, this will ensure that the majority of the pillar space between the emplacement drifts will remain below the boiling temperature of water at the repository altitude following repository closure.

5.2.2 RESERVED.

5.2.3 The MGR shall be capable of accommodating the emplacement of 70,000 MTHM of the WP inventory with the size and heat output up to that shown in Table 5-5 (CRWMS M&O 2000e and CRWMS M&O 2000l).

Table 5-5. Design Basis WP Inventory

Content of WP	WP Length (m)	Average Heat Output/Package (kW)	Nominal Quantity*	Maximum Quantity**
21 PWR AP	5.17	11.330	4299	4500
21 PWR CR	5.17	3.260	95	100
12 PWR AP Long	5.65	8.970	163	170
44 BWR AP	5.17	7.000	2831	3000
24 BWR AP	5.11	0.540	84	90
5 IPWF	3.59	2.450	95	100
5 DHLW Short/1 DOE SNF Short	3.59	2.575	1052	1100
5 DHLW Long/1 DOE SNF Long	5.22	2.575	1406	1500
2 MCO/2 DHLW	5.22	1.230	149	160
5 HLW Long/1 DOE SNF Short	5.22	2.575	126	130
HLW Long Only	5.22	2.450	584	600
Naval Short	5.43	3.100	200	200
Naval Long	6.07	3.100	100	100

* Nominal quantities represent those used to specify the 70,000 MTHM (or equivalent) described in 5.1.4.1.

** These quantities are rounded up to two significant figures from the values in the cited reference, and represent "not to exceed" values for each WP category. It is recognized that if the total quantity of each type of WP were emplaced, the repository would exceed the 70,000 MTHM (or equivalent) described in 5.1.4.1. This constraint applies to the capability of the subsurface emplacement, and is not intended to conflict with, or violate, any other design requirement, criterion, or constraint. ~~Naval WP categories are excluded from the rounding up.~~ Naval WP categories are excluded from the rounding up.

NOTE: See Acronyms and Abbreviations for acronym definitions.

5.2.4 The MGR shall not preclude the capability of accommodating the emplacement of the WP inventory with the size and heat output up to that shown in Table 5-6 (CRWMS M&O 2000e).

Table 5-6. WP Inventory for Maximum Subsurface Emplacement

Content of WP	WP Length (m)	Average Heat Output/Package (kW)	Quantity*
21 PWR AP	5.17	11.330	5700
21 PWR CR	5.17	3.260	110
12 PWR AP Long	5.65	8.970	300
44 BWR AP	5.17	7.000	3750
24 BWR AP	5.11	0.540	100
5 IPWF	3.59	2.450	130
5 DHLW Short/1 DOE SNF Short	3.59	2.575	1410
5 DHLW Long/1 DOE SNF Long	5.22	2.575	1880
2 MCO/2 DHLW	5.22	1.230	200
5 HLW Long/1 DOE SNF Short	5.22	2.575	170
HLW Long Only	5.22	2.450	800
Naval Short	5.43	3.100	200
Naval Long	6.07	3.100	100

* These quantities, which are rounded up to two significant figures from the values in the cited reference, represent "not to exceed" values for each WP category. It is recognized that if the total quantity of each type of WP were emplaced, the repository would exceed the inventory described in 5.1.4.2. This constraint applies to the capability of the subsurface emplacement, and is not intended to conflict with, or violate, any other design requirement, criterion, or constraint.

NOTE: See Acronyms and Abbreviations for acronym definitions.

5.2.5 The excavated emplacement drift diameter shall be nominally 5.5 m. This diameter provides adequate space to accommodate the largest WP, the associated handling and emplacement equipment, the ground support, and drip shield installation.

5.2.6 The ground support in the repository emplacement drift shall be carbon steel (e.g., steel sets and/or rock bolts and mesh) with cementitious grout allowed, where necessary, to anchor the rock bolts.

5.2.7 With periodic maintenance, if necessary, the emplacement drift ground support shall keep the emplacement drift open and stable for the entire preclosure period. This ensures a pathway for emplacement drift ventilation and allowance of remote controlled equipment and/or human access for off-normal conditions.

5.2.8 The invert along the bottom of drifts shall be constructed of a carbon steel frame with granular natural material used as ballast.

5.2.9 The MGR design shall not preclude the option of physically installing the emplacement drift backfill during the repository closure phase, in accordance with the MGR RD (YMP 2000a, 3.3.I).

5.2.10 The emplacement drifts shall be ~~line-~~loaded with WPs ~~spaced with a minimum distance of 10 cm~~separated by a minimum of 0.1 m between the ends of adjacent WPs. (In this context, the "ends" of the WPs include any skirts or other structures that extend beyond the lid of the WP.) The ~~maximum~~ nominal linear heat load shall be 1.0~~5~~ kW/m, averaged over a fully loaded emplacement drift at the time of completion of loading an entire emplacement drift.

5.2.11 A free-standing drip shield, fabricated from Titanium, Grade 7 with a minimum thickness of 15 mm, shall be installed, at the time of repository closure, above, but not in contact with the WP.

5.2.12 Each disposal container shall be a two-layer device consisting of an inner structural barrier of nominally 50-mm thick nuclear grade 316 stainless steel and an outer barrier of nominally 20-mm thick alloy 22 material. This constraint is intended only to address the corrosion environment. The design must also address other functions such as structural (handling) and seismic conditions, and, if needed, consider additional thickness.

5.2.13 Individual WPs shall have a maximum heat output of 11.8 kW at the time of emplacement. In combination with other criteria and constraints, this will ensure that the conditions of the zirconium-alloy cladding of the CSNF will not be impaired.

5.2.14 The surface facilities shall accommodate a blending inventory of up to 5,000 MTHM.

5.2.15 Transportation requirements and architecture shall not be maintained for post-retrieval waste transport capability, in accordance with the MGR RD (YMP 2000a, 3.2.K).

5.2.16 A preclosure controlled area boundary shall be established in accordance with the MGR RD (YMP 2000a, 3.3.J).

5.2.17 The MGR design shall provide communication and control capabilities in accordance with the MGR RD (YMP 2000a, 3.3.K).

5.2.18 The MGR surface facilities shall be capable of accommodating WPs that need to be recovered from the emplacement drifts in accordance with the MGR RD (YMP 2000a, 3.3.L).

5.2.19 The repository and WP designs shall not preclude the addition of filler material in accordance with the MGR RD (YMP 2000a, 3.3.N).

5.2.20 Solar electrical power generation shall supplement the site electrical systems in accordance with the CRD (DOE 2000b, 3.4.D) and the MGR RD (YMP 2000a, 3.3.Q).

5.2.21 Liquid waste generated from pool water that contacts SNF or HLW will be processed in the Waste Handling Building for shipment to the off-site waste disposal facility addressed in Section 5.1.3.7.

5.2.22 The MGR shall provide parking facilities for 15 legal-weight trucks, 5 heavy-haul vehicles, and 140 rail cars all loaded with transportation casks containing nuclear materials.

5.2.23 WP design will provide sufficient shielding to protect the WP materials (in the as-emplaced condition) from radiation enhanced corrosion.

5.2.24 The repository design shall ensure that the surface temperature of the emplacement drift wall, at any position or time, does not exceed 96°C under normal operating conditions ~~maximum emplacement drift wall temperature, at any position or any time, will not exceed~~or 200°C under abnormal conditions (Frey 2000).

5.2.25 The Engineered Barrier System within the emplacement drift shall be designed to be compatible with a relative humidity of 95 percent (Frey 2000).

5.2.26 The Engineered Barrier System within the emplacement drift shall be designed to accommodate seepages into the emplacement drifts as a function of infiltration rates of 4.6 mm/yr during the period from the present to the year 2600; 12.2 mm/yr during the period from the years 2600 to 3000; and 17.8 mm/yr during the period from the years 3000 to 12,000 (CRWMS M&O 2000q, p. ix).

5.2.27 The emplacement drift system shall be designed to accommodate the drainage volume of liquid phase water from the emplacement drifts based on seepages as a function of infiltration rates of 4.6 mm/yr during the period from the present to the year 2600; 12.2 mm/yr during the period from the years 2600 to 3000; and 17.8 mm/yr during the period from the years 3000 to 12,000 (CRWMS M&O 2000q, p. ix).

5.2.28 The Engineered Barrier System within the emplacement drift shall be designed to accommodate seepage water into the emplacement drifts within the pH range of 7-11 (bounded by CRWMS M&O 2000q, p. xi; CRWMS M&O 2000r, ~~p.~~ Section 7.72~~34~~).

5.2.29 The design and operation of the MGR shall limit the temperature of the zeolite layers located beneath the emplacement area horizon to less than 90°C (Bish and Aronson 1993).

5.2.30 ~~5.2.30~~The design and operation of the MGR shall limit the temperature at the base of the PTn hydrogeologic/thermal/mechanical units to less than 70°C (derived from the midpoint in the range in Levy and O'Neil 1989).

5.2.31 Under normal oerating conditions, the temperature at any point on the surface of any WP shall not exceed 85°C unless the relative humidity in the immediate vicinity of the WP is less than 50%.

5.2.32 The MGR design and operation shall result in an Areal Mass Loading of between 25 and 85 MTHM/acre.

5.2.33 Facilities for surface aging shall accommodate up to 40,000 MTHM of commercial SNF that is within 30 years of its out-of-reactor date.

5.3 OPERATING CRITERIA

5.3.1 Operation of systems and components that have been identified as important to safety in the Safety Analysis Report and in the license shall be performed only by trained and certified personnel or by personnel under the direct visual supervision of an individual with training and certification in such operation. Supervisory personnel who direct operations that are important to safety shall also be certified in such operations (Dyer 1999, Subpart H, Section 151).

5.3.2 The repository system (in combination with appropriate shielding and ventilation) shall allow limited-time personnel access, in consideration of workers' radiation protection, into the emplacement drifts, only for the purpose of evaluating and remediating operational upset conditions after initiation of waste emplacement.

5.3.3 For all workers entering radiological control areas of the Surface Facilities, the average Total Effective Dose Equivalent shall be less than 250 mrem/yr and the maximum annual dose to any individual worker shall be less than 500 mrem/yr (DOE 1994, Article 128.1).

5.3.4 Any MGR system or process with an expected exposure to an individual exceeding 250 mrem/yr or an expected collective exposure exceeding 1 person-rem/yr Total Effective Dose Equivalent, shall receive a formal assessment in accordance with the ALARA program (10 CFR 20.1101(b)).

5.3.5 Any MGR system or process where the dose to an individual member of the public is expected to exceed 10 mrem/yr Total Effective Dose Equivalent from air emissions, shall receive a formal assessment in accordance with the ALARA program (10 CFR 20.1101(b)).

5.4 RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND INSPECTION CRITERIA

~~This section is to be completed in a subsequent revision.~~

5.5 ALLOCATION OF TECHNICAL REQUIREMENTS

Table 5-7 provides the primary allocation of the PDD technical requirements for the MGR design. This allocation is to the fourth level of the MGR Architecture as described in Section 4.1. This allocation identifies the architecture that is assigned the primary responsibility for meeting each PDD technical requirement. Additional applications and/or traces to the PDD technical requirements are also allowed, as necessary, to successfully complete the MGR design.

Table 5-7. Allocation of PDD Technical Requirements for MGR Design

MGR PDD Technical Requirement Number	Fifth Level MGR Architecture*
5.1.1.1	BES, SED, PCA, ERS, SEP, SOS, HBE, WPR, WES, OMC, PCM, VDC, NDC, SFP, UDC, CDC, DDC, EDC, SVS, DCH, EDS, MSL, ADS, GCS, SWS, GST
5.1.1.2	UDC, DCH, WES, ADS, SVS
5.1.1.3	EDS, ADS, SVS
5.1.1.4	EDS, VDC, SFS
5.1.1.5	WES, MSL, DCH
5.1.1.6	EDS, BES
5.1.1.7	No fifth level architecture element allocated to this technical requirement
5.1.2	PCM, DCH, BES, SED, TVS, EDC, MSL, PCA, SSG, TBS, CCT, HBV, PLS, DDC, VDC, NDC, CTS, SFR, HBF, HBS, UDC, CMH, CCH, WPR, CDC, SFS, CBS, SVS, SCS, GCS, ATS, SES, EDS, WES, SRW, HBE, OMC, ERS
5.1.2.1	No fifth level architecture element allocated to this technical requirement
5.1.2.2	OMC, TVS, HBV, TBS, CBS, SFS, BES, DCH, WPR, CMH, PCM, CCH, CCT, ATS, CTS, VDC, DDC, UDC, CDC, EDC, NDC, SFR, WPR, PCA, MSL, SRW, SVS, PLS, HBS, HBF, HBE, WES, ERS
5.1.2.3	SED, SEP, OMC, VDC, CDC, DDC, UDC, EDC, MSL, SSG, CMH, CCH, CCT, ATS, CTS, WPR, WES, TBS, CBS, HBS
5.1.2.4	SEP, SED, SVS, BES, PLS, CTS, SFR, OMC, SFP, SRW, HBF, HBV, HBE, CCT, DCH, WPR, PCA, MSL, SFS, PCM, SES, ATS, CCH, TBS, CBS, CMH, HBS, TVS, WES, SOS, SWS, ERS
5.1.2.5	SVS, SES, SED, SCS, DCH, HBF, SEP, PCA, SFP, CBS, HBV, PLS, SFS, TBS, MSL, GCS, BES, HBS, SFR, TVS, SSG, WES, CTS, ATS, SRW, SWS
5.1.2.6	ERS, SED, SCS, HBS, MSL, EDC, UDC, EDS, SWS, PCA, SSG, CDC, TBS, HBE, VDC, NDC, DDC, ATS, TBS, SOS, CCT, SEP, SVS, HBF, CTS, SES, SRW, PLS, PCM, DCH, WPR, OMC, BES, CMH, WES, SFR, CCH, HBV, SFP, GST, TVS
5.1.2.7	No fifth level architecture element allocated to this technical requirement
5.1.3.1	SFS, SVS, SET, GCS, EDS
5.1.3.2	GCS, CBS, CMH, HBS, ATS, DCH, CCH, CTS, TBS, SFS, SET, SDT, WPR, WES
5.1.3.3	SFS, EDS
5.1.3.4	CCH, CMH, CCT, CTS, ATS
5.1.3.5	SRW, TBS, HBS
5.1.3.6	SRW
5.1.3.7	TBS, WPR, PLS, SRW, DCH
5.1.3.8	SSG, MSL
5.1.4.1	CDC, NDC, SFS, DDC, EDS, EDC, ATS, SOS, UDC, VDC
5.1.4.2	EDS, NDC, SFS, DDC
5.1.4.3	SRW, DCH, SEP, MSL, WES, CCH, ATS, HBF, SFP, CTS, WPR, CCT, HBS, CBS, TBS, TVS, HBV, EDS, SED, CMH, OMC, HBE, SOS, SES, PLS
5.1.4.4	MSL, SRW, DCH, SEP, WES, CCH, ATS, HBF, SFP, CTS, WPR, CCT, HBS, CBS, TBS, TVS, HBV, EDS, SED, CMH, OMC, HBE, SOS, SES, PLS
5.1.4.5	ATS, DCH
5.1.4.6	MSL, HBS, CCT, CMH, WES, SOS, CTS, ATS, DCH, CCH
5.1.4.7	No fifth level architecture element allocated to this technical requirement
5.1.4.8	ERS, SOS
5.1.4.9	MSL, CTS, CCT
5.1.4.10	CCH, CTS, CCT, MSL, ATS, CMH

MGR PDD Technical Requirement Number	Fifth Level MGR Architecture*
5.1.4.11	CDC, DDC, CMH, CCT, WPR, CCH, VDC, UDC, EDC, CBS, NDC, WES
5.1.4.12	CTS, ATS, SRW
5.1.4.13	CCT, CMH
5.1.4.14	CCT, CMH, CCH
5.1.4.15	CCT, CMH
5.1.4.16	CMH, CTS, ATS
5.1.4.17	SOS
5.1.4.18	No fifth level architecture element allocated to this technical requirement
5.1.4.19	SOS
5.1.4.20	No fifth level architecture element allocated to this technical requirement
5.1.4.21	SOS
5.1.4.22	No fifth level architecture element allocated to this technical requirement
5.1.4.23	No fifth level architecture element allocated to this technical requirement
5.1.4.24	No fifth level architecture element allocated to this technical requirement
5.1.6	PLS, ERS, GCS, PCM, SEP, SWS, ATS, SFS, CMH, DCH, CTS, CCT, HBE, PCA, HBV, TVS, OMC, HBS, BES, EDS, MSL, CCH, SOS, SES, HBF, SFP, WES, SSG, SED, UDC, VDC, DDC, SVS, TBS, WPR, CBS, SRW, GST, CDC, NDC, EDC
5.2.1	SFS, EDS
5.2.3	SFS, EDS, SVS, WES, MSL
5.2.4	SFS, EDS, SVS, WES, MSL
5.2.5	SFS, EDS, SES, GCS
5.2.6	SFS, EDS, GCS, SES
5.2.7	SFS, GCS
5.2.8	SFS, EDS
5.2.9	BES, EDS, GCS
5.2.10	SFS, EDS, SET, WES
5.2.11	SFS, EDS
5.2.12	SFS, EDS, UDC, CDC, VDC, DDC, EDC, NDC, WPR
5.2.13	UDC, DCH, WES, ADS, SVS, EDS, WPR, CDC, DDC, EDC, NDC, VDC
5.2.14	HBS
5.2.15	No fifth level architecture element allocated to this technical requirement
5.2.16	MSL
5.2.17	ERS, SEP, OMC, VDC, UDC, DDC, EDC, CCT, CMH, DCH, WPR, SOS, CTS, ATS, SRW, CCH, SSG, WES, NDC, CDC
5.2.18	WPR, DCH
5.2.19	UDC
5.2.20	SEP
5.2.21	PLS
5.2.22	GST, MSL
5.2.23	UDC, CDC, VDC, EDC, DDC
5.2.24	EDS, SVS, DCH, ADS
5.2.25	EDS, GCS, UDC, CDC, VDC, EDC, DDC, NDC, SFS
5.2.26	EDS, SWC, UDC, CDC, VDC, EDC, DDC, NDC, SFS.

MGR PDD Technical Requirement Number	Fifth Level MGR Architecture*
5.2.27	EDS, SWS, SFS
5.2.28	EDS, UDC, CDC, VDC, EDC, DDC, NDC, SFS
5.2.29	EDS, SFS
5.2.30	EDS, SFS
5.3.1	ADS, SOS
5.3.2	SFS, SVS, ADS, EDS
5.3.3	CBS, HBS, TBS, ADS, SOS, HSS, SRM
5.3.4	CBS, HBS, TBS, ADS, SOS, HSS, SRM
5.3.5	CBS, HBS, TBS, ADS, SOS, HSS, SRM

* These MGR architecture designators are defined in Figures 4-1 through 4-4.

Table 5-8 provides the primary allocation of the regulatory requirements from the "Revised Interim Guidance Pending Issuance of New U.S. Nuclear Regulatory Commission (NRC) Regulations (Revision 01, July 22, 1999), for Yucca Mountain, Nevada" (Dyer 1999) for the SR design. This allocation is to the fifth level of the MGR Architecture as described in Section 4.1. This allocation identifies the architecture that is assigned the primary responsibility for meeting each regulatory requirement.

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design

Regulatory Requirement	Fifth Level MGR Architecture
63.21(c)(17)	Assembly Transfer System
63.78	Assembly Transfer System
63.111(a)(1)	Assembly Transfer System
63.111(a)(2)	Assembly Transfer System
63.111(b)(2)	Assembly Transfer System
63.112(e)(2)	Assembly Transfer System
63.112(e)(6)	Assembly Transfer System
63.112(e)(8)	Assembly Transfer System
63.112(e)(10)	Assembly Transfer System
63.112(e)(13)	Assembly Transfer System
63.113(b)	Assembly Transfer System
63.21(c)(17)	Backfill Emplacement System
63.111(a)(1)	Backfill Emplacement System
63.111(a)(2)	Backfill Emplacement System
63.111(b)(2)	Backfill Emplacement System
63.112(e)(8)	Backfill Emplacement System
63.112(e)(13)	Backfill Emplacement System
63.21(c)(17)	Canister Transfer System
63.78	Canister Transfer System
63.111(a)(1)	Canister Transfer System
63.111(a)(2)	Canister Transfer System
63.111(b)(2)	Canister Transfer System
63.112(e)(2)	Canister Transfer System
63.112(e)(6)	Canister Transfer System
63.112(e)(8)	Canister Transfer System

Regulatory Requirement	Fifth Level MGR Architecture
63.112(e)(10)	Canister Transfer System
63.112(e)(13)	Canister Transfer System
63.21(c)(17)	Carrier Preparation Building Materials Handling System
63.78	Carrier Preparation Building Materials Handling System
63.111(a)(1)	Carrier Preparation Building Materials Handling System
63.112(e)(10)	Carrier Preparation Building Materials Handling System
63.112(e)(13)	Carrier Preparation Building Materials Handling System
63.21(c)(17)	Carrier/Cask Handling System
63.78	Carrier/Cask Handling System
63.111(a)(1)	Carrier/Cask Handling System
63.112(e)(8)	Carrier/Cask Handling System
63.112(e)(10)	Carrier/Cask Handling System
63.112(e)(13)	Carrier/Cask Handling System
63.78	DHLW Disposal Container
63.111(a)(2)	DHLW Disposal Container
63.111(b)(2)	DHLW Disposal Container
63.111(e)(1)	DHLW Disposal Container

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

63.112(e)(2)	DHLW Disposal Container
63.112(e)(6)	DHLW Disposal Container
63.112(e)(8)	DHLW Disposal Container
63.113(a)	DHLW Disposal Container
63.113(b)	DHLW Disposal Container
63.21(c)(17)	Disposal Container Handling System
63.78	Disposal Container Handling System
63.111(a)(1)	Disposal Container Handling System
63.111(a)(2)	Disposal Container Handling System
63.111(b)(1)	Disposal Container Handling System
63.111(b)(2)	Disposal Container Handling System
63.111(d)	Disposal Container Handling System
63.112(e)(6)	Disposal Container Handling System
63.112(e)(8)	Disposal Container Handling System
63.112(e)(13)	Disposal Container Handling System
63.113(b)	Disposal Container Handling System
63.131(b)	Disposal Container Handling System
63.134(d)	Disposal Container Handling System
63.111(e)(1)	Emplacement Drift System
63.113(a)	Emplacement Drift System
63.113(b)	Emplacement Drift System
63.111(a)(2)	Ground Control System
63.111(b)(2)	Ground Control System
63.111(d)	Ground Control System
63.111(e)(1)	Ground Control System
63.112(e)(8)	Ground Control System
63.113(b)	Ground Control System
63.132(a)	Ground Control System
63.132(e)	Ground Control System

Regulatory Requirement	Fifth Level MGR Architecture
63.111(a)(1)	Monitored Geologic Repository Operations Monitoring and Control System
63.111(a)(2)	Monitored Geologic Repository Operations Monitoring and Control System
63.111(b)(2)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(7)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(8)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(10)	Monitored Geologic Repository Operations Monitoring and Control System
63.112(e)(13)	Monitored Geologic Repository Operations Monitoring and Control System
63.131(b)	Monitored Geologic Repository Operations Monitoring and Control System
63.132(a)	Monitored Geologic Repository Operations Monitoring and Control System
63.132(e)	Monitored Geologic Repository Operations Monitoring and Control System
63.134(d)	Monitored Geologic Repository Operations Monitoring and Control System
63.78	Naval Spent Nuclear Fuel Disposal Container
63.111(a)(2)	Naval Spent Nuclear Fuel Disposal Container
63.111(b)(2)	Naval Spent Nuclear Fuel Disposal Container
63.111(e)(1)	Naval Spent Nuclear Fuel Disposal Container
63.111(e)(2)	Naval Spent Nuclear Fuel Disposal Container
63.112(e)(2)	Naval Spent Nuclear Fuel Disposal Container
63.112(e)(6)	Naval Spent Nuclear Fuel Disposal Container
63.112(e)(8)	Naval Spent Nuclear Fuel Disposal Container

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

63.113(a)	Naval Spent Nuclear Fuel Disposal Container
63.113(b)	Naval Spent Nuclear Fuel Disposal Container
63.21(c)(17)	Pool Water Treatment and Cooling System
63.111(a)(1)	Pool Water Treatment and Cooling System
63.112(e)(2)	Pool Water Treatment and Cooling System
63.112(e)(3)	Pool Water Treatment and Cooling System
63.112(e)(8)	Pool Water Treatment and Cooling System
63.112(e)(13)	Pool Water Treatment and Cooling System
63.21(c)(17)	Site-Generated Radiological Waste Handling System
63.111(a)(1)	Site-Generated Radiological Waste Handling System
63.111(b)(1)	Site-Generated Radiological Waste Handling System
63.112(e)(2)	Site-Generated Radiological Waste Handling System
63.112(e)(13)	Site-Generated Radiological Waste Handling System
63.111(d)	Subsurface Facility System
63.113(a)	Subsurface Facility System
63.113(b)	Subsurface Facility System
63.131(a)(1)	Subsurface Facility System
63.131(a)(2)	Subsurface Facility System
63.131(c)	Subsurface Facility System
63.132(b)	Subsurface Facility System
63.132(e)	Subsurface Facility System
63.133(a)	Subsurface Facility System
63.133(c)	Subsurface Facility System
63.133(d)	Subsurface Facility System
63.134(a)	Subsurface Facility System
63.134(b)	Subsurface Facility System
63.111(a)(1)	Subsurface Ventilation System

Regulatory Requirement	Fifth Level MGR Architecture
63.111(e)(2)	Subsurface Ventilation System
63.112(e)(3)	Subsurface Ventilation System
63.112(e)(5)	Subsurface Ventilation System
63.78	Uncanistered SNF Disposal Container
63.111(a)(2)	Uncanistered SNF Disposal Container
63.111(b)(2)	Uncanistered SNF Disposal Container
63.111(e)(1)	Uncanistered SNF Disposal Container
63.112(e)(2)	Uncanistered SNF Disposal Container
63.112(e)(6)	Uncanistered SNF Disposal Container
63.112(e)(8)	Uncanistered SNF Disposal Container
63.113(a)	Uncanistered SNF Disposal Container
63.113(b)	Uncanistered SNF Disposal Container
63.78	Waste Emplacement/Retrieval System
63.111(a)(1)	Waste Emplacement/Retrieval System
63.111(a)(2)	Waste Emplacement/Retrieval System
63.111(b)(2)	Waste Emplacement/Retrieval System
63.111(d)	Waste Emplacement/Retrieval System
63.111(e)(1)	Waste Emplacement/Retrieval System
63.111(e)(3)	Waste Emplacement/Retrieval System
63.112(e)(1)	Waste Emplacement/Retrieval System
63.112(e)(8)	Waste Emplacement/Retrieval System
63.112(e)(10)	Waste Emplacement/Retrieval System

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

63.112(e)(13)	Waste Emplacement/Retrieval System
63.131(b)	Waste Emplacement/Retrieval System
63.131(d)(3)	Waste Emplacement/Retrieval System
63.134(d)	Waste Emplacement/Retrieval System
63.111(a)(1)	Waste Handling Building Electrical System
63.112(e)(2)	Waste Handling Building Electrical System
63.112(e)(3)	Waste Handling Building Electrical System
63.112(e)(8)	Waste Handling Building Electrical System
63.112(e)(11)	Waste Handling Building Electrical System
63.112(e)(12)	Waste Handling Building Electrical System
63.112(e)(13)	Waste Handling Building Electrical System
63.21(c)(17)	Waste Handling Building System
63.111(a)(1)	Waste Handling Building System
63.111(a)(2)	Waste Handling Building System
63.111(b)(2)	Waste Handling Building System
63.112(e)(1)	Waste Handling Building System
63.112(e)(2)	Waste Handling Building System
63.112(e)(3)	Waste Handling Building System
63.112(e)(4)	Waste Handling Building System
63.112(e)(5)	Waste Handling Building System
63.112(e)(8)	Waste Handling Building System
63.112(e)(10)	Waste Handling Building System
63.112(e)(13)	Waste Handling Building System
63.111(a)(1)	Waste Handling Building Ventilation System

Regulatory Requirement	Fifth Level MGR Architecture
63.111(a)(2)	Waste Handling Building Ventilation System
63.111(b)(2)	Waste Handling Building Ventilation System
63.112(e)(1)	Waste Handling Building Ventilation System
63.112(e)(2)	Waste Handling Building Ventilation System
63.112(e)(3)	Waste Handling Building Ventilation System
63.112(e)(4)	Waste Handling Building Ventilation System
63.112(e)(8)	Waste Handling Building Ventilation System
63.112(e)(10)	Waste Handling Building Ventilation System
63.112(e)(11)	Waste Handling Building Ventilation System
63.112(e)(13)	Waste Handling Building Ventilation System
63.21(c)(17)	Waste Package Remediation System
63.78	Waste Package Remediation System
63.111(a)(1)	Waste Package Remediation System
63.112(e)(8)	Waste Package Remediation System
63.112(e)(10)	Waste Package Remediation System
63.112(e)(13)	Waste Package Remediation System
63.21(c)(17)	Waste Treatment Building System
63.111(a)(1)	Waste Treatment Building System
63.112(e)(1)	Waste Treatment Building System
63.112(e)(2)	Waste Treatment Building System
63.112(e)(3)	Waste Treatment Building System
63.112(e)(4)	Waste Treatment Building System
63.112(e)(5)	Waste Treatment Building System
63.112(e)(8)	Waste Treatment Building System

Table 5-8. Allocation of Regulatory Requirements from 10 CFR 63 for MGR Design (Continued)

63.112(e)(10)	Waste Treatment Building System
63.112(e)(13)	Waste Treatment Building System
63.111(a)(1)	Waste Treatment Building Ventilation System
63.112(e)(1)	Waste Treatment Building Ventilation System
63.112(e)(2)	Waste Treatment Building Ventilation System
63.112(e)(3)	Waste Treatment Building Ventilation System
63.112(e)(4)	Waste Treatment Building Ventilation System
63.112(e)(10)	Waste Treatment Building Ventilation System
63.112(e)(13)	Waste Treatment Building Ventilation System

Item 3

Waste Package Design Information supporting a "Cool" Repository Design Information for Performance Assessment

Waste Package Design Information supporting a "Cool" Repository Design Information for Performance Assessment

1 Introduction

The transmittal contains waste package design information requested by Performance Assessment to compute the performance of a "cool" repository design (CRWMS M&O 2001). Since that information request included requests to a wide range of organizations for completeness, the information contained herein is identified by reference to numbering scheme used in that request.

2 Responses to §II of Request, Operational Plans

2.1 Item 5

Request: Waste Package spacing—variable spacing with a two meter average and average loading of 1 kW/m

Response: The anticipated design requirement for the variable separation of waste packages is that the loading maintain an average linear power within the drifts of 1.0 kW/m at emplacement of the waste packages. Since the various waste packages will each have a unique thermal power at emplacement, this is an operational issue; however, for design purposes, it is desirable to have a relatively simple scheme for creating drift segment loadings. This response describes the development of such a scheme. For this purpose, it is assumed that each waste package is adequately characterized by the average thermal power at emplacement for this purpose.

A pre-requisite for developing such a loading scheme is to define the various waste package inventories. These are shown in Table 1. In addition, it is necessary to state the lengths and average thermal powers of the waste packages at emplacement. These are shown in Worksheet 1. Note that the lengths are the same as those provided in §3.3.

An obvious way to determine the individual waste package spacing is to merely add sufficient empty drift length on each side of the waste package to obtain an effective linear power of 1.0 kW/m over that length. In this approach, it will result that low power waste packages have linear powers less than 1.0 kW/m for the design-waste package length. For such waste packages, a minimum skirt-to-skirt separation of 0.1 m is used. When the information from Worksheet 1 is used to develop variable waste package separations, the separations shown in Worksheet 2 are obtained. It should be noted that this results in a significantly greater average separation than the approximate 2 m separation required for the "cool" design. This is because there is an unrealized reservoir of thermal capacitance associated with the low-power waste packages (i. e., such packages will not thermally exhaust the rock mass allocated for them in the rejection of thermal energy). Further, it is not possible to obtain the target linear power of 1.0 kW/m, even though the separations for the high-power waste packages have been set to meet this goal.

Table 1 Waste Package Inventories

Design Designation	Nominal Quantity	
	Truncated SR Design Case [a]	Full Inventory Case [b]
21 PWR Absorber Plate	4299	5690
21 PWR Control Rod	95	106
12 PWR Long	163	293
44 BWR Absorber Plate	2831	3732
24 BWR Thick Absorber Plate	84	98
5 IPWF	95 [c]	127
5 DHLW Short/1 DOE SNF Short	1052	1403
5 DHLW Long/1 DOE SNF Long	1406	1874
2 MCO/2 DHLW Long	149	199
5 HLW Long/1 DOE SNF Short	126	167
5 HLW Long Only	584	780
Naval Short	200	200
Naval Long	100	100

[a]. Quantities taken from a Waste Acceptance transmittal (CRWMS-M&O 2000e) before rounding as shown in the *Monitored Geologic Repository Project Description Document* (MGR PDD) (CRWMS-M&O 2000f, Table 5-5). These are based on continuing to accept HLW and co-dispose DSNF with the HLW even though the allocated 4667 MTHM equivalent of HLW would be used up prior to the disposal of all the DSNF. This is conservative from a thermal design viewpoint.

[b]. Quantities taken from the Waste Acceptance transmittal (CRWMS-M&O 2000e) before rounding as shown in the MGR PDD (CRWMS-M&O 2000f, Table 5-6).

[c]. This quantity does not allow for the acceptance of the entire expected quantity (17 tU nominal, 18.2 tU actual) of immobilized plutonium as required by the *Civilian Radioactive Waste Management System Requirements Document* (DOE 2000a) and the *Monitored Geologic Repository Requirements Document* (YMP 2000). It allows for acceptance of only 13.6 tU.

Worksheet 1 Waste Package Parameters for Variable Spacing Development

Design Designation	Inventories		Fractional Inventory (%)		Waste Package Length (m)	Average Thermal Power @ Emplacement (kW)	
	Truncated SR Design Case	Full Inventory Case	Truncated SR Design Case	Full Inventory Case		Case A-- 63,000 tU CSNF	Case A-- 83,800 tU CSNF
21-PWR Absorber Plate	4299	5690	38.4%	38.5%	5.165	11.53	11.33
21-PWR Control Rod	95	106	0.8%	0.7%	5.165	3.11	3.26
12-PWR Long	163	293	1.5%	2.0%	5.651	9.55	8.97
44-BWR Absorber Plate	2831	3732	25.3%	25.3%	5.165	7.38	7.00
24-BWR Thick Absorber Plate	84	98	0.8%	0.7%	5.105	0.52	0.54
5-IPWF	95	127	0.8%	0.9%	3.590	3.53	3.53
5-DHLW Short/1-DOE SNF Short	1052	1403	9.4%	9.5%	3.590	2.98	2.98
5-HLW Long/1-DOE SNF Short	126	167	1.1%	1.1%	5.217	0.407	0.407
5-DHLW Long/1-DOE SNF Long	1406	1874	12.6%	12.7%	5.217	0.407	0.407
2 MCO/2-DHLW Long	149	199	1.3%	1.3%	5.217	1.665	1.665
5-HLW Long	584	780	5.2%	5.3%	5.217	0.282	0.282
Naval Canistered SNF Short	200	200	1.8%	1.4%	6.065	3.07	3.07
Naval Canistered SNF Long	100	100	0.9%	0.7%	5.430	3.07	3.07
Total	11184	14769	100.0%	100.0%		77,784	100,551
						6.95	6.81

5.039 = Average Length for Truncated Case

5.036 = Average Length for Full Case

Worksheet 2 Spacing Developed for Individual Waste Packages

Design Designation	Linear Power (0.1 m Spacing)		Spacing for 1.0 kW/m		Total Spacing Length (m)	
	Case A-- 63,000 tU CSNF	Case A-- 83,800 tU CSNF	Case A-- 63,000 tU CSNF	Case A-- 83,800 tU CSNF	Case A-- 63,000 tU CSNF	Case A-- 83,800 tU CSNF
21-PWR Absorber Plate	2.19	2.15	6.37	6.17	27363	35079
21-PWR Control Rod	0.59	0.62	0.10	0.10	10	11
12-PWR Long	1.66	1.56	3.90	3.32	636	972
44-BWR Absorber Plate	1.40	1.33	2.22	1.84	6271	6848
24-BWR Thick Absorber Plate	0.10	0.10	0.10	0.10	8	10
5-IPWF	0.96	0.96	0.10	0.10	10	13
5-DHLW Short/1-DOE SNF Short	0.81	0.81	0.10	0.10	105	140
5-HLW Long/1-DOE SNF Short	0.08	0.08	0.10	0.10	13	17
5-DHLW Long/1-DOE SNF Long	0.08	0.08	0.10	0.10	141	187
2 MCO/2-DHLW Long	0.31	0.31	0.10	0.10	15	20
5-HLW Long	0.05	0.05	0.10	0.10	58	78
Naval Canistered SNF Short	0.50	0.50	0.10	0.10	20	20
Naval Canistered SNF Long	0.56	0.56	0.10	0.10	10	10
Total Space Length (m) =					34,658	43,405
Total Waste Package Length (m) =					56,357	74,372
Average Allotment (Waste Package and Spacing) (m) =					8.14	7.97
Average Spacing (m) =					3.10	2.94
Linear Power (kW/m) =					0.85	0.85

To rectify this under-utilization, high-power 21-PWR Absorber Plate waste packages are juxtaposed with lower power waste packages to better utilize the thermal capacitance of the host rock. The resulting waste package suite is shown in Worksheet 3. The 5-DHLW/Co-disposal Short waste package is not paired with a 21-PWR Absorber Plate waste package because the short length of this waste package does not promote good capacitance utilization when paired with 21-PWR package. The separations resulting from this approach are shown in Worksheet 4. As may be seen from that worksheet, the linear power goal is met and the average separations are much closer to the target of 2 meters.

While the merit of any spacing scheme can only be assessed by examining the time-dependent temperature fields obtained in the drifts, this scheme results in reasonably good conformance to the linear power and spacing requirements.

Worksheet 3 Waste Package Parameter for Paired Inventory

Design Designation	Inventories		Fractional Inventory (%)		Waste Package Length (m)*	Average Thermal Power @ Emplacement (kW)	
	Truncated SR Design Case	Full Inventory Case	Truncated SR Design Case	Full Inventory Case		Case A– 63,000 tU CSNF	Case A– 83,800 tU CSNF
21-PWR Absorber Plate (unpaired)	1555	2166	18.4%	19.3%	5.165	11.53	11.33
21-PWR Control Rod (paired)	95	106	1.1%	0.9%	10.430	14.64	14.59
12-PWR Long	163	293	1.9%	2.6%	5.651	9.55	8.97
44-BWR Absorber Plate	2831	3732	33.5%	33.2%	5.165	7.38	7.00
21-PWR AP/24-BWR (paired)	84	98	1.0%	0.9%	10.370	12.05	11.87
5-DHLW Short	1147	1530	13.6%	13.6%	3.590	3.03	3.03
21-PWR AP/5-DHLW Long (paired)	2116	2821	25.1%	25.1%	10.482	11.90	11.70
21-PWR AP/MCO (paired)	149	199	1.8%	1.8%	10.482	13.195	12.995
21-PWR AP/Naval Short (paired)	200	200	2.4%	1.8%	11.330	14.6	14.4
21-PWR AP/Naval Long (paired)	100	100	1.2%	0.9%	10.695	14.6	14.4
	8440	11245	100.0%	100.0%		77,779	100,544
						9.22	8.94

6.710 = Average Length for Truncated Case

6.645 = Average Length for Full Case

Number of Waste Packages with "Low" Thermal Power =	2744	3524	63.8%	61.9%
Number of Unpaired 21-PWR Absorber Plate Waste Packages =	1555	2166	36.2%	38.1%
			100.0%	100.0%

10.449 = Pair Length for Truncated Case

10.434 = Pair Length for Full Case

* - includes 0.1 m spacing between paired waste packages

Average Power of Paired Waste Packages (kW) = 6.319 6.185

Worksheet 4 Separations Developed for Paired Waste Packages

Design Designation	Linear Power (0.1 m Spacing)		Spacing for 1.0 kW/m		Total Spacing Length (m)	
	Case A--63,000 tU CSNF	Case A--83,800 tU CSNF	Case A--63,000 tU CSNF	Case A--83,800 tU CSNF	Case A--63,000 tU CSNF	Case A--83,800 tU CSNF
21-PWR Absorber Plate (unpaired)	2.19	2.15	6.37	6.17	9898	13353
21-PWR Control Rod (paired)	1.39	1.39	4.21	4.16	400	441
12-PWR Long	1.66	1.56	3.90	3.32	636	972
44-BWR Absorber Plate	1.40	1.33	2.22	1.84	6271	6848
21-PWR AP/24-BWR (paired)	1.15	1.13	1.68	1.50	141	147
5-DHLW Short	0.82	0.82	0.10	0.10	115	153
21-PWR AP/5-DHLW Long (paired)	1.12	1.11	1.42	1.22	3001	3437
21-PWR AP/MCO (paired)	1.25	1.23	2.71	2.51	404	500
21-PWR AP/Naval Short (paired)	1.28	1.26	3.27	3.07	654	614
21-PWR AP/Naval Long (paired)	1.35	1.33	3.91	3.71	391	371
				Total Space Length (m) =	21,909	26,836
				Total Waste Package Length (m) =	56,632	74,725
				Average Allotment (Waste Package and Spacing) (m) =	7.02	6.88
				Average Spacing (m) =	1.96	1.82
				Linear Power (kW/m) =	0.99	0.99

2.2 Item 8

Request: Development of an idealized drift segment for use in 3-D drift-scale models (i. e., a 7-waste package model with an appropriate number of 21-PWRs in the segment and where they are located wrt other packages in the segment, etc.).

Response: Based on the scheme developed in §2.1, multi-waste package drift segments can be developed for variably spaced waste packages.

First, the population of a drift segment incorporating a given number of waste packages must be developed. This consists of determining the number of waste packages out of a given segment-total number that are implied by the entire inventory. For the inventory denoted as the "Truncated SR Design Case," this exercise is shown in Worksheet 5. Based on the fractional inventory of each waste package (or waste package pair), drift-segment inventories are selected. Several metrics are then computed for the assumed drift-segment inventory. These are defined in Table 2.

Table 2 Drift Segment Optimization Metrics

Metric	Description
Average Allotment (m)	The average drift length allotted to each waste package, or waste package pair. This is a measure of how well the drift segment represents the average of the entire repository (at least with regard to the continuously loaded parts of the drift system). The target allotments for each inventory are obtained from Worksheet 4.
Linear Power (kW/m)	This ratio of the thermal power in the drift segment at emplacement to the total length of the drift segment. This value should be very close to 1.0 kW/m.
Average Separation (m)	This is the average skirt-to-skirt waste package separation for the drift segment. This value is compared to 2 meters.

A review of the metrics computed in Worksheet 5 indicates that a nine-package segment best satisfies the metrics. From the nine-package drift inventory, a loading layout is developed, including a 21-PWR design-basis package (viz., having a thermal power at emplacement of 11.8 kW). This is shown in

Worksheet 6. This nine-waste package loading sequence is shown in Table 3. Note that the total at the bottom of the column denoted as "Length (m)" is the sum of the waste package length and the spacings.

Table 3 Nine-Package Segment Loading for 63,000 tU CSNF Case

WP Type	Spacing (m) Left	Spacing (m) Right	Length (m)	Power (kW/m)
½ 21-PWR	0.0	3.18	2.58	5.77
5-DHLW Long	3.18	0.10	5.22	0.10
21-PWR	0.10	2.53	5.17	11.80
44-BWR	2.53	2.53	5.17	7.38
21-PWR	2.53	0.10	5.17	11.53
5-DHLW Long	0.10	1.11	5.22	0.37
44-BWR	1.11	1.16	5.17	7.38
5-DHLW Short	1.16	3.23	3.59	3.03
21-PWR	3.23	4.29	5.17	11.53
½ 44-BWR	4.29	0.00	2.58	3.69
		18.22	63.24	62.57
Average Separation (m) =		2.02		

The development of this segment has identified some loading rules implied by the thermal requirements. These are:

1) For the paired waste packages, the separation allowances identified in Worksheet 4, should be applied to the 21-PWR side of the pair. Thus, the waste package on the opposite of the 5-DHLW/Co-disposal waste package from the 21-PWR should only have separation from the 5-DHLW package implied for that package, whatever it is (viz., half of the separation allowance).

2) In general, 21-PWR waste packages should not be juxtaposed.

3) Some care should be taken to ensure that waste packages near the end of segment do not result in islands of high-power waste packages due to the reflection of these waste packages at the boundary (after all, the segment is assumed to be mirror reflective at the boundaries).

Comparable information for the full inventory case is shown in Worksheets 7 and 8.

Table 4 Nine-Package Segment Loading for 83,800 tU CSNF Case

WP Type	Spacing (m) Left	Spacing (m) Right	Length (m)	Power (kW/m)
½ 21-PWR	0.0	3.08	2.58	5.67
5-DHLW Long	3.08	0.10	5.22	0.23
21-PWR	0.10	2.14	5.17	11.80
44-BWR	2.14	2.14	5.17	7.00
21-PWR	2.14	0.10	5.17	11.33
5-DHLW Long	0.10	0.92	5.22	0.37
44-BWR	0.92	0.97	5.17	7.00
5-DHLW Short	0.97	3.13	3.59	3.03
21-PWR	3.13	4.00	5.17	11.33
½ 44-BWR	4.00	0.00	2.58	3.50
		16.57	61.59	61.25
Average Separation (m) =		1.84		

Worksheet 5 Drift Segment Optimization for Truncated SR Design Case Inventory

Design Designation	Number		Power (kW)	Percentage		Segment Optimization					Equivalent "Paired" Numbers				
	Paired	WP's		Paired	WP's	7	7.5	8	8.5	9	7	7.5	8	8.5	9
21-PWR Absorber Plate (unpaired)	1555	1555	11.53	18.4%	13.9%	0.97	1.04	1.11	1.18	1.25	0.97	1.04	1.11	1.18	1.25
21-PWR Control Rod (paired)	95	190	14.64	1.1%	1.7%	0.12	0.13	0.14	0.14	0.15	0.06	0.06	0.07	0.07	0.08
12-PWR Long	163	163	9.55	1.9%	1.5%	0.10	0.11	0.12	0.12	0.13	0.10	0.11	0.12	0.12	0.13
44-BWR Absorber Plate	2831	2831	7.38	33.5%	25.3%	1.77	1.90	2.03	2.15	2.28	1.77	1.90	2.03	2.15	2.28
21-PWR AP/24-BWR (paired)	84	168	12.05	1.0%	1.5%	0.11	0.11	0.12	0.13	0.14	0.05	0.06	0.06	0.06	0.07
5-DHLW Short	1147	1147	3.03	13.6%	10.3%	0.72	0.77	0.82	0.87	0.92	0.72	0.77	0.82	0.87	0.92
21-PWR AP/5-DHLW Long (paired)	2116	4232	11.90	25.1%	37.8%	2.65	2.84	3.03	3.22	3.41	1.32	1.42	1.51	1.61	1.70
21-PWR AP/MCO (paired)	149	298	13.20	1.8%	2.7%	0.19	0.20	0.21	0.23	0.24	0.09	0.10	0.11	0.11	0.12
21-PWR AP/Naval Short (paired)	200	400	14.60	2.4%	3.6%	0.25	0.27	0.29	0.30	0.32	0.13	0.13	0.14	0.15	0.16
21-PWR AP/Naval Long (paired)	100	200	14.60	1.2%	1.8%	0.13	0.13	0.14	0.15	0.16	0.06	0.07	0.07	0.08	0.08
Individual and Pairs =	8440	11184	9.22	100.0%	100.0%	7.00	7.50	8.00	8.50	9.00					

Design Designation	7-Package Segment					7.5-Package Segment				
	#	Length	Spacing	Total	Power (kW)	#	Length	Spacing	Total	Power (kW)
21-PWR Absorber Plate (unpaired)	1.5	5.165	6.37	17.3	17.30	1.5	5.165	6.37	17.3	17.295
21-PWR Control Rod (paired)	0	10.430	4.21	0	0.00	0	10.430	4.21	0	0
12-PWR Long	0	5.651	3.90	0	0.00	0	5.651	3.90	0	0
44-BWR Absorber Plate	2.5	5.165	2.22	18.45	18.45	3	5.165	2.22	22.14	22.14
21-PWR AP/24-BWR (paired)	0	10.370	1.68	0	0.00	0	10.370	1.68	0	0
5-DHLW Short	1	3.590	0.10	3.69	3.03	1	3.590	0.10	3.69	3.0256
21-PWR AP/5-DHLW Long (paired)	1	10.482	1.42	11.9	11.90	1	10.482	1.42	11.9	11.9
21-PWR AP/MCO (paired)	0	10.482	2.71	0	0.00	0	10.482	2.71	0	0
21-PWR AP/Naval Short (paired)	0	11.330	3.27	0	0.00	0	11.330	3.27	0	0
21-PWR AP/Naval Long (paired)	0	10.695	3.91	0	0.00	0	10.695	3.91	0	0
Actual Packages	7.0		16.60	51.34	50.67	7.5		17.71	55.03	54.36

Design Designation	8-Package Segment					8.5-Package Segment						
	#	Length	Spacing	Total	Power (kW)	#	Length	Spacing	Total	Power (kW)	#	Ler
21-PWR Absorber Plate (unpaired)	1	5.165	6.37	11.53	11.53	1	5.165	6.37	11.53	11.53	1.5	5.1
21-PWR Control Rod (paired)	0	10.430	4.21	0	0	0	10.430	4.21	0	0	0	10.
12-PWR Long	0	5.651	3.90	0	0	0	5.651	3.90	0	0	0	5.6
44-BWR Absorber Plate	2	5.165	2.22	14.76	14.76	2.5	5.165	2.22	18.45	18.45	2.5	5.1
21-PWR AP/24-BWR (paired)	0	10.370	1.68	0	0	0	10.370	1.68	0	0	0	10.
5-DHLW Short	1	3.590	0.10	3.69	3.0256	1	3.590	0.10	3.69	3.0256	1	3.5
21-PWR AP/5-DHLW Long (paired)	2	10.482	1.42	23.8	23.801	2	10.482	1.42	23.8	23.801	2	10.
21-PWR AP/MCO (paired)	0	10.482	2.71	0	0	0	10.482	2.71	0	0	0	10.
21-PWR AP/Naval Short (paired)	0	11.330	3.27	0	0	0	11.330	3.27	0	0	0	11.
21-PWR AP/Naval Long (paired)	0	10.695	3.91	0	0	0	10.695	3.91	0	0	0	10.
Actual Packages	8.0		13.73	53.78	53.12	8.5		14.84	57.47	56.81	9.0	

Target Allotment (m) = 7.02

Target Linear Power (kW/m) = 1.0

	7-Package Segment	7.5-Package Segment	8-Package Segment	8.5-Package Segment	
Avg. Allotment (m) =	7.33	7.34	6.72	6.76	Avg. A
Linear Power =	0.99	0.99	0.99	0.99	
Avg. Separation (m) =	2.37	2.36	1.72	1.75	Avg. Se

Worksheet 6 Nine-Waste Package Segment for Truncated SR Design Case Inventory

Design Designation	Number	Percentage	Length	Thermal Power (kW) Actual	Contribution	9 Waste Packages #	Length (m)	Spacing (m)	Total	Power (kW)	1	2	3	4
21-PWR Absorber Plate (unpaired)	1555	18.42%	5.165	11.53	2.12	1.5	5.165	6.37	17.3	17.30	11.53	5.77		
21-PWR Control Rod (paired)	95	1.13%	10.43	14.64	0.16	0	10.43	4.21	0	0.00				
12-PWR Long	163	1.93%	5.651	9.55	0.18	0	5.651	3.90	0	0.00				
44-BWR Absorber Plate	2831	33.54%	5.165	7.38	2.48	2.5	5.165	2.22	18.45	18.45	7.38	7.38	3.69	
21-PWR AP/24-BWR (paired)	84	1.00%	10.37	12.05	0.12	0	10.37	1.68	0	0.00				
5-DHLW Short	1147	13.59%	3.59	3.03	0.41	1	3.59	0.10	3.69	3.03				
21-PWR AP/5-DHLW Long (paired)	2116	25.07%	10.482	11.90	2.98	2	10.48	1.42	23.8	23.80	11.8	0.37	11.53	0.10
21-PWR AP/MCO (paired)	149	1.77%	10.482	13.20	0.23	0	10.48	2.71	0	0.00				
21-PWR AP/Naval Short (paired)	200	2.37%	11.33	14.60	0.35	0	11.33	3.27	0	0.00				
21-PWR AP/Naval Long (paired)	100	1.18%	10.695	14.60	0.17	0	10.7	3.91	0	0.00				
Individual and Pairs =	8440	100.0%	6.710			9.0			63.24	62.57				

Linear Power (kW/m) = 0.99

Waste Package Suite along Drift Segment

WP Type	Left	Right	Length	Power
½ 21-PWR	0.0	3.18	2.58	5.77
5-DHLW Long	3.18	0.10	5.22	0.10
21-PWR	0.10	2.53	5.17	11.80
44-BWR	2.53	2.53	5.17	7.38
21-PWR	2.53	0.10	5.17	11.53
5-DHLW Long	0.10	1.11	5.22	0.37
44-BWR	1.11	1.16	5.17	7.38
5-DHLW Short	1.16	3.23	3.59	3.03
21-PWR	3.23	4.29	5.17	11.53
½ 44-BWR	4.29	0.00	2.58	3.69
		18.22	63.24	62.57

Average Separation (m) = 2.02

Worksheet 7 Drift Segment Optimization for Full Inventory

Design Designation	Number		Power (kW)	Percentage		Segment Optimization					Equivalent "Paired" Numbers				
	Paired	WP's		Paired	WP's	7	7.5	8	8.5	9	7	7.5	8	8.5	9
21-PWR Absorber Plate (unpaired)	2166	2166	11.33	19.3%	14.7%	1.03	1.10	1.17	1.25	1.32	1.03	1.10	1.17	1.25	1.32
21-PWR Control Rod (paired)	106	212	14.59	0.9%	1.4%	0.10	0.11	0.11	0.12	0.13	0.05	0.05	0.06	0.06	0.06
12-PWR Long	293	293	8.97	2.6%	2.0%	0.14	0.15	0.16	0.17	0.18	0.14	0.15	0.16	0.17	0.18
44-BWR Absorber Plate	3732	3732	7.00	33.2%	25.3%	1.77	1.90	2.02	2.15	2.27	1.77	1.90	2.02	2.15	2.27
21-PWR AP/24-BWR (paired)	98	196	11.87	0.9%	1.3%	0.09	0.10	0.11	0.11	0.12	0.05	0.05	0.05	0.06	0.06
5-DHLW Short	1530	1530	3.03	13.6%	10.4%	0.73	0.78	0.83	0.88	0.93	0.73	0.78	0.83	0.88	0.93
21-PWR AP/5-DHLW Long (paired)	2821	5642	11.70	25.1%	38.2%	2.67	2.87	3.06	3.25	3.44	1.34	1.43	1.53	1.62	1.72
21-PWR AP/MCO (paired)	199	398	13.00	1.8%	2.7%	0.19	0.20	0.22	0.23	0.24	0.09	0.10	0.11	0.11	0.12
21-PWR AP/Naval Short (paired)	200	400	14.40	1.8%	2.7%	0.19	0.20	0.22	0.23	0.24	0.09	0.10	0.11	0.12	0.12
21-PWR AP/Naval Long (paired)	100	200	14.40	0.9%	1.4%	0.09	0.10	0.11	0.12	0.12	0.05	0.05	0.05	0.06	0.06
Individual and Pairs =	11245	14769	8.94	100.0%	100.0%	7.00	7.50	8.00	8.50	9.00					

Design Designation	7-Package Segment					7.5-Package Segment					8-Package Segment					8.5-Package Segment						
	#	Length	Spacing	Total	Power (kW)	#	Length	Spacing	Total	Power (kW)	#	Length	Spacing	Total	Power (kW)	#	Length	Spacing	Total	Power (kW)	#	Ler
21-PWR Absorber Plate (unpaired)	1.5	5.165	6.17	17	16.995	1.5	5.165	6.17	17	16.995	1	5.165	6.17	11.33	11.33	1	5.165	6.17	11.33	11.33	1.5	5.1
21-PWR Control Rod (paired)	0	10.430	4.16	0	0	0	10.430	4.16	0	0	0	10.430	4.16	0	0	0	10.430	4.16	0	0	0	10.
12-PWR Long	0	5.651	3.32	0	0	0	5.651	3.32	0	0	0	5.651	3.32	0	0	0	5.651	3.32	0	0	0	5.6
44-BWR Absorber Plate	2.5	5.165	1.84	17.5	17.5	3	5.165	1.84	21	21	2	5.165	1.84	14	14	2.5	5.165	1.84	17.5	17.5	2.5	5.1
21-PWR AP/24-BWR (paired)	0	10.370	1.50	0	0	0	10.370	1.50	0	0	0	10.370	1.50	0	0	0	10.370	1.50	0	0	0	10.
5-DHLW Short	1	3.590	0.10	3.69	3.0257	1	3.590	0.10	3.69	3.0257	1	3.590	0.10	3.69	3.0257	1	3.590	0.10	3.69	3.0257	1	3.5
21-PWR AP/5-DHLW Long (paired)	1	10.482	1.22	11.7	11.7	1	10.482	1.22	11.7	11.7	2	10.482	1.22	23.4	23.401	2	10.482	1.22	23.4	23.401	2	10.
21-PWR AP/MCO (paired)	0	10.482	2.51	0	0	0	10.482	2.51	0	0	0	10.482	2.51	0	0	0	10.482	2.51	0	0	0	10.
21-PWR AP/Naval Short (paired)	0	11.330	3.07	0	0	0	11.330	3.07	0	0	0	11.330	3.07	0	0	0	11.330	3.07	0	0	0	11.
21-PWR AP/Naval Long (paired)	0	10.695	3.71	0	0	0	10.695	3.71	0	0	0	10.695	3.71	0	0	0	10.695	3.71	0	0	0	10.
Actual Packages	7.0		15.15	49.89	49.22	7.5		16.07	53.39	52.72	8.0		12.37	52.42	51.76	8.5		13.29	55.92	55.26	9.0	

Target Allotment (m) = 6.877 — Avg. Allotment (m) = 7.13 — Avg. Allotment (m) = 7.12 — Avg. Allotment (m) = 6.55 — Avg. Allotment (m) = 6.58 — Avg. All

Target Linear Power (kW/m) = 1.0 — Linear Power = $\boxed{0.99}$ — Linear Power = $\boxed{0.99}$ — Linear Power = $\boxed{0.99}$ — Linear Power = $\boxed{0.99}$

Avg. Separation (m) = 2.16 — Avg. Separation (m) = 2.14 — Avg. Separation (m) = 1.55 — Avg. Separation (m) = 1.56 — Avg. Sep

Worksheet 8 Nine-Waste Package Segment for Full Inventory

				Thermal Power (kW)		9 Waste Packages								
Design Designation	Number	Percentage	Length	Actual	Contribution	#	Length (m)	Spacing (m)	Total	Power (kW)	1	2	3	4
21-PWR Absorber Plate (unpaired)	2166	19.26%	5.165	11.33	2.18	1.5	5.165	6.17	17	16.995	11.33	5.67		
21-PWR Control Rod (paired)	106	0.94%	10.43	14.59	0.14	0	10.430	4.16	0	0.000				
12-PWR Long	293	2.61%	5.651	8.97	0.23	0	5.651	3.32	0	0.000				
44-BWR Absorber Plate	3732	33.19%	5.165	7.00	2.32	2.5	5.165	1.84	17.5	17.500	7.00	7.00	3.50	
21-PWR AP/24-BWR (paired)	98	0.87%	10.37	11.87	0.10	0	10.370	1.50	0	0.000				
5-DHLW Short	1530	13.61%	3.59	3.03	0.41	1	3.590	0.10	3.69	3.026				
21-PWR AP/5-DHLW Long (paired)	2821	25.09%	10.482	11.70	2.94	2	10.482	1.22	23.4	23.400	11.8	0.37	11.0	0.228
21-PWR AP/MCO (paired)	199	1.77%	10.482	13.00	0.23	0	10.482	2.51	0	0.000				
21-PWR AP/Naval Short (paired)	200	1.78%	11.33	14.40	0.26	0	11.330	3.07	0	0.000				
21-PWR AP/Naval Long (paired)	100	0.89%	10.695	14.40	0.13	0	10.695	3.71	0	0.000				
Individual and Pairs =	11245	100.0%	6.645		8.94	9.0			61.59	60.92				

Linear Power (kW/m) = 0.99

Waste Package Suite along Drift Segment

WP Type	Left	Right	Length	Power
½ 21-PWR	0.0	3.08	2.58	5.67
5-DHLW Long	3.08	0.10	5.22	0.23
21-PWR	0.10	2.14	5.17	11.80
44-BWR	2.14	2.14	5.17	7.00
21-PWR	2.14	0.10	5.17	11.33
5-DHLW Long	0.10	0.92	5.22	0.37
44-BWR	0.92	0.97	5.17	7.00
5-DHLW Short	0.97	3.13	3.59	3.03
21-PWR	3.13	4.00	5.17	11.33
½ 44-BWR	4.00	0.00	2.58	3.50
		16.57	61.59	61.25

Average Separation (m) = 1.84

3 Responses to §V of Request, Engineered Barriers

3.1 Item 1

For this request, the drip shield geometry is identified as a "mail box" design. This term has no meaning within design. The recipients should review the following information to ensure that it is consistent with their understanding of this informal nomenclature.

For the currently baselined design, the drip shields are connected to one another and therefore continuous in coverage of the waste packages in the drift. The information contained herein is for that design. A drip shield design that covers individual waste packages, and is dubbed the "stand alone" drip shield design, is currently under development and the requisite information will be supplied when available.

Request: Drip shield geometry; a) for mailbox type: inside radius, thickness, and height above invert, b) if not mailbox type, all critical dimensions should be supplied, c) spacing/configuration for adjacent drip shields, d) dimensions and thickness of plates, e) locations and thickness of reinforcing bars, f) dimensions of overlaps and clearances between adjacent components (if any)

Response: For the currently baselined design, the majority of the requested values are show in the report entitled, *Design Analysis for the Ex-Container Components* (CRWMS M&O 2000). The details for each specific items selected are discussed below.

a) The radius of curvature for the outer surface of the curved portion of the drip shield is 1.300 m. The radius of curvature for the inner surface of the curved portion of the drip shield is 1.285 m. This information is obtained from engineering sketch SK-0148 REV 05 (CRWMS M&O 2000, Attachment II).

b) See note above about the informal term, "mailbox type."

c) The spacings between and configuration of adjacent drip shields is shown in Figure 2.

d) The dimensions and thickness of the plates that comprise the drip shield are shown in Table 5. Note that the connector dimensions are not included.

Table 5 Drip Shield Plate Dimensions

Component	Length (m)	Width (m)	Thickness (mm)
Drip Shield Plate 1 (curved plate)	5.485 [a]	1.997 [b]	15
Drip Shield Plate 2 (side plates)	5.485 [a]	2.051 [b]	15

[a]. This length includes 0.290 m length under the connector plate.

[b]. This is the projection in the plan view; the actual width greater due to the curvature of the surface.

These values are shown in engineering sketch SK-0148 REV 05 (CRWMS M&O 2000, Attachment II).

e) These values are shown in engineering sketch SK-0148 REV 05 (CRWMS M&O 2000, Attachment II).

f) The spacings between and configuration of adjacent drip shields is shown in Figure 2.

3.2 Item 2

Request: Drip Shield Thermal Properties: a) thermal conductivity, b) specific heat, c) density, d) emissivity, and e) possible ranges of thermal properties, i. e., thermal conductivity, $k_{th} \pm x$, etc.

Response: Except for the structural support members, the bulk of the drip shield is composed of grade 7 titanium (SB-265 R52400). The density and emissivity are shown in Table 6. The temperature-dependent thermal conductivity and specific heat are shown in Table 7. The basis for these values is the *Waste Package Design Methodology Report* (CRWMS M&O 2000d, §4.1.3.1, Table 3), which provides appropriate citations in ASME and ASTM standards, as well as other references. The underlying references for each of the values is shown in the notes associated with each table.

Table 6 Titanium Grade 7 Density and Emissivity

	Density (kg/m^3) [a]	Emissivity [b]
Titanium Grade 7	4512	0.63

[a]. *ASME Boiler and Pressure Vessel Code.* Section II, Part D (ASME 1995, Table NF-2).

[b]. *CRC Handbook of Chemistry and Physics. 76th Edition, 1995-1996* (Lide, D. R., ed. 1995, p. 10-298).

Table 7 Titanium Grade 7 Thermal Conductivity and Specific Heat

Temperature		Thermal Conductivity [a]	Thermal Diffusivity [b]	Thermal Conductivity	Specific Heat
(°F)	(°C)	(Btu/hr·ft·°F)	(ft²/hr)	(W/m·K)	(J/kg·K)
70	21.11	12.68	0.359	21.95	525.00
100	37.78	12.52	0.352	21.67	528.68
150	65.56	12.25	0.340	21.20	535.54
200	93.33	12.00	0.331	20.77	538.87
250	121.11	11.85	0.322	20.51	547.01
300	148.89	11.72	0.314	20.28	554.79
350	176.67	11.60	0.306	20.08	563.47
400	204.44	11.45	0.300	19.82	567.31
450	232.22	11.35	0.294	19.64	573.83
500	260.00	11.29	0.290	19.54	578.67
550	287.78	11.23	0.286	19.44	583.64
600	315.56	11.20	0.283	19.38	588.26
650	343.33	11.17	0.280	19.33	592.97
700	371.11	11.15	0.278	19.30	596.16
750	398.89	11.18	0.276	19.35	602.10
800	426.67	11.20	0.275	19.38	605.37
850	454.44	11.23	0.274	19.44	609.21
900	482.22	11.30	0.273	19.56	615.25
950	510.00	11.36	0.272	19.66	620.79
1000	537.78	11.43	0.271	19.78	626.92
1050	565.56	11.51	0.270	19.92	633.64
1100	593.33	11.58	0.270	20.04	637.50

[a]. *ASME Boiler and Pressure Vessel Code.* Section II, Part D (ASME 1995, Table TCD).

[b]. *ASME Boiler and Pressure Vessel Code.* Section II, Part D (ASME 1995, Table TCD)—computed from the thermal diffusivity.

3.3 Item 3

For this request, items V.f and V.g, Depth of Invert, are supplied by other organizations (Waste Package Materials and Subsurface Design, respectively).

Request: Waste Package Geometry (for 5 main types, including: 21-PWR, 44-BWR, 5-DHLW/DOE SNF, 2-MCO/2-DHLW, and Naval SNF): a) diameters (for different waste package types and for different material layers), b) lengths, c) minimum gap between the bottom waste package surface and the top of the invert, d) initial waste package internal surface area, e) initial waste package void and porosity, and g) emplacement drawings for these waste packages.

Response: For the currently baselined design, the majority of the requested values are shown the design reports for the various waste packages and for the ex-container components. These reports are listed immediately below and the details for each specific items selected are discussed subsequently.

- *Design Analysis for UCF Waste Packages,* ANL-UDC-MD-000001 REV 00 (CRWMS M&O 2000a)
- *Design Analysis for Defense High-Level Waste Disposal Container,* ANL-DDC-ME-000001 REV 00 (CRWMS M&O 2000b)
- *Design Analysis for the Naval SNF Waste Package,* ANL-VDC-ME-000001 REV 00 (CRWMS M&O 2000c)

- *Design Analysis for the Ex-Container Components,* ANL-XCS-ME-000001 REV 00 (CRWMS M&O 2000)

a) The diameters for the two waste package shells are shown in the references provided in Table 8.

Table 8 References for Waste Package Engineering Sketches

Design	Diameter (m) [a]	Length (m) [b]	Reference
21-PWR	1.564	5.165	Engineering Sketch SK-0175, REV 02, CRWMS M&O 2000a, Attachment I
44-BWR	1.594	5.165	Engineering Sketch SK-0192 REV 00, CRWMS M&O 2000a, Attachment II
24-BWR	1.238	5.105	Engineering Sketch SK-0184 REV 00
12-PWR Long	1.250	5.651	Engineering Sketch SK-0183 REV 01
5-DHLW/DOE Co-disposal Short	2.030	3.590	Engineering Sketch SK-0196 REV 03, CRWMS M&O 2000b, Attachment III
5-DHLW/DOE Co-disposal Long	2.030	5.217	Engineering Sketch SK-0200, REV 04, CRWMS M&O 2000b, Attachment V
2-MCO/2-DHLW	1.734	5.217	Engineering Sketch SK-0198, REV 01, CRWMS M&O 2000b, Attachment VII
Naval SNF Long	1.869	6.065	Engineering Sketch SK-0194, REV 01, CRWMS M&O 2000c, Attachment II
Naval SNF Short	1.869	5.430	Engineering Sketch SK-0203, REV 00

[a]. In all cases, this is the outer diameter of the outer barrier. The Trunnion Collar Sleeve extends beyond this diameter.

[b]. This is total length from the maximum extend of the waste package skirt.

b) The outer lengths for the waste packages are shown in the references provided in Table 8.

c) The minimum gap between the top of the invert and the bottom of the waste package for the 21-PWR, 44-BWR, 5-DHLW/DOE Co-disposal Long and Short and Naval SNF Long and Short waste packages are shown in Engineering Sketch SK-0154 REV 02 (CRWMS M&O 2000, Attachment II, page II-3). For the 2-MCO/2-DHLW waste package, the gap distance may be estimated from the existing information, as shown in Table 9. The appropriateness of this procedure is shown in Figure 1.

Table 9 Waste Package to Invert Gap Estimate for 2-MCO/2-DHLW Waste Package

Design	OD (mm)	WP Centerline to Top of Invert (mm)	Gap (mm)
21-PWR	1564	1012	230
44-BWR	1594	1030	233
2-MCO/2-DHLW	1734	1110	243
Naval	1869	1188	254
5-DHLW/Co-disposal	2030	1281	266

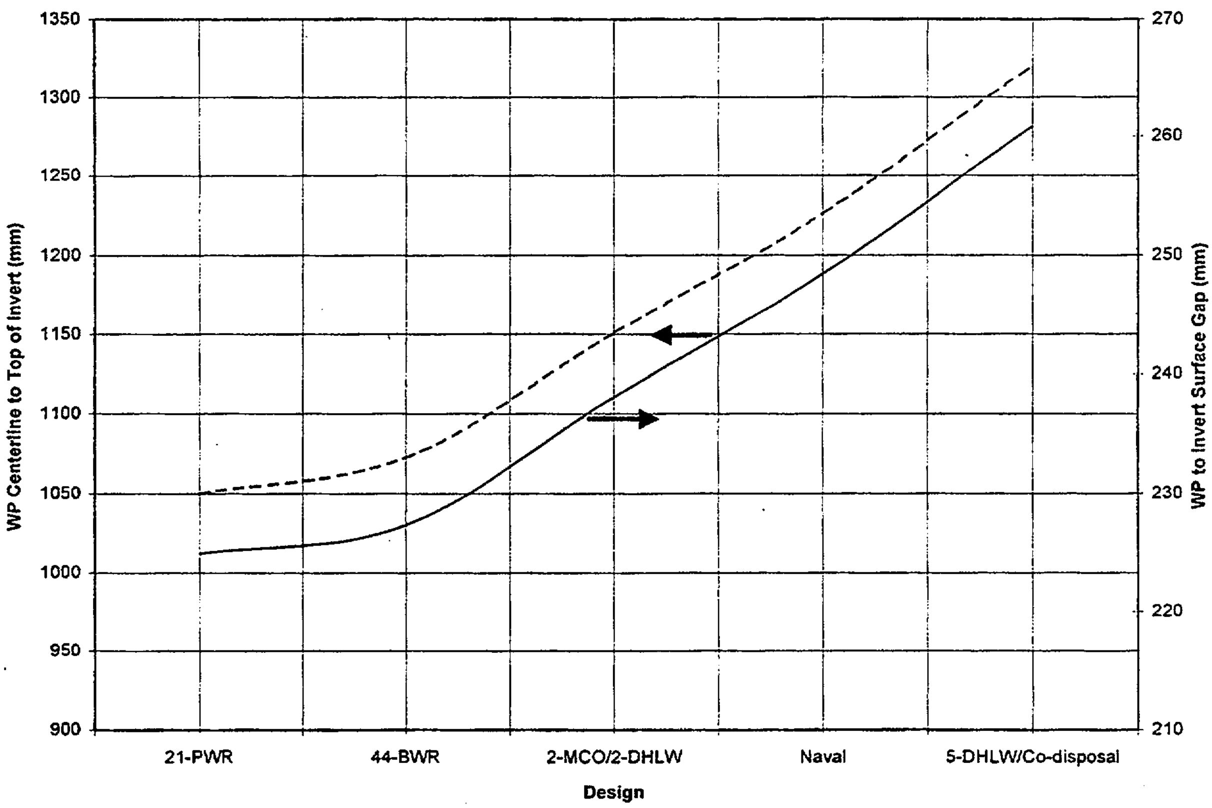

Figure 1 Waste Package to Invert Gap Estimate for 2-MCO/2-DHLW Waste Package

d) The computation of the initial waste package internal surface area will be supplied in a future transmittal.

e) The computation of the void volume will require a calculation and will be supplied in a future transmittal. A working definition of the "porosity" is required to supply this value.

g) The nominal emplacement locations for the 21-PWR, 44-BWR, 5-DHLW/DOE Co-disposal Long and Short and Naval SNF Long and Short waste packages are shown in Engineering Sketch SK-0154 REV 02 (CRWMS M&O 2000, Attachment II, page II-3).

3.4 Item 4

Request: Waste Package Thermal Properties (effective and bulk): a) thermal conductivity, b) specific heat, c) density, d) emissivity, e) possible ranges of thermal properties.

Response: It is not clear what the difference is between effective and bulk properties. The values supplied as those used for design engineering as documented in the *Waste Package Design Methodology Report* (CRWMS M&O 2000d, §4.1.3.1, Table 3), which provides appropriate citations in ASME and ASTM standards, as well as other references. The underlying references for each of the values is shown the notes associated with each table.

The outer barrier of the waste package is composed of alloy 22 (SB-575 N06022). The density and emissivity values are shown in Table 10. The temperature-dependent thermal conductivity and specific heat are provided in Table 11.

Table 10 Alloy 22 Density and Emissivity

	Density (kg/m^3) [a]	Emissivity [b]
alloy 22	8690	0.87

[a]. *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.* ASTM B 575-97 (ASTM B 575-97 1998, p. 2)

[b]. *CRC Handbook of Chemistry and Physics. 76th Edition, 1995-1996* (Lide, D. R., ed. 1995, p. 10-297) for nickel-chromium alloy.

Table 11 Alloy 22 Thermal Conductivity and Specific Heat

Temperature (°C)	Thermal Conductivity (W/m·K) [a]	Temperature (°C)	Specific Heat (J/kg·K) [a]
48	10.1	52	414
100	11.1	100	423
200	13.4	200	444
300	15.5	300	460
400	17.5	400	476
500	19.5	500	485
600	21.3	600	514

[a]. *Hastelloy C-22 Alloy* (Haynes 1997, page 13)

The inner shell of the waste package is composed of stainless steel 316NG (SA-240 S31600). The density and emissivity values are shown in Table 12. The temperature-dependent thermal conductivity and specific heat are shown in Table 13.

Table 12 SS 316 NG Density and Emissivity

	Density (kg/m^3) [a]	Emissivity [b]
SS 316 NG	7980	0.62

[a]. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens* (ASTM G 1-90 1990, page 7)

[b]. *Marks' Standard Handbook for Mechanical Engineers* (Avallone and Baumeister 1987, page 4-86)

Table 13 SS 316 NG Thermal Conductivity and Specific Heat

Temperature		Thermal Conductivity [a]	Thermal Diffusivity [b]	Thermal Conductivity	Specific Heat
(°F)	(°C)	(Btu/hr·ft·°F)	(ft^2/hr)	(W/m·K)	(J/kg·K)
70	21.11	7.7	0.134	13.33	482.93
100	37.78	7.9	0.136	13.67	488.19
150	65.56	8.2	0.138	14.19	499.38
200	93.33	8.4	0.141	14.54	500.68
250	121.11	8.7	0.143	15.06	511.31
300	148.89	9.0	0.145	15.58	521.64

350	176.67	9.2	0.148	15.92	522.43
400	204.44	9.5	0.151	16.44	528.75
450	232.22	9.8	0.153	16.96	538.31
500	260.00	10.0	0.156	17.31	538.74
550	287.78	10.3	0.159	17.83	544.43
600	315.56	10.5	0.162	18.17	544.72
650	343.33	10.7	0.164	18.52	548.33
700	371.11	11.0	0.167	19.04	553.58
750	398.89	11.2	0.170	19.38	553.69
800	426.67	11.5	0.173	19.90	558.67

[a]. *ASME Boiler and Pressure Vessel Code.* Section II, Part D (ASME 1995, Table TCD).

[b]. *ASME Boiler and Pressure Vessel Code.* Section II, Part D (ASME 1995, Table TCD)—computed from the thermal diffusivity.

The effective thermal conductivities for the internals of the waste package have been explicitly determined for the 21-PWR Absorber Plate and 44-BWR Absorber Plate waste packages and effective specific heats have been determined for all the waste packages. Values have also been provided by Naval Reactors for Naval Canistered Spent Nuclear Fuel for effective density, thermal conductivity and specific heat (Naples, E.M. 1999, Enclosure 2). Due to the highly conductive and isotropic thermal behavior of the waste package outer barrier and inner shell when compared with the internals, these have generally been modeled separately in ANSYS drift-scale calculations. These values are provided in Table 14.

Table 14 Thermal Properties for Homogeneous Waste Package Internals

Property	21PWR	44BWR	5DHLW-S	5DHLW-L	Naval	
					longer canister	shorter canister
Thermal Conductivity (KW/m·K)	1.5 [a]	1.8 [b]	1.5 [c]	1.5 [c]	3.3 [d]	3.7 [d]
Density (kg/m^2)	3495	3342	2175	2302	4005 [d]	
Specific Heat (J/kg·K)	378	395	718	731	See Table 15 [d]	

[a]. CRWMS M&O 1999c, page 8.

[b]. CRWMS M&O 2000i.

[c]. Use the value for the 21-PWR as representative.

[d]. Naples, E.M. 1999.

Table 15 Temperature-Dependent Specific Heat for Naval Canister

Parameter	**Naval Canister**								
Temperature (°C)	0	38	93	148	204	260	316	371	400
Specific Heat (J/kg·K)	0.095	0.100	0.104	0.108	0.113	0.115	0.118	0.120	0.121

These are nominal values for thermal transport properties. Expected variability will be provided in a later version of this transmittal.

3.5 Item 5

Request: Emplacement Pallet material and dimensions: a) material, dimensions and thicknesses of plates, b) material, locations and thicknesses of reinforcing bars.

Response: For the currently baselined design, the requested values are show in the report entitled, *Design Analysis for the Ex-Container Components* (CRWMS M&O 2000). The details for each specific items selected are discussed below.

a) The thicknesses of the alloy 22 (SB-575 N06022) plates that comprise the pier portion of the emplacement pallet are shown in Engineering Sketch SK-0144 REV 01 (CRWMS M&O 2000, Attachment III, page III-1) for the short pallet and in Engineering Sketch SK-0189 REV 00 (CRWMS M&O 2000, Attachment III, page III-2). For the plate on which the waste package rests, the thickness is 25.4 mm. For the balance of the plates, the thicknesses are shown in the cited sketches.

b) The thickness of the stainless steel 316 (SA-240 S31603) tubes that comprise the support beam portion of the emplacement pallet is 9.525 mm as shown in Engineering Sketch SK-0144 REV 01 (CRWMS M&O 2000, Attachment III, page III-1) for the short pallet and in Engineering Sketch SK-0189 REV 00 (CRWMS M&O 2000, Attachment III, page III-2).

4 Responses to §VI of Request, Waste Form and Heat Output

4.1 Item 1

Request: Heat decay curves in kW as a function of time for each (averaged) representative waste type—out to 1 million years.

Response: It is presumed that a "representative waste type" refers implies information on a waste package-type basis. The decay curves for the various CSNF waste packages are shown in Tables 16 and 17. (CRWMS-M&O 2000g, these values were abstracted from the computer files on the accompanying CDs, \BIN.EXE_FILES\output_files\Case_A_63k\thermal.dat and \BIN.EXE_FILES\output_files\Case_A_84k\thermal.dat).

For the vitrified high-level waste and DOE spent nuclear fuel, the following limitations were necessary:

- When computing the canister-number averaged decay heat for the Short HLW glass canister, the INEEL INTEC canisters were not included because they are on a different time grid and because their heat generation rates are small relative to the other DOE SNF waste forms.
- For the 2MCO/2 DHLW Long co-disposal package, each MCO canister is assumed to have a decay heat generation rate of 776 W at emplacement (DOE 2000b) and to decay at the same rate as the DHLW Long glass canisters in the same package. This assumption is necessary since no data are available for the actual decay rate and assuming no decay would be unreasonably conservative.
- For all co-disposal packages except the 2MCO/2 DHLW Long package, each DOE SNF canister is assumed to have a heat generation rate of 125 W at emplacement (CRWMS-M&O 2000e) and to decay at the same rate as the average HLW glass canister in the same package. Again, this assumption is necessary since no decay rate data are available.

Table 16 Average Decay Curves for CSNF Waste Packages, 63,000 tU Inventory

Average Decay Heat Profile (kW/package) for Waste Stream A—63,000 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
0.000001	11.52837	3.10611	9.54888	7.37748	0.52056
0.01	11.52417	3.10569	9.546	7.37484	0.52032
0.02	11.51997	3.10506	9.54312	7.3722	0.52032
0.03	11.51598	3.10443	9.54024	7.37	0.52008
0.04	11.51178	3.1038	9.53736	7.36736	0.52008
0.05	11.50758	3.10317	9.53448	7.36472	0.52008
0.06	11.50359	3.10254	9.5316	7.36208	0.51984
0.07	11.49939	3.10191	9.52872	7.35988	0.51984
0.08	11.49519	3.10149	9.52584	7.35724	0.5196
0.09	11.4912	3.10086	9.52296	7.3546	0.5196
0.1	11.487	3.10023	9.52008	7.3524	0.51936
0.15	11.46684	3.09729	9.5058	7.33964	0.51888
0.2	11.44668	3.09435	9.49164	7.32732	0.5184
0.25	11.42652	3.09141	9.4776	7.31544	0.51792
0.3	11.40678	3.08847	9.46356	7.30312	0.51744
0.35	11.38725	3.08553	9.44964	7.29124	0.51696
0.4	11.36772	3.08259	9.43584	7.27892	0.51648
0.45	11.3484	3.07965	9.42204	7.26748	0.516
0.5	11.32929	3.07671	9.40836	7.2556	0.51528
0.55	11.31018	3.07377	9.3948	7.24372	0.5148
0.6	11.29128	3.07104	9.38136	7.23228	0.51432
0.65	11.27259	3.0681	9.36792	7.22084	0.51384
0.7	11.25411	3.06516	9.3546	7.2094	0.51336
0.75	11.23584	3.06243	9.34128	7.19796	0.51288
0.8	11.21757	3.05949	9.32808	7.18696	0.5124
0.85	11.1993	3.05676	9.315	7.17596	0.51192
0.9	11.18145	3.05403	9.30204	7.16452	0.51144
0.95	11.1636	3.05109	9.28908	7.15352	0.51096
1	11.14596	3.04836	9.27624	7.14296	0.51048
1.5	10.97985	3.02043	9.15156	7.04132	0.50544
2	10.82466	2.99376	9.03372	6.94584	0.50064
2.5	10.67934	2.96667	8.91924	6.85608	0.49584
3	10.54221	2.94063	8.81052	6.77116	0.49128
3.5	10.4118	2.9148	8.7054	6.6902	0.48648
4	10.28811	2.88981	8.60532	6.61276	0.48216
4.5	10.16841	2.86461	8.5074	6.53796	0.4776
5	10.05459	2.84025	8.4138	6.46668	0.47328
5.5	9.9435	2.81547	8.322	6.39584	0.46896
6	9.83724	2.79132	8.23404	6.32808	0.46464
6.5	9.73266	2.76738	8.14692	6.26076	0.46032
7	9.63228	2.74407	8.06316	6.19608	0.456
7.5	9.53337	2.72097	7.98012	6.13272	0.45192
8	9.43803	2.6985	7.9002	6.072	0.44784

Average Decay Heat Profile (kW/package) for Waste Stream A—63,000 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
8.5	9.34332	2.67603	7.82064	6.00996	0.444
9	9.25218	2.65419	7.74408	5.95056	0.44016
9.5	9.16125	2.63214	7.66728	5.89248	0.43608
10	9.07347	2.61072	7.59312	5.83616	0.43224
15	8.27232	2.41038	6.91488	5.31256	0.39576
20	7.58268	2.23251	6.32904	4.85672	0.3636
25	6.97893	2.07354	5.81736	4.45148	0.3348
30	6.44427	1.93158	5.36364	4.09552	0.30936
35	5.97009	1.80432	4.96128	3.77828	0.28656
40	5.54925	1.69008	4.6044	3.4958	0.26616
45	5.17104	1.58781	4.28328	3.24368	0.24792
50	4.83336	1.49562	3.99708	3.01796	0.23184
55	4.53222	1.41309	3.74316	2.816	0.2172
60	4.26069	1.33854	3.5136	2.63516	0.20424
65	4.01688	1.27155	3.30816	2.4728	0.19272
70	3.79743	1.21128	3.12144	2.32716	0.18216
75	3.60003	1.15689	2.95404	2.19648	0.17304
80	3.4209	1.10775	2.80272	2.07856	0.16464
85	3.25899	1.06344	2.6658	1.97252	0.1572
90	3.11325	1.02354	2.54256	1.87616	0.15048
95	2.98137	0.98721	2.43168	1.78992	0.14448
100	2.86293	0.95445	2.33196	1.71248	0.13896
150	2.1042	0.74676	1.69296	1.22848	0.10632
200	1.74153	0.64743	1.38972	1.00804	0.09264
250	1.52985	0.58779	1.21524	0.88484	0.0852
300	1.3797	0.54348	1.09248	0.80036	0.08016
350	1.26273	0.50715	0.99684	0.7348	0.07584
400	1.16592	0.47544	0.91884	0.68112	0.07224
450	1.08339	0.44751	0.85248	0.63492	0.06888
500	1.01136	0.42252	0.79488	0.59488	0.066
550	0.94773	0.39942	0.744	0.55968	0.06336
600	0.89082	0.37842	0.69852	0.52756	0.06072
650	0.83958	0.35931	0.65772	0.4994	0.05856
700	0.79317	0.34209	0.62088	0.47344	0.0564
750	0.75075	0.32571	0.5874	0.44968	0.05448
800	0.7119	0.31059	0.55656	0.42768	0.05256
850	0.6762	0.29715	0.52848	0.40788	0.05088
900	0.64323	0.28434	0.50244	0.3894	0.0492
950	0.61299	0.27279	0.47844	0.37268	0.04776
1000	0.58485	0.26187	0.45612	0.3564	0.04656
1500	0.399	0.18921	0.30924	0.25168	0.0372
2000	0.31038	0.15393	0.23964	0.20108	0.0324
2500	0.26607	0.13608	0.2046	0.17512	0.03
3000	0.24171	0.12621	0.18564	0.1606	0.02832
3500	0.22638	0.11949	0.1734	0.15092	0.02736

Average Decay Heat Profile (kW/package) for Waste Stream A—63,000 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
4000	0.21567	0.11487	0.16512	0.14388	0.0264
4500	0.20727	0.11109	0.15864	0.13772	0.02568
5000	0.19971	0.10752	0.15276	0.13244	0.02496
5500	0.19278	0.10437	0.14736	0.1276	0.02424
6000	0.18606	0.10143	0.14232	0.1232	0.02352
6500	0.17976	0.09849	0.13728	0.11924	0.02304
7000	0.1743	0.09576	0.1332	0.11484	0.02256
7500	0.16842	0.09324	0.12864	0.11132	0.02184
8000	0.16317	0.09072	0.12456	0.10736	0.02136
8500	0.15813	0.0882	0.1206	0.10384	0.02088
9000	0.1533	0.08589	0.11688	0.10076	0.0204
9500	0.14868	0.08379	0.11328	0.09724	0.01992
10000	0.14406	0.08148	0.1098	0.09416	0.01944
15000	0.10857	0.06405	0.08244	0.06996	0.0156
20000	0.08442	0.05187	0.06396	0.05368	0.01296
25000	0.06783	0.04284	0.05136	0.04268	0.0108
30000	0.05607	0.03591	0.04224	0.03476	0.00912
35000	0.04704	0.03066	0.03552	0.02904	0.00792
40000	0.04032	0.02646	0.03036	0.02464	0.00696
45000	0.03486	0.02289	0.02628	0.02112	0.006
50000	0.03066	0.02016	0.02304	0.01848	0.00528
55000	0.02709	0.01764	0.0204	0.01628	0.0048
60000	0.02394	0.01554	0.01824	0.01452	0.00432
65000	0.02142	0.01386	0.01632	0.0132	0.00384
70000	0.01932	0.01239	0.01476	0.01188	0.00336
75000	0.01764	0.01113	0.01344	0.01056	0.00312
80000	0.01596	0.01008	0.01224	0.00968	0.00288
85000	0.0147	0.00903	0.01128	0.0088	0.00264
90000	0.01365	0.0084	0.01044	0.00836	0.0024
95000	0.0126	0.00756	0.00972	0.00792	0.00216
100000	0.01176	0.00693	0.00912	0.00704	0.00192
150000	0.00798	0.0042	0.00624	0.00484	0.0012
200000	0.00714	0.00357	0.00576	0.0044	0.0012
250000	0.00693	0.00336	0.00552	0.0044	0.00096
300000	0.00672	0.00336	0.0054	0.0044	0.00096
350000	0.00672	0.00336	0.00528	0.00396	0.00096
400000	0.00651	0.00315	0.00504	0.00396	0.00096
450000	0.0063	0.00315	0.00492	0.00396	0.00096
500000	0.00588	0.00294	0.00468	0.00352	0.00096
550000	0.00567	0.00294	0.00456	0.00352	0.00096
600000	0.00546	0.00273	0.00432	0.00352	0.00072
650000	0.00525	0.00273	0.0042	0.00352	0.00072
700000	0.00525	0.00252	0.00408	0.00308	0.00072
750000	0.00504	0.00252	0.00396	0.00308	0.00072
800000	0.00483	0.00231	0.00372	0.00308	0.00072

Average Decay Heat Profile (kW/package) for Waste Stream A—63,000 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
850000	0.00462	0.00231	0.0036	0.00308	0.00072
900000	0.00462	0.00231	0.0036	0.00264	0.00072
950000	0.00441	0.00231	0.00348	0.00264	0.00072
1000000	0.0042	0.0021	0.00336	0.00264	0.00072

Table 17 Average Decay Curves for CSNF Waste Packages, 83,800 tU Inventory

Average Decay Heat Profile (kW/package) for Waste Stream A – 83,800 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
0.000001	11.32593	3.25731	8.9718	6.99688	0.54096
0.01	11.32194	3.25668	8.96868	6.99468	0.54096
0.02	11.31795	3.25605	8.96544	6.99248	0.54072
0.03	11.31396	3.25542	8.9622	6.98984	0.54072
0.04	11.31018	3.25479	8.95896	6.98764	0.54072
0.05	11.30619	3.25416	8.95572	6.98544	0.54048
0.06	11.3022	3.25353	8.9526	6.98324	0.54048
0.07	11.29842	3.2529	8.94936	6.98104	0.54024
0.08	11.29443	3.25227	8.94624	6.97884	0.54024
0.09	11.29044	3.25164	8.943	6.97664	0.54
0.1	11.28666	3.25101	8.93976	6.97444	0.54
0.15	11.26713	3.24765	8.92404	6.96344	0.53952
0.2	11.24781	3.2445	8.90832	6.95244	0.53904
0.25	11.22891	3.24135	8.89272	6.94144	0.53832
0.3	11.2098	3.2382	8.87724	6.93088	0.53784
0.35	11.19111	3.23505	8.86188	6.91988	0.53736
0.4	11.17242	3.2319	8.84664	6.90932	0.53688
0.45	11.15415	3.22875	8.83164	6.89876	0.5364
0.5	11.13567	3.2256	8.81664	6.8882	0.53592
0.55	11.11761	3.22245	8.80176	6.87808	0.53544
0.6	11.09955	3.2193	8.787	6.86752	0.53496
0.65	11.0817	3.21615	8.77224	6.8574	0.53424
0.7	11.06406	3.21321	8.75772	6.84728	0.53376
0.75	11.04642	3.21006	8.74332	6.83716	0.53328
0.8	11.02899	3.20712	8.72892	6.82704	0.5328
0.85	11.01177	3.20397	8.71476	6.81692	0.53232
0.9	10.99455	3.20103	8.7006	6.80724	0.53184
0.95	10.97754	3.19788	8.68656	6.79712	0.53136
1	10.96053	3.19494	8.67264	6.78744	0.53088
1.5	10.80156	3.16491	8.5416	6.69592	0.52584
2	10.65267	3.13593	8.41896	6.60924	0.5208
2.5	10.51302	3.10695	8.30316	6.5274	0.516
3	10.38135	3.07902	8.19396	6.44996	0.5112
3.5	10.25556	3.0513	8.08992	6.37516	0.5064

Average Decay Heat Profile (kW/package) for Waste Stream A -- 83,800 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
4	10.13628	3.02463	7.99128	6.30388	0.50184
4.5	10.02078	2.99775	7.89612	6.2348	0.49728
5	9.91053	2.97192	7.80552	6.1688	0.49272
5.5	9.8028	2.94546	7.71708	6.1028	0.48816
6	9.6999	2.91984	7.63248	6.03988	0.48384
6.5	9.59826	2.89443	7.54956	5.9774	0.47928
7	9.50082	2.86986	7.47012	5.91712	0.4752
7.5	9.40443	2.84529	7.3914	5.85772	0.47088
8	9.31182	2.82156	7.31568	5.80096	0.4668
8.5	9.21963	2.79783	7.24068	5.74332	0.46248
9	9.13059	2.77473	7.16844	5.68744	0.45864
9.5	9.04197	2.75142	7.09632	5.63288	0.45456
10	8.95629	2.72895	7.02684	5.58008	0.45048
15	8.1732	2.51706	6.39492	5.08728	0.41304
20	7.49763	2.32953	5.85264	4.65696	0.37992
25	6.90543	2.16216	5.37924	4.27416	0.35016
30	6.38106	2.01264	4.96128	3.93756	0.32376
35	5.91591	1.87887	4.59012	3.63748	0.30024
40	5.50242	1.75875	4.26084	3.3704	0.27936
45	5.13156	1.65123	3.96588	3.13104	0.2604
50	4.80018	1.55442	3.70248	2.9172	0.2436
55	4.50429	1.46748	3.468	2.7258	0.22872
60	4.23759	1.38915	3.25668	2.5542	0.21528
65	3.99819	1.3188	3.06792	2.4002	0.20328
70	3.78273	1.25559	2.89668	2.26204	0.19248
75	3.58869	1.19847	2.74296	2.13752	0.18288
80	3.41292	1.14702	2.60424	2.02576	0.17424
85	3.25374	1.10061	2.4786	1.925	0.16656
90	3.11031	1.05861	2.36508	1.83348	0.1596
95	2.98053	1.02039	2.2626	1.7512	0.15336
100	2.86335	0.98595	2.17056	1.67728	0.1476
150	2.11365	0.76881	1.58292	1.2144	0.11376
200	1.75203	0.6657	1.30308	1.001	0.09936
250	1.53972	0.60417	1.14084	0.88088	0.09144
300	1.38852	0.55839	1.0266	0.79772	0.08592
350	1.2705	0.52101	0.93768	0.73304	0.0816
400	1.17306	0.48846	0.86472	0.67936	0.07752
450	1.0899	0.45969	0.80268	0.63404	0.07392
500	1.01745	0.43386	0.7488	0.594	0.0708
550	0.9534	0.41034	0.70128	0.5588	0.06792
600	0.89607	0.38871	0.6588	0.52712	0.06528
650	0.84462	0.36918	0.62064	0.49852	0.06264
700	0.79779	0.35133	0.58608	0.473	0.06048
750	0.75516	0.33453	0.55464	0.44924	0.05832
800	0.7161	0.3192	0.52584	0.42724	0.05616

Average Decay Heat Profile (kW/package) for Waste Stream A -- 83,800 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
850	0.6804	0.30513	0.49944	0.40744	0.05448
900	0.64722	0.29211	0.47508	0.3894	0.0528
950	0.61677	0.28014	0.45264	0.37224	0.05112
1000	0.58863	0.2688	0.43176	0.3564	0.04968
1500	0.40173	0.19425	0.294	0.25168	0.0396
2000	0.31269	0.15813	0.22872	0.20152	0.0348
2500	0.26817	0.13965	0.19584	0.17556	0.03192
3000	0.2436	0.12957	0.17784	0.1606	0.03024
3500	0.22806	0.12285	0.16632	0.15136	0.02904
4000	0.21735	0.11802	0.1584	0.14388	0.02808
4500	0.20874	0.11403	0.15228	0.13816	0.02736
5000	0.20118	0.11046	0.14664	0.13288	0.02664
5500	0.19404	0.1071	0.14148	0.12804	0.02592
6000	0.18753	0.10395	0.13656	0.12364	0.0252
6500	0.18123	0.10122	0.132	0.11924	0.02448
7000	0.17556	0.09828	0.12792	0.11528	0.024
7500	0.16968	0.09555	0.1236	0.11132	0.02328
8000	0.16443	0.09303	0.11964	0.1078	0.0228
8500	0.15918	0.09051	0.11592	0.10428	0.02232
9000	0.15435	0.0882	0.11232	0.10076	0.0216
9500	0.14973	0.08589	0.10884	0.09768	0.02112
10000	0.14511	0.08379	0.1056	0.0946	0.02064
15000	0.1092	0.06573	0.07932	0.06996	0.01656
20000	0.08505	0.05313	0.06168	0.05368	0.01368
25000	0.06825	0.04389	0.04944	0.04268	0.01152
30000	0.05628	0.03696	0.04068	0.03476	0.00984
35000	0.04746	0.0315	0.0342	0.02904	0.0084
40000	0.04053	0.02709	0.02928	0.02464	0.0072
45000	0.03507	0.02352	0.02532	0.02156	0.00648
50000	0.03066	0.02058	0.0222	0.01848	0.00552
55000	0.02709	0.01806	0.01968	0.01628	0.00504
60000	0.02415	0.01596	0.01752	0.01452	0.00432
65000	0.02163	0.01428	0.01572	0.0132	0.00408
70000	0.01953	0.01281	0.01416	0.01188	0.0036
75000	0.01764	0.01134	0.01284	0.01056	0.00312
80000	0.01617	0.01029	0.01176	0.00968	0.00288
85000	0.01491	0.00945	0.0108	0.0088	0.00264
90000	0.01365	0.00861	0.00996	0.00836	0.0024
95000	0.01281	0.00777	0.00924	0.00792	0.00216
100000	0.01197	0.00714	0.00864	0.00704	0.00216
150000	0.00798	0.00441	0.006	0.00484	0.00144
200000	0.00735	0.00378	0.0054	0.0044	0.0012
250000	0.00714	0.00357	0.00516	0.0044	0.0012
300000	0.00693	0.00357	0.00516	0.0044	0.0012
350000	0.00672	0.00336	0.00492	0.00396	0.00096

Average Decay Heat Profile (kW/package) for Waste Stream A -- 83,800 tU CSNF					
Time after loading (y)	Type of Waste Package				
	21 PWR AP	21 PWR CR	12 PWR AP Long	44 BWR AP	24 BWR AP
400000	0.00651	0.00336	0.0048	0.00396	0.00096
450000	0.0063	0.00315	0.00468	0.00396	0.00096
500000	0.00609	0.00294	0.00444	0.00352	0.00096
550000	0.00588	0.00294	0.00432	0.00352	0.00096
600000	0.00567	0.00273	0.00408	0.00352	0.00096
650000	0.00546	0.00273	0.00396	0.00352	0.00072
700000	0.00525	0.00273	0.00384	0.00308	0.00072
750000	0.00504	0.00252	0.00372	0.00308	0.00072
800000	0.00483	0.00252	0.0036	0.00308	0.00072
850000	0.00462	0.00231	0.00348	0.00308	0.00072
900000	0.00462	0.00231	0.00336	0.00264	0.00072
950000	0.00441	0.00231	0.00324	0.00264	0.00072
1000000	0.00441	0.00231	0.00312	0.00264	0.00072

Table 18 Average Decay Curves for HLW and DOE SNF

Time since Empl. (y)	5 IPWF Short (kW/WP)	5 HLW Short - DOE SNF Short (kW/WP)	5 HLW Long - DOE SNF Long (kW/WP)	2 MCO - 2 HLW Long (kW/WP)	5 HLW Long - DOE SNF Short (kW/WP)	5 HLW Long Only (kW/WP)	Year
0.000001	3.5264	2.9312	0.4069	1.6648	0.4069	0.2819	2010
1	3.2451	2.6632	0.3975	1.6264	0.3975	0.2754	2011
2	3.0689	2.4945	0.3882	1.5880	0.3882	0.2689	2012
3	2.9528	2.3877	0.3788	1.5496	0.3788	0.2624	2013
4	2.8668	2.3094	0.3701	1.5142	0.3701	0.2564	2014
5	2.8010	2.2441	0.3614	1.4787	0.3614	0.2504	2015
6	2.7402	2.1872	0.3528	1.4433	0.3528	0.2444	2016
7	2.6896	2.1304	0.3441	1.4079	0.3441	0.2384	2017
8	2.6290	2.0819	0.3362	1.3754	0.3362	0.2329	2018
9	2.5785	2.0292	0.3282	1.3429	0.3282	0.2274	2019
10	2.5331	1.9850	0.3203	1.3104	0.3203	0.2219	2020
11	2.4827	1.9369	0.3131	1.2809	0.3131	0.2169	2021
12	2.4374	1.8928	0.3059	1.2513	0.3059	0.2119	2022
13	2.3921	1.8530	0.2986	1.2218	0.2986	0.2069	2023
14	2.3518	1.8094	0.2914	1.1923	0.2914	0.2019	2024
15	2.3066	1.7697	0.2849	1.1657	0.2849	0.1974	2025
16	2.2664	1.7300	0.2777	1.1362	0.2777	0.1924	2026
17	2.2262	1.6904	0.2712	1.1096	0.2712	0.1879	2027
18	2.1861	1.6508	0.2654	1.0860	0.2654	0.1839	2028
19	2.1509	1.6157	0.2589	1.0594	0.2589	0.1794	2029
20	2.1108	1.5803	0.2525	1.0328	0.2525	0.1749	2030
21	2.0707	1.5448	0.2467	1.0092	0.2467	0.1709	2031
22	2.0406	1.5098	0.2409	0.9856	0.2409	0.1669	2032
23	2.0056	1.4787	0.2351	0.9620	0.2351	0.1629	2033
24	1.9755	1.4479	0.2301	0.9413	0.2301	0.1594	2034
25	1.9354	1.4127	0.2243	0.9176	0.2243	0.1554	2035

Time since Empl. (y)	5 IPWF Short (kW/WP)	5 HLW Short - DOE SNF Short (kW/WP)	5 HLW Long - DOE SNF Long (kW/WP)	2 MCO - 2 HLW Long (kW/WP)	5 HLW Long - DOE SNF Short (kW/WP)	5 HLW Long Only (kW/WP)	Year
26	1.9054	1.4354	0.2192	0.8970	0.2192	0.1519	2036
27	1.8753	1.4072	0.2142	0.8763	0.2142	0.1484	2037
28	1.8403	1.3753	0.2091	0.8556	0.2091	0.1449	2038
29	1.8153	1.3431	0.2041	0.8349	0.2041	0.1414	2039
30	1.7852	1.3154	0.1998	0.8172	0.1998	0.1384	2040
31	1.7552	1.2877	0.1947	0.7966	0.1947	0.1349	2041
32	1.7252	1.2597	0.1904	0.7788	0.1904	0.1319	2042
33	1.7002	1.2321	0.1860	0.7611	0.1860	0.1289	2043
34	1.6701	1.2046	0.1817	0.7434	0.1817	0.1259	2044
35	1.6451	1.1813	0.1774	0.7257	0.1774	0.1229	2045
36	1.6201	1.1534	0.1730	0.7079	0.1730	0.1199	2046
37	1.6001	1.1301	0.1687	0.6902	0.1687	0.1169	2047
38	1.5701	1.1069	0.1651	0.6754	0.1651	0.1144	2048
39	1.5501	1.0837	0.1615	0.6607	0.1615	0.1119	2049
40	1.5251	1.0604	0.1572	0.6430	0.1572	0.1089	2050
41	1.5001	1.0373	0.1535	0.6282	0.1535	0.1064	2051
42	1.4800	1.0142	0.1499	0.6134	0.1499	0.1039	2052
43	1.4600	0.9911	0.1470	0.6016	0.1470	0.1019	2053
44	1.4350	0.9721	0.1434	0.5868	0.1434	0.0994	2054
45	1.4150	0.9532	0.1398	0.5720	0.1398	0.0969	2055
46	1.3950	0.9302	0.1369	0.5602	0.1369	0.0949	2056
47	1.3750	0.9114	0.1333	0.5455	0.1333	0.0924	2057
48	1.3550	0.8929	0.1304	0.5337	0.1304	0.0904	2058
49	1.3350	0.8741	0.1275	0.5218	0.1275	0.0884	2059
50	1.3200	0.8554	0.1247	0.5100	0.1247	0.0864	2060
51	1.3000	0.8366	0.1218	0.4982	0.1218	0.0844	2061
52	1.2800	0.8224	0.1189	0.4864	0.1189	0.0824	2062
53	1.2650	0.8037	0.1160	0.4745	0.1160	0.0804	2063
54	1.2500	0.7851	0.1131	0.4627	0.1131	0.0784	2064
55	1.2300	0.7705	0.1109	0.4539	0.1109	0.0769	2065
56	1.2150	0.7564	0.1081	0.4421	0.1081	0.0749	2066
57	1.2000	0.7377	0.1059	0.4332	0.1059	0.0734	2067
58	1.1800	0.7237	0.1030	0.4214	0.1030	0.0714	2068
59	1.1650	0.7093	0.1008	0.4125	0.1008	0.0699	2069
60	1.1550	0.6948	0.0987	0.4036	0.0987	0.0684	2070
61	1.1400	0.6808	0.0958	0.3918	0.0958	0.0664	2071
62	1.1250	0.6664	0.0936	0.3830	0.0936	0.0649	2072
63	1.1100	0.6525	0.0914	0.3741	0.0914	0.0634	2073
64	1.1000	0.6382	0.0893	0.3652	0.0893	0.0618	2074
65	1.0865	0.6283	0.0878	0.3593	0.0878	0.0608	2075
66	1.0695	0.6144	0.0857	0.3504	0.0857	0.0593	2076
67	1.0585	0.6001	0.0835	0.3416	0.0835	0.0578	2077
68	1.0470	0.5904	0.0813	0.3327	0.0813	0.0563	2078
69	1.0365	0.5760	0.0799	0.3268	0.0799	0.0553	2079
70	1.0205	0.5668	0.0777	0.3179	0.0777	0.0538	2080
71	1.0105	0.5554	0.0763	0.3120	0.0763	0.0528	2081
72	1.0005	0.5445	0.0741	0.3031	0.0741	0.0513	2082
73	0.9855	0.5336	0.0727	0.2972	0.0727	0.0503	2083

Time since Empl. (y)	5 IPWF Short (kW/WP)	5 HLW Short - DOE SNF Short (kW/WP)	5 HLW Long - DOE SNF Long (kW/WP)	2 MCO - 2 HLW Long (kW/WP)	5 HLW Long - DOE SNF Short (kW/WP)	5 HLW Long Only (kW/WP)	Year
74	0.9760	0.5231	0.0710	0.2905	0.0710	0.0492	2084
75	0.9665	0.5130	0.0693	0.2836	0.0693	0.0480	2085
76	0.9575	0.5030	0.0677	0.2771	0.0677	0.0469	2086
77	0.9435	0.4926	0.0662	0.2706	0.0662	0.0458	2087
78	0.9345	0.4833	0.0646	0.2644	0.0646	0.0448	2088
79	0.9260	0.4737	0.0632	0.2585	0.0632	0.0438	2089
80	0.9180	0.4646	0.0617	0.2526	0.0617	0.0428	2090
81	0.9095	0.4558	0.0603	0.2467	0.0603	0.0418	2091
82	0.8965	0.4471	0.0589	0.2411	0.0589	0.0408	2092
83	0.8890	0.4379	0.0576	0.2357	0.0576	0.0399	2093
84	0.8815	0.4296	0.0563	0.2304	0.0563	0.0390	2094
85	0.8740	0.4214	0.0550	0.2251	0.0550	0.0381	2095
86	0.8620	0.4135	0.0537	0.2198	0.0537	0.0372	2096
87	0.8550	0.4056	0.0525	0.2147	0.0525	0.0364	2097
88	0.8480	0.3977	0.0513	0.2100	0.0513	0.0356	2098
89	0.8415	0.3903	0.0502	0.2053	0.0502	0.0348	2099
90	0.8295	0.3830	0.0490	0.2005	0.0490	0.0340	2100
91	0.8235	0.3760	0.0479	0.1961	0.0479	0.0332	2101
92	0.8170	0.3685	0.0469	0.1917	0.0469	0.0325	2102
93	0.8110	0.3619	0.0458	0.1872	0.0458	0.0317	2103
94	0.8050	0.3554	0.0448	0.1831	0.0448	0.0310	2104
95	0.7940	0.3489	0.0437	0.1790	0.0437	0.0303	2105
96	0.7885	0.3424	0.0427	0.1748	0.0427	0.0296	2106
97	0.7830	0.3358	0.0418	0.1710	0.0418	0.0290	2107
98	0.7775	0.3297	0.0408	0.1671	0.0408	0.0283	2108
99	0.7675	0.3236	0.0399	0.1633	0.0399	0.0277	2109
100	0.7620	0.3175	0.0390	0.1597	0.0390	0.0271	2110
110	0.7070	0.2656	0.0311	0.1272	0.0311	0.0215	2120
120	0.6615	0.2233	0.0249	0.1020	0.0249	0.0173	2130
130	0.6235	0.1890	0.0200	0.0819	0.0200	0.0139	2140
140	0.5965	0.1612	0.0162	0.0661	0.0162	0.0112	2150
150	0.5690	0.1390	0.0131	0.0537	0.0131	0.0091	2160
160	0.5485	0.1204	0.0107	0.0439	0.0107	0.0074	2170
170	0.5308	0.1049	0.0088	0.0359	0.0088	0.0061	2180
180	0.5158	0.0923	0.0073	0.0298	0.0073	0.0050	2190
190	0.5032	0.0819	0.0061	0.0250	0.0061	0.0042	2200
200	0.4919	0.0729	0.0052	0.0211	0.0052	0.0036	2210
250	0.4534	0.0452	0.0027	0.0110	0.0027	0.0019	2260
300	0.4303	0.0313	0.0019	0.0078	0.0019	0.0013	2310
350	0.4141	0.0232	0.0016	0.0066	0.0016	0.0011	2360
400	0.4017	0.0181	0.0015	0.0061	0.0015	0.0010	2410
450	0.3916	0.0147	0.0014	0.0058	0.0014	0.0010	2460
500	0.3831	0.0124	0.0014	0.0056	0.0014	0.0009	2510
550	0.3755	0.0107	0.0013	0.0054	0.0013	0.0009	2560
600	0.3690	0.0094	0.0013	0.0052	0.0013	0.0009	2610
650	0.3635	0.0085	0.0012	0.0050	0.0012	0.0008	2660
700	0.3585	0.0078	0.0012	0.0049	0.0012	0.0008	2710
750	0.3535	0.0072	0.0012	0.0047	0.0012	0.0008	2760

Time since Empl. (y)	5 IPWF Short (kW/WP)	5 HLW Short - DOE SNF Short (kW/WP)	5 HLW Long - DOE SNF Long (kW/WP)	2 MCO - 2 HLW Long (kW/WP)	5 HLW Long - DOE SNF Short (kW/WP)	5 HLW Long Only (kW/WP)	Year
800	0.3490	0.0068	0.0011	0.0046	0.0011	0.0008	2810
850	0.3450	0.0064	0.0011	0.0045	0.0011	0.0008	2860
900	0.3415	0.0061	0.0011	0.0044	0.0011	0.0007	2910
950	0.3380	0.0058	0.0011	0.0043	0.0011	0.0007	2960
1000	0.3345	0.0056	0.0010	0.0042	0.0010	0.0007	3010
1500	0.3110	0.0042	0.0009	0.0036	0.0009	0.0006	3510
2000	0.2970	0.0036	0.0008	0.0033	0.0008	0.0006	4010
2500	0.2870	0.0032	0.0008	0.0031	0.0008	0.0005	4510
3000	0.2790	0.0031	0.0007	0.0030	0.0007	0.0005	5010
3500	0.2720	0.0029	0.0007	0.0029	0.0007	0.0005	5510
4000	0.2660	0.0028	0.0007	0.0029	0.0007	0.0005	6010
4500	0.2600	0.0028	0.0007	0.0028	0.0007	0.0005	6510
5000	0.2545	0.0027	0.0007	0.0028	0.0007	0.0005	7010
5500	0.2490	0.0026	0.0007	0.0027	0.0007	0.0005	7510
6000	0.2435	0.0026	0.0007	0.0027	0.0007	0.0005	8010
6500	0.2385	0.0025	0.0006	0.0027	0.0006	0.0004	8510
7000	0.2335	0.0025	0.0006	0.0026	0.0006	0.0004	9010
7500	0.2290	0.0024	0.0006	0.0026	0.0006	0.0004	9510
8000	0.2240	0.0024	0.0006	0.0025	0.0006	0.0004	10010
8500	0.2195	0.0023	0.0006	0.0025	0.0006	0.0004	10510
9000	0.2155	0.0023	0.0006	0.0025	0.0006	0.0004	11010
9500	0.2110	0.0022	0.0006	0.0024	0.0006	0.0004	11510
10000	0.2070	0.0022	0.0006	0.0024	0.0006	0.0004	12010
15000	0.1715	0.0018	0.0005	0.0021	0.0005	0.0004	17010
20000	0.1440	0.0015	0.0005	0.0018	0.0005	0.0003	22010
25000	0.1220	0.0013	0.0004	0.0016	0.0004	0.0003	27010
30000	0.1040	0.0012	0.0004	0.0015	0.0004	0.0002	32010
35000	0.0895	0.0010	0.0003	0.0013	0.0003	0.0002	37010
40000	0.0770	0.0009	0.0003	0.0012	0.0003	0.0002	42010
45000	0.0665	0.0009	0.0003	0.0011	0.0003	0.0002	47010
50000	0.0575	0.0008	0.0002	0.0010	0.0002	0.0002	52010
55000	0.0496	0.0007	0.0002	0.0009	0.0002	0.0002	57010
60000	0.0430	0.0007	0.0002	0.0008	0.0002	0.0001	62010
65000	0.0372	0.0006	0.0002	0.0008	0.0002	0.0001	67010
70000	0.0323	0.0006	0.0002	0.0007	0.0002	0.0001	72010
75000	0.0281	0.0006	0.0002	0.0007	0.0002	0.0001	77010
80000	0.0244	0.0006	0.0002	0.0006	0.0002	0.0001	82010
85000	0.0212	0.0005	0.0001	0.0006	0.0001	0.0001	87010
90000	0.0184	0.0005	0.0001	0.0006	0.0001	0.0001	92010
95000	0.0161	0.0005	0.0001	0.0005	0.0001	0.0001	97010
100000	0.0140	0.0005	0.0001	0.0005	0.0001	0.0001	102010
150000	0.0038	0.0004	0.0001	0.0004	0.0001	0.0001	152010
200000	0.0014	0.0004	0.0001	0.0004	0.0001	0.0001	202010
250000	0.0009	0.0004	0.0001	0.0003	0.0001	0.0001	252010
300000	0.0007	0.0004	0.0001	0.0003	0.0001	0.0001	302010
350000	0.0006	0.0003	0.0001	0.0003	0.0001	0.0001	352010
400000	0.0006	0.0003	0.0001	0.0003	0.0001	0.0001	402010
450000	0.0006	0.0003	0.0001	0.0003	0.0001	0.0001	452010

Time since Empl. (y)	5 IPWF Short (kW/WP)	5 HLW Short - DOE SNF Short (kW/WP)	5 HLW Long - DOE SNF Long (kW/WP)	2 MCO - 2 HLW Long (kW/WP)	5 HLW Long - DOE SNF Short (kW/WP)	5 HLW Long Only (kW/WP)	Year
500000	0.0005	0.0002	0.0001	0.0003	0.0001	0.0001	502010
550000	0.0005	0.0002	0.0001	0.0003	0.0001	0.0001	552010
600000	0.0005	0.0002	0.0001	0.0003	0.0001	0.0000	602010
650000	0.0005	0.0002	0.0001	0.0003	0.0001	0.0000	652010
700000	0.0005	0.0002	0.0001	0.0003	0.0001	0.0000	702010
750000	0.0004	0.0001	0.0001	0.0003	0.0001	0.0000	752010
800000	0.0004	0.0001	0.0001	0.0003	0.0001	0.0000	802010
850000	0.0004	0.0001	0.0001	0.0003	0.0001	0.0000	852010
900000	0.0004	0.0001	0.0001	0.0003	0.0001	0.0000	902010
950000	0.0004	0.0001	0.0001	0.0003	0.0001	0.0000	952010
1000000	0.0004	0.0001	0.0001	0.0003	0.0001	0.0000	1002010

4.2 Item 3

Request: Mass loading for each (averaged) representative waste type

Response: It is presumed that a "representative waste type" refers implies information on a waste package-type basis. The values are shown in Table 19.

Table 19 Initial Heavy Metal Loading by Waste Package

Waste Package	Mass (tHM)
21 PWR AP	9.98 [a]
21 PWR CR	9.98 [a]a
12 PWR AP Long	6.60 [b]
44 BWR AP	8.80 [c]
24 BWR AP	4.80 [c]
5 IPWF	0.135 [d]
5 DHLW Short/1 DOE SNF Short	0.267 = (0.172 [e] + 0.0949 [f])
5 DHLW Long/1 DOE SNF Long	0.992 = (0.850 [g] + 0.142 [h])
2 MCO/2 DHLW Long	10.9 = (10.6 [i] + 0.340 [j])
5 HLW Long/1 DOE SNF Short	0.945 = (0.850 [g] + 0.0949 [f])
5 HLW Long Only	0.850 [g]
Naval Short	0.217 [k]
Naval Long	0.217 [k]

[a]. This mass is based on a value of 0.475 tHM (tonnes of heavy metal) per assembly (CRWMS-M&O 1999a).

[b]. This mass is based on a value of 0.550 tHM per South Texas assembly (CRWMS-M&O 1999a).

[c]. This mass is based on a value of 0.200 tHM per assembly (CRWMS-M&O 1999b).

[d]. This mass is based on a value of 0.027 tHM plutonium per canister (Shaw 1999).

[e]. This mass is based on 5 DHLW Short canisters using a number-weighted average value of 0.0344 tHM per canister of SRS, WVDP, and INEEL canisters using tHM per canister data from Table 5-3 and number of canisters from Table 5-11 of *Source Terms for HLW Glass Canisters* (CRWMS-M&O 2000h), except that 300 canisters of WVDP (instead of 260 from Table 5-11) were used per the MGR PDD (CRWMS-M&O 2000f).

[f]. The DOE SNF Short canister mass of 0.0949 MTHM is based on a total of 390.6 tHM DOE SNF in canisters other than that for the N-Reactor assemblies (390.6 = ~2500 MTHM for Full Inventory case – 2109.4 tHM for the N-Reactor assemblies). This mass is divided between 1570 DOE SNF Short canisters and 1696 DOE SNF Long canisters (CRWMS-M&O 2000e), assuming that a short canister has 2/3 the mass of a long canister (the ratio of the canister lengths), for lack of more detailed information.

[g]. This mass is based on 5 DHLW Long canisters (from Hanford) having 0.170 MTHM per canister from Table 5-3 of *Source Terms for HLW Glass Canisters* (CRWMS-M&O 2000h).

[h]. The DOE SNF Long canister mass of 0.142 tHM is based on the same data and assumption as for footnote f.

[i]. This mass is based on two canisters of N-Reactor fuel having a mass of 5.30 tHM per canister, which is derived from N-Reactor data for TSPA-SR Fuel Group 7 in worksheet "Inventory by Category" within the Microsoft EXCEL spreadsheet 11RW_Input399A.xls on the diskette accompanying *DOE Spent Nuclear Fuel Information in Support of TSPA-SR* (DOE 1999).

[j]. This mass is based on two DOE DHLW Long canisters (from Hanford) having 0.170 tHM per canister from Table 5-3 of *Source Terms for HLW Glass Canisters* (CRWMS-M&O 2000h).

[k]. This mass is based on 65 tHM for 300 Naval packages (Naples, E.M. 1999). No distinction of mass loading is made between the Naval Short and Naval Long packages in the Naval Reactors transmittal.

4.3 Item 4

Request: Representative lineal heat load time-history in kW/m out to 1 million years.

Response: It is assumed that the representative lineal heat load for the entire repository is 1.0 kW/m at emplacement. These values are shown in Table 20. If the average linear power at emplacement is different, these values should be changed proportionately. Information concerning the generation of these values is provided in §4.4.

Table 20 Repository-Averaged Decay Heat Curves

Decay Heat Generation Summary							
Time since Empl. (y)		Repository Total (kW) - Truncated SR Design	Repository Package Average (kW/WP) - Truncated SR Design	Lineal Heat Load (kW/m) - Truncated SR Design	Repository Total (kW) - Full Inventory Case	Repository Package Average (kW/WP) - Full Inventory Case	Lineal Heat Load (kW/m) - Full Inventory Case
	# Packages Truncated SR Design	11184					
	# Packages Full Inventory				14769		
	Year						
0.000001	2010	7.77E+04	6.95E+00	1.00E+00	1.00E+05	6.80E+00	1.00E+00
1	2011	7.50E+04	6.71E+00	9.65E-01	9.70E+04	6.57E+00	9.66E-01
2	2012	7.28E+04	6.51E+00	9.36E-01	9.42E+04	6.38E+00	9.38E-01
3	2013	7.09E+04	6.34E+00	9.12E-01	9.18E+04	6.21E+00	9.14E-01
4	2014	6.91E+04	6.18E+00	8.90E-01	8.96E+04	6.07E+00	8.92E-01
5	2015	6.76E+04	6.04E+00	8.69E-01	8.76E+04	5.93E+00	8.72E-01
6	2016	6.61E+04	5.91E+00	8.51E-01	8.57E+04	5.80E+00	8.54E-01
7	2017	6.47E+04	5.79E+00	8.33E-01	8.40E+04	5.68E+00	8.36E-01
8	2018	6.34E+04	5.67E+00	8.16E-01	8.23E+04	5.57E+00	8.19E-01
9	2019	6.21E+04	5.56E+00	7.99E-01	8.06E+04	5.46E+00	8.03E-01
10	2020	6.09E+04	5.45E+00	7.84E-01	7.91E+04	5.36E+00	7.87E-01
11	2021	5.96E+04	5.33E+00	7.67E-01	7.74E+04	5.24E+00	7.71E-01
12	2022	5.84E+04	5.22E+00	7.52E-01	7.59E+04	5.14E+00	7.55E-01
13	2023	5.73E+04	5.13E+00	7.38E-01	7.45E+04	5.04E+00	7.42E-01
14	2024	5.64E+04	5.04E+00	7.25E-01	7.32E+04	4.96E+00	7.29E-01
15	2025	5.54E+04	4.96E+00	7.13E-01	7.21E+04	4.88E+00	7.17E-01
16	2026	5.44E+04	4.86E+00	6.99E-01	7.07E+04	4.78E+00	7.03E-01
17	2027	5.33E+04	4.77E+00	6.86E-01	6.94E+04	4.70E+00	6.91E-01
18	2028	5.24E+04	4.69E+00	6.74E-01	6.82E+04	4.61E+00	6.79E-01
19	2029	5.15E+04	4.61E+00	6.63E-01	6.70E+04	4.54E+00	6.67E-01
20	2030	5.07E+04	4.53E+00	6.53E-01	6.60E+04	4.47E+00	6.57E-01
21	2031	4.98E+04	4.45E+00	6.40E-01	6.48E+04	4.38E+00	6.45E-01
22	2032	4.89E+04	4.37E+00	6.29E-01	6.36E+04	4.31E+00	6.33E-01

Decay Heat Generation Summary

Time since Empl. (y)	Year	Repository Total (kW) - Truncated SR Design	Repository Package Average (kW/WP) - Truncated SR Design	Lineal Heat Load (kW/m) - Truncated SR Design	Repository Total (kW) - Full Inventory Case	Repository Package Average (kW/WP) - Full Inventory Case	Lineal Heat Load (kW/m) - Full Inventory Case
	# Packages Truncated SR Design	11184					
	# Packages Full Inventory				14769		
	Year						
23	2033	4.81E+04	4.30E+00	6.19E-01	6.26E+04	4.24E+00	6.23E-01
24	2034	4.73E+04	4.23E+00	6.08E-01	6.16E+04	4.17E+00	6.13E-01
25	2035	4.65E+04	4.16E+00	5.99E-01	6.06E+04	4.10E+00	6.03E-01
26	2036	4.58E+04	4.09E+00	5.89E-01	5.96E+04	4.04E+00	5.94E-01
27	2037	4.50E+04	4.03E+00	5.79E-01	5.86E+04	3.97E+00	5.84E-01
28	2038	4.43E+04	3.96E+00	5.70E-01	5.77E+04	3.91E+00	5.74E-01
29	2039	4.36E+04	3.90E+00	5.61E-01	5.68E+04	3.84E+00	5.65E-01
30	2040	4.29E+04	3.84E+00	5.52E-01	5.59E+04	3.79E+00	5.57E-01
31	2041	4.22E+04	3.77E+00	5.43E-01	5.50E+04	3.72E+00	5.48E-01
32	2042	4.15E+04	3.71E+00	5.34E-01	5.41E+04	3.66E+00	5.39E-01
33	2043	4.09E+04	3.65E+00	5.26E-01	5.33E+04	3.61E+00	5.30E-01
34	2044	4.02E+04	3.60E+00	5.18E-01	5.25E+04	3.55E+00	5.22E-01
35	2045	3.96E+04	3.54E+00	5.10E-01	5.17E+04	3.50E+00	5.15E-01
36	2046	3.90E+04	3.49E+00	5.02E-01	5.09E+04	3.45E+00	5.07E-01
37	2047	3.84E+04	3.43E+00	4.94E-01	5.01E+04	3.39E+00	4.99E-01
38	2048	3.78E+04	3.38E+00	4.87E-01	4.94E+04	3.34E+00	4.91E-01
39	2049	3.73E+04	3.33E+00	4.79E-01	4.86E+04	3.29E+00	4.84E-01
40	2050	3.67E+04	3.28E+00	4.73E-01	4.79E+04	3.25E+00	4.77E-01
41	2051	3.62E+04	3.23E+00	4.65E-01	4.72E+04	3.20E+00	4.70E-01
42	2052	3.56E+04	3.18E+00	4.58E-01	4.65E+04	3.15E+00	4.63E-01
43	2053	3.51E+04	3.14E+00	4.52E-01	4.58E+04	3.10E+00	4.56E-01
44	2054	3.46E+04	3.09E+00	4.45E-01	4.52E+04	3.06E+00	4.50E-01
45	2055	3.41E+04	3.05E+00	4.39E-01	4.46E+04	3.02E+00	4.44E-01
46	2056	3.36E+04	3.01E+00	4.32E-01	4.39E+04	2.97E+00	4.37E-01
47	2057	3.31E+04	2.96E+00	4.26E-01	4.33E+04	2.93E+00	4.31E-01
48	2058	3.27E+04	2.92E+00	4.20E-01	4.27E+04	2.89E+00	4.25E-01
49	2059	3.22E+04	2.88E+00	4.15E-01	4.21E+04	2.85E+00	4.19E-01
50	2060	3.18E+04	2.84E+00	4.09E-01	4.16E+04	2.81E+00	4.14E-01
51	2061	3.13E+04	2.80E+00	4.03E-01	4.10E+04	2.78E+00	4.08E-01
52	2062	3.09E+04	2.76E+00	3.98E-01	4.04E+04	2.74E+00	4.03E-01
53	2063	3.05E+04	2.73E+00	3.92E-01	3.99E+04	2.70E+00	3.97E-01
54	2064	3.01E+04	2.69E+00	3.87E-01	3.94E+04	2.67E+00	3.92E-01

Decay Heat Generation Summary							
Time since Empl. (y)		Repository Total (kW) - Truncated SR Design	Repository Package Average (kW/WP) - Truncated SR Design	Lineal Heat Load (kW/m) - Truncated SR Design	Repository Total (kW) - Full Inventory Case	Repository Package Average (kW/WP) - Full Inventory Case	Lineal Heat Load (kW/m) - Full Inventory Case
	# Packages Truncated SR Design	11184					
	# Packages Full Inventory				14769		
	Year						
55	2065	2.97E+04	2.66E+00	3.82E-01	3.89E+04	2.63E+00	3.87E-01
56	2066	2.93E+04	2.62E+00	3.77E-01	3.84E+04	2.60E+00	3.82E-01
57	2067	2.89E+04	2.59E+00	3.72E-01	3.79E+04	2.56E+00	3.77E-01
58	2068	2.85E+04	2.55E+00	3.67E-01	3.74E+04	2.53E+00	3.72E-01
59	2069	2.82E+04	2.52E+00	3.63E-01	3.69E+04	2.50E+00	3.68E-01
60	2070	2.78E+04	2.49E+00	3.58E-01	3.65E+04	2.47E+00	3.63E-01
61	2071	2.75E+04	2.46E+00	3.53E-01	3.60E+04	2.44E+00	3.58E-01
62	2072	2.71E+04	2.43E+00	3.49E-01	3.56E+04	2.41E+00	3.54E-01
63	2073	2.68E+04	2.40E+00	3.45E-01	3.51E+04	2.38E+00	3.50E-01
64	2074	2.65E+04	2.37E+00	3.40E-01	3.47E+04	2.35E+00	3.45E-01
65	2075	2.61E+04	2.34E+00	3.36E-01	3.43E+04	2.32E+00	3.41E-01
66	2076	2.58E+04	2.31E+00	3.32E-01	3.39E+04	2.29E+00	3.37E-01
67	2077	2.55E+04	2.28E+00	3.28E-01	3.35E+04	2.27E+00	3.33E-01
68	2078	2.52E+04	2.25E+00	3.24E-01	3.31E+04	2.24E+00	3.29E-01
69	2079	2.49E+04	2.23E+00	3.21E-01	3.27E+04	2.22E+00	3.26E-01
70	2080	2.46E+04	2.20E+00	3.17E-01	3.23E+04	2.19E+00	3.22E-01
71	2081	2.43E+04	2.18E+00	3.13E-01	3.20E+04	2.17E+00	3.18E-01
72	2082	2.41E+04	2.15E+00	3.10E-01	3.16E+04	2.14E+00	3.15E-01
73	2083	2.38E+04	2.13E+00	3.06E-01	3.13E+04	2.12E+00	3.11E-01
74	2084	2.35E+04	2.10E+00	3.03E-01	3.09E+04	2.09E+00	3.08E-01
75	2085	2.33E+04	2.08E+00	3.00E-01	3.06E+04	2.07E+00	3.05E-01
76	2086	2.30E+04	2.06E+00	2.96E-01	3.03E+04	2.05E+00	3.01E-01
77	2087	2.28E+04	2.04E+00	2.93E-01	2.99E+04	2.03E+00	2.98E-01
78	2088	2.25E+04	2.01E+00	2.90E-01	2.96E+04	2.01E+00	2.95E-01
79	2089	2.23E+04	1.99E+00	2.87E-01	2.93E+04	1.98E+00	2.92E-01
80	2090	2.21E+04	1.97E+00	2.84E-01	2.90E+04	1.96E+00	2.89E-01
81	2091	2.18E+04	1.95E+00	2.81E-01	2.87E+04	1.94E+00	2.86E-01
82	2092	2.16E+04	1.93E+00	2.78E-01	2.84E+04	1.92E+00	2.83E-01
83	2093	2.14E+04	1.91E+00	2.75E-01	2.81E+04	1.91E+00	2.80E-01
84	2094	2.12E+04	1.89E+00	2.72E-01	2.79E+04	1.89E+00	2.77E-01
85	2095	2.09E+04	1.87E+00	2.70E-01	2.76E+04	1.87E+00	2.75E-01
86	2096	2.07E+04	1.85E+00	2.67E-01	2.73E+04	1.85E+00	2.72E-01

Decay Heat Generation Summary							
Time since Empl. (y)		Repository Total (kW) - Truncated SR Design	Repository Package Average (kW/WP) - Truncated SR Design	Lineal Heat Load (kW/m) - Truncated SR Design	Repository Total (kW) - Full Inventory Case	Repository Package Average (kW/WP) - Full Inventory Case	Lineal Heat Load (kW/m) - Full Inventory Case
	# Packages Truncated SR Design	11184					
	# Packages Full Inventory				14769		
	Year						
87	2097	2.05E+04	1.84E+00	2.64E-01	2.71E+04	1.83E+00	2.69E-01
88	2098	2.03E+04	1.82E+00	2.62E-01	2.68E+04	1.81E+00	2.67E-01
89	2099	2.01E+04	1.80E+00	2.59E-01	2.65E+04	1.80E+00	2.64E-01
90	2100	1.99E+04	1.78E+00	2.57E-01	2.63E+04	1.78E+00	2.62E-01
91	2101	1.98E+04	1.77E+00	2.54E-01	2.61E+04	1.76E+00	2.59E-01
92	2102	1.96E+04	1.75E+00	2.52E-01	2.58E+04	1.75E+00	2.57E-01
93	2103	1.94E+04	1.73E+00	2.50E-01	2.56E+04	1.73E+00	2.55E-01
94	2104	1.92E+04	1.72E+00	2.47E-01	2.54E+04	1.72E+00	2.52E-01
95	2105	1.91E+04	1.70E+00	2.45E-01	2.51E+04	1.70E+00	2.50E-01
96	2106	1.89E+04	1.69E+00	2.43E-01	2.49E+04	1.69E+00	2.48E-01
97	2107	1.87E+04	1.67E+00	2.41E-01	2.47E+04	1.67E+00	2.46E-01
98	2108	1.86E+04	1.66E+00	2.39E-01	2.45E+04	1.66E+00	2.44E-01
99	2109	1.84E+04	1.64E+00	2.37E-01	2.43E+04	1.64E+00	2.42E-01
100	2110	1.82E+04	1.63E+00	2.35E-01	2.41E+04	1.63E+00	2.40E-01
110	2120	1.69E+04	1.51E+00	2.17E-01	2.23E+04	1.51E+00	2.22E-01
120	2130	1.57E+04	1.41E+00	2.03E-01	2.08E+04	1.41E+00	2.07E-01
130	2140	1.48E+04	1.32E+00	1.90E-01	1.96E+04	1.32E+00	1.95E-01
140	2150	1.39E+04	1.24E+00	1.79E-01	1.84E+04	1.25E+00	1.84E-01
150	2160	1.31E+04	1.18E+00	1.69E-01	1.75E+04	1.18E+00	1.74E-01
160	2170	1.26E+04	1.12E+00	1.62E-01	1.67E+04	1.13E+00	1.66E-01
170	2180	1.21E+04	1.08E+00	1.55E-01	1.60E+04	1.09E+00	1.60E-01
180	2190	1.16E+04	1.04E+00	1.49E-01	1.54E+04	1.04E+00	1.54E-01
190	2200	1.12E+04	9.99E-01	1.44E-01	1.49E+04	1.01E+00	1.48E-01
200	2210	1.08E+04	9.64E-01	1.39E-01	1.44E+04	9.72E-01	1.43E-01
250	2260	9.44E+03	8.44E-01	1.22E-01	1.26E+04	8.52E-01	1.25E-01
300	2310	8.51E+03	7.61E-01	1.10E-01	1.14E+04	7.69E-01	1.13E-01
350	2360	7.79E+03	6.97E-01	1.00E-01	1.04E+04	7.04E-01	1.03E-01
400	2410	7.20E+03	6.44E-01	9.27E-02	9.60E+03	6.50E-01	9.56E-02
450	2460	6.70E+03	5.99E-01	8.62E-02	8.93E+03	6.05E-01	8.89E-02
500	2510	6.26E+03	5.60E-01	8.05E-02	8.35E+03	5.65E-01	8.31E-02
550	2560	5.87E+03	5.25E-01	7.56E-02	7.83E+03	5.30E-01	7.80E-02
600	2610	5.53E+03	4.94E-01	7.11E-02	7.37E+03	4.99E-01	7.34E-02

Decay Heat Generation Summary

Time since Empl. (y)		Repository Total (kW) - Truncated SR Design	Repository Package Average (kW/WP) - Truncated SR Design	Lineal Heat Load (kW/m) - Truncated SR Design	Repository Total (kW) - Full Inventory Case	Repository Package Average (kW/WP) - Full Inventory Case	Lineal Heat Load (kW/m) - Full Inventory Case
	# Packages Truncated SR Design	11184					
	# Packages Full Inventory				14769		
	Year						
650	2660	5.22E+03	4.66E-01	6.71E-02	6.96E+03	4.71E-01	6.92E-02
700	2710	4.93E+03	4.41E-01	6.35E-02	6.58E+03	4.46E-01	6.55E-02
750	2760	4.68E+03	4.18E-01	6.02E-02	6.24E+03	4.22E-01	6.21E-02
800	2810	4.44E+03	3.97E-01	5.71E-02	5.92E+03	4.01E-01	5.89E-02
850	2860	4.22E+03	3.78E-01	5.43E-02	5.63E+03	3.81E-01	5.61E-02
900	2910	4.02E+03	3.60E-01	5.18E-02	5.37E+03	3.63E-01	5.34E-02
950	2960	3.84E+03	3.43E-01	4.94E-02	5.12E+03	3.47E-01	5.10E-02
1000	3010	3.67E+03	3.28E-01	4.72E-02	4.89E+03	3.31E-01	4.87E-02
1500	3510	2.54E+03	2.27E-01	3.26E-02	3.38E+03	2.29E-01	3.37E-02
2000	4010	1.99E+03	1.78E-01	2.57E-02	2.66E+03	1.80E-01	2.65E-02
2500	4510	1.72E+03	1.54E-01	2.21E-02	2.30E+03	1.56E-01	2.29E-02
3000	5010	1.57E+03	1.40E-01	2.02E-02	2.10E+03	1.42E-01	2.09E-02
3500	5510	1.47E+03	1.32E-01	1.90E-02	1.97E+03	1.33E-01	1.96E-02
4000	6010	1.40E+03	1.26E-01	1.81E-02	1.88E+03	1.27E-01	1.87E-02
4500	6510	1.35E+03	1.21E-01	1.74E-02	1.80E+03	1.22E-01	1.79E-02
5000	7010	1.30E+03	1.16E-01	1.67E-02	1.74E+03	1.18E-01	1.73E-02
5500	7510	1.25E+03	1.12E-01	1.61E-02	1.67E+03	1.13E-01	1.67E-02
6000	8010	1.21E+03	1.08E-01	1.56E-02	1.62E+03	1.10E-01	1.61E-02
6500	8510	1.17E+03	1.05E-01	1.51E-02	1.56E+03	1.06E-01	1.56E-02
7000	9010	1.13E+03	1.01E-01	1.46E-02	1.51E+03	1.03E-01	1.51E-02
7500	9510	1.10E+03	9.81E-02	1.41E-02	1.46E+03	9.91E-02	1.46E-02
8000	10010	1.06E+03	9.49E-02	1.37E-02	1.42E+03	9.61E-02	1.41E-02
8500	10510	1.03E+03	9.20E-02	1.32E-02	1.37E+03	9.30E-02	1.37E-02
9000	11010	9.98E+02	8.92E-02	1.28E-02	1.33E+03	9.01E-02	1.33E-02
9500	11510	9.66E+02	8.64E-02	1.24E-02	1.29E+03	8.74E-02	1.29E-02
10000	12010	9.37E+02	8.37E-02	1.21E-02	1.25E+03	8.48E-02	1.25E-02
15000	17010	7.05E+02	6.30E-02	9.07E-03	9.40E+02	6.37E-02	9.36E-03
20000	22010	5.48E+02	4.90E-02	7.05E-03	7.31E+02	4.95E-02	7.28E-03
25000	27010	4.40E+02	3.93E-02	5.66E-03	5.87E+02	3.97E-02	5.84E-03
30000	32010	3.63E+02	3.24E-02	4.66E-03	4.83E+02	3.27E-02	4.81E-03
35000	37010	3.04E+02	2.72E-02	3.91E-03	4.07E+02	2.75E-02	4.05E-03
40000	42010	2.60E+02	2.33E-02	3.35E-03	3.47E+02	2.35E-02	3.45E-03

Decay Heat Generation Summary							
Time since Empl. (y)		Repository Total (kW) - Truncated SR Design	Repository Package Average (kW/WP) - Truncated SR Design	Lineal Heat Load (kW/m) - Truncated SR Design	Repository Total (kW) - Full Inventory Case	Repository Package Average (kW/WP) - Full Inventory Case	Lineal Heat Load (kW/m) - Full Inventory Case
	# Packages Truncated SR Design	11184					
	# Packages Full Inventory				14769		
	Year						
45000	47010	2.25E+02	2.01E-02	2.89E-03	3.01E+02	2.04E-02	3.00E-03
50000	52010	1.97E+02	1.76E-02	2.54E-03	2.62E+02	1.77E-02	2.61E-03
55000	57010	1.74E+02	1.56E-02	2.24E-03	2.31E+02	1.57E-02	2.30E-03
60000	62010	1.54E+02	1.38E-02	1.98E-03	2.06E+02	1.39E-02	2.05E-03
65000	67010	1.38E+02	1.24E-02	1.78E-03	1.85E+02	1.25E-02	1.84E-03
70000	72010	1.25E+02	1.12E-02	1.60E-03	1.67E+02	1.13E-02	1.66E-03
75000	77010	1.13E+02	1.01E-02	1.45E-03	1.50E+02	1.02E-02	1.49E-03
80000	82010	1.03E+02	9.17E-03	1.32E-03	1.37E+02	9.30E-03	1.37E-03
85000	87010	9.40E+01	8.40E-03	1.21E-03	1.26E+02	8.53E-03	1.25E-03
90000	92010	8.77E+01	7.84E-03	1.13E-03	1.16E+02	7.89E-03	1.16E-03
95000	97010	8.15E+01	7.28E-03	1.05E-03	1.09E+02	7.41E-03	1.09E-03
100000	102010	7.50E+01	6.70E-03	9.65E-04	1.01E+02	6.82E-03	1.00E-03
150000	152010	5.06E+01	4.52E-03	6.51E-04	6.73E+01	4.55E-03	6.70E-04
200000	202010	4.53E+01	4.05E-03	5.83E-04	6.14E+01	4.16E-03	6.11E-04
250000	252010	4.43E+01	3.96E-03	5.69E-04	6.00E+01	4.06E-03	5.97E-04
300000	302010	4.33E+01	3.87E-03	5.57E-04	5.87E+01	3.98E-03	5.85E-04
350000	352010	4.20E+01	3.75E-03	5.40E-04	5.57E+01	3.77E-03	5.55E-04
400000	402010	4.10E+01	3.66E-03	5.27E-04	5.44E+01	3.69E-03	5.42E-04
450000	452010	4.00E+01	3.58E-03	5.15E-04	5.31E+01	3.60E-03	5.29E-04
500000	502010	3.69E+01	3.30E-03	4.74E-04	5.02E+01	3.40E-03	4.99E-04
550000	552010	3.59E+01	3.21E-03	4.62E-04	4.89E+01	3.31E-03	4.87E-04
600000	602010	3.49E+01	3.12E-03	4.49E-04	4.76E+01	3.22E-03	4.73E-04
650000	652010	3.40E+01	3.04E-03	4.37E-04	4.63E+01	3.13E-03	4.61E-04
700000	702010	3.26E+01	2.92E-03	4.20E-04	4.34E+01	2.94E-03	4.32E-04
750000	752010	3.17E+01	2.83E-03	4.08E-04	4.21E+01	2.85E-03	4.19E-04
800000	802010	3.07E+01	2.75E-03	3.95E-04	4.08E+01	2.77E-03	4.07E-04
850000	852010	2.98E+01	2.66E-03	3.83E-04	3.96E+01	2.68E-03	3.94E-04
900000	902010	2.85E+01	2.55E-03	3.67E-04	3.79E+01	2.56E-03	3.77E-04
950000	952010	2.76E+01	2.47E-03	3.55E-04	3.66E+01	2.48E-03	3.65E-04
1000000	1002010	2.66E+01	2.38E-03	3.43E-04	3.66E+01	2.48E-03	3.64E-04

4.4 Item 5

Request: Overall repository-wide averaged heat decay curve in kW as a function of time.

Response: This information is provided in Table 20. The following restrictions apply to this information:

- When interpolation was necessary, the previously validated equation (power log interpolation) from the Spent Nuclear Fuel Decay Heat Function code (CRWMS M&O 1996, pp. 9-11) was used.
- For the 2-MCO/2-DHLW Long co-disposal package, each MCO canister is assumed to have a decay heat generation rate of 776 W at emplacement (DOE 2000b) and to decay at the same rate as the DHLW Long glass canisters in the same package. This assumption is necessary since no data are available for the actual decay rate and assuming no decay would be too conservative.
- For all co-disposal packages except the 2-MCO/2-DHLW Long package, each DOE SNF canister is assumed to have a heat generation rate of 125 W at emplacement (CRWMS M&O 2000a) and to decay at the same rate as the average DOE HLW glass canister in the same package. Again, this assumption is necessary since no decay rate data are available.
- The data for the Navy packages are taken from the Naval Reactors transmittal (Naples, E.M. 1999), which gives decay heat generation rates only out to 241 years. The power log interpolation formula, was used to extrapopolate just to the next time point of 250 years. Since we cannot make any assumptions about the classified navy fuel, it is assumed that the decay heat generation (kW per package) is zero after that time. It should be noted that the rate per package at 241 years is only 0.01 kW per package and this assumption should have a negligible effect.

4.5 Item 6

Request: Total waste mass including total for commercial and non-commercial waste.

Response: This information will be provided in a future transmittal.

4.6 Item 7

Request: Waste Package Emplacement Strategy including schedule and where CSNF and DSNF will be located at emplacement.

Response: It is assumed that the information supplied in the response provided in §2.2 fully satisfies this request.

5 Responses to §VIII of Request, Mechanical Response of EBS Elements to Postclosure Ground Motion and Fault Displacement

5.1 Item 2

Request: Structural response of the drip shield to the 10^{-8} annual frequency ground motion spectrum and 10^{-8} fault displacement: a) provide structural response in as-emplaced condition, and b) provide structural response in corroded state.

Response: The dynamic response of both the continuous and stand alone drip shield to severe ground motion is complex and not amenable to kinematic analysis; therefore, in the absence of detailed ground motion time histories, it must be assumed that these extreme ground motion events result in the loss of all drip shield functions.

5.2 Item 4

Request: Time dependent structural response of the drip shield to rock falls; a) permanent deflection of the drip shield due to rock fall, b) incidence of stress corrosion cracking due to rock fall, c) uncertainty range in permanent deflection and number of stress corrosion sites, and d) provide structural response in both as-emplaced and corroded states.

Response: This information will be provided in a subsequent transmittal on a mutually agreed upon schedule.

5.3 Item 5

Request: Structural response of the emplacement pallet to the 10^{-8} annual frequency ground motion spectrum and 10^{-8} fault displacement: a) provide structural response in as-emplaced state, and b) provide structural response in a corroded state; lifetime function indicating pallet failure over time.

Response: The dynamic response of the emplacement pallet to severe ground motion is complex and not amenable to kinematic analysis; therefore, in the absence of detailed ground motion time histories, it must be assumed that these extreme ground motion events result in the loss of all emplacement pallet functions.

5.4 Item 6

Request: Structural response of the waste package to the 10^{-8} annual frequency ground motion spectrum and 10^{-8} fault displacement: a) provide structural response in as-emplaced state, and b) provide structural response in a corroded state; lifetime function indicating pallet failure over time.

Response: This information will be provided in a subsequent transmittal on a mutually agreed upon schedule. It should be noted that this a rudimentary kinematic evaluation and will be quite conservative.

6 Responses to §IX of Request, Thermal Response of Drip Shield

6.1 Item 1

Request: Physical dimensions of the drip shield, particularly clearances between adjacent segments of the drip shield

Response: It is assumed that the information supplied in the response provided in §3.1 fully satisfies this request.

6.2 Item 2

Request: Maximum temperature of the drip shield for various waste package types, waste package spacings, and ventilation histories.

Response: The maximum temperature of the drip shield, considering various designs should conservatively be taken to be 85°C, since the external temperature of the waste package is limited to 85°C by design. For the emplaced waste package covered by a drip shield, the temperature of the drip shield is only slightly less than the peak waste package temperature because, radiative heat transfer largely equilibrates the waste package and drip shield surface temperatures within the drift.

6.3 Item 3

Request: Thermal expansion coefficient of titanium or drip shield material

Response: The thermal expansion coefficients for titanium, grade 7, are shown in Table 21.

Table 21 Thermal Expansion Coefficients for Titanium, Grade 7

°F	°C	in/in/°F	in/in/°F
		α_i [a,c]	α_m [b,c]
70	21.11	4.64	4.64
100	37.78	4.66	4.65
150	65.56	4.7	4.68
200	93.33	4.75	4.7
250	121.11	4.79	4.72
300	148.89	4.83	4.75
350	176.67	4.87	4.78
400	204.44	4.91	4.8

[a]. α_i is the instantaneous coefficient of thermal expansion

[b]. α_m is the mean coefficient of thermal expansion (i. e., averaged from 70°F to the indicated temperature).

[c]. *ASME Boiler and Pressure Vessel Code.* Section II, Part D (ASME 1995, Table TE-5).

6.4 Item 4

Request: Uncertainties in maximum temperature and thermal expansion coefficients

Response: Based on the logic delineated in the response in §6.2, the uncertainty in the drip shield maximum surface temperature should be comparable to the computed uncertainties in the waste package maximum surface temperature. An assessment of the uncertainties in the thermal expansion coefficients will be provided in a future transmittal.

7 Responses to §X of Request, Mechanical Response of the Emplacement Pallet

7.1 Item 1

Request: Physical dimensions of the emplacement pallet

Response: This information is provided in §3.5.

7.2 Item 2

Request: Structural response of the emplacement pallet and waste package design to 10-8 ground motion event.

Response: The response to this request is equivalent to that provided in §5.

8 References

Avallone, E. A. and Baumeister, T. III, ed. 1987. *Marks' Standard Handbook for Mechanical Engineers.* 9th Edition. New York, New York: McGraw-Hill. TIC 206891.

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

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 Material. TIC: 241816.

ASTM G 1-90 (Reapproved 1999). 1990. *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens.* West Conshohocken, Pennsylvania: American Society for Testing Material. TIC: 238771.

CRWMS M&O 1996. *Software qualification Report for the Spent Nuclear Fuel Decay Heat Function (SNFDHF)*,20026-2003, Rev. 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOV.19970212.0231.

CRWMS-M&O 1999a. *PWR Source Term Generation and Evaluation.* BBAC-00000-01717-0210-0010 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000113.0333.

CRWMS-M&O 1999b. *BWR Source Term Generation and Evaluation.* BBAC-00000-01717-0210-0006 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000113.0334.

CRWMS M&O 1999c. *Thermal Calculation of the Waste Package with Backfill.* BB0000000-01717-0210-00001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19981214.0073. (p. 8)

CRWMS M&O 2000. *Design Analysis for the Ex-Container Components.* ANL-XCS-ME-000001 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000525.0374.

CRWMS M&O 2000a. *Design Analysis for UCF Waste Packages.* ANL-UDC-MD-000001 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000526.0336.

CRWMS M&O 2000b. *Design Analysis for Defense High-Level Waste Disposal Container.* ANL-DDC-ME-000001 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000627.0254.

CRWMS M&O 2000c. *Design Analysis for the Naval SNF Waste Package.* ANL-VDC-ME-000001 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000915.0029.

CRWMS M&O 2000d. *Waste Package Design Methodology Report.* ANL-EBS-MD-000053 REV 00. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000526.0335.

CRWMS-M&O 2000e. *DOE and Commercial Waste package Inventory: Various Input Scenarios for Design.* Input Transmittal RSO-SSR-099360.Ta. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000317.0388.

CRWMS-M&O 2000f. *Monitored Geologic Repository Project Description Document.* TDR-MGR-SE-000004 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001031.0062.

CRWMS-M&O 2000g. *Waste Packages and Source Terms for the Commercial 1999 Design Basis Waste Streams.* CAL-MGR-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000214.0479.

CRWMS-M&O 2000h. *Source Terms for HLW Glass Canisters.* CAL-MGR-NU-000002 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000823.0004.

CRWMS M&O 2000i. *Thermal Loading Study of 44-BWR Waste Package.* CAL-UDC-TH-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000605.0429

CRWMS M&O 2001. Input Request, Design Input for the Engineered Barrier System Environment and Barriers. 00422.R. Las Vegas, NV: CRMWS M&O. ACC: pending.

DOE 1999. *DOE Spent Nuclear Fuel Information in Support of TSPA-SR.* DOE/SNF/REP-0047 Rev. 0. Idaho Falls, Idaho: U.S. Department of Energy, Spent Fuel Management Office. TIC: 245482.

DOE 2000a. *Civilian Radioactive Waste Management System Requirements Document.* DOE/RW-0406 Rev. 5, DCN 02 (A00000000-00811-1708-00003 REV 05 DCN 02). Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20010117.0341.

DOE 2000b. *N Reactor (U-metal) Fuel Characteristics for Disposal Criticality Analysis.* DOE/SNF/REP-056 Rev. 0. Idaho Falls, Idaho: U.S. Department of Energy, Office of Nuclear Material and Spent Fuel. TIC: 247956.

Haynes International 1997. *Hastelloy C-22 Alloy.* Kokomo, Indiana: Haynes International, Inc. TIC: 238121.

Lide, D. R., ed. 1995. *CRC Handbook of Chemistry and Physics.* 76th Edition. Boca Raton, Florida: CRC Press. TIC: 216194.

Naples, E.M. 1999. Thermal, Shielding, and Structural Information on the Naval Spent Nuclear Fuel (SNF) Canister. Letter from E.M. Naples (Department of the Navy) to D.C. Haught (DOE/YMSCO), August 6, 1999, with enclosures. ACC: MOL.19991001.0133.

Shaw, H., ed., 1999. *Plutonium Immobilization Project Input for Yucca Mountain Total Systems Performance Assessment.* PIP-99-107. Livermore, California: Lawrence Livermore National Laboratory. TIC: 245437.

YMP 2000. *Monitored Geologic Repository Requirements Document.* YMP/CM-0025, Rev. 3, DCN 02. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.20000720.0540.

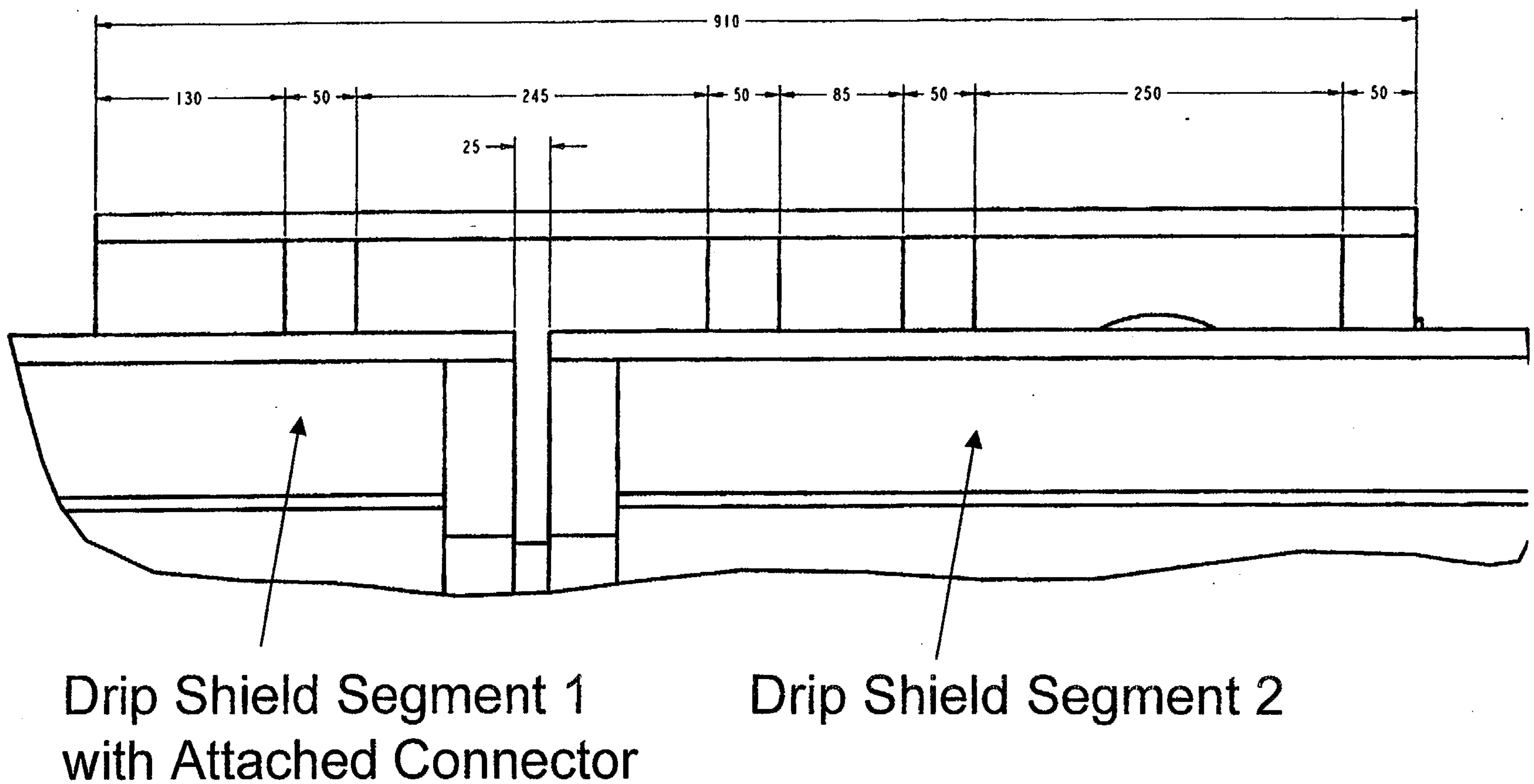

Figure 2 Drip Shield Overlap

Item 4

Hydrologic and Thermal Properties of the Invert (from *Water Distribution and Removal Model*, ANL-EBS-MD-000032 REV 01, Attachment XIV. MOL Pending)

ATTACHMENT XIV.

Hydrologic and Thermal Properties of the Invert

Attachment XIV. Hydrologic and Thermal Properties of the invert

Crushed tuff is selected for the invert (Section 4.1.2.4) to provide geochemical compatibility with the surrounding host rock. The basis for the selection of the crushed is that the material provides diffusion-barrier performance when transport from the waste package to the rock floor is diffusion dominated. This could occur if a waste package is breached but the protecting drip shield is intact, so that the invert ballast material immediately below the drip shield is unsaturated and protected from advective flow from other engineered barrier components.

Crushed welded tuff sieved between 2.0 and 4.75 mm has been selected for pilot testing and the properties are described below for this material. The final design may require a different size distribution or material type, or both.

XIV.1 Bulk Density and Porosity

The invert material is crushed tuff from the Tptpll lithostratigraphic unit which is part of the TSw2 thermal/mechanical unit (CRWMS M&O 2000v, p.13). The Repository Host Horizon is located mainly in the TSw2 unit. The invert material hydrological properties are presently unavailable for the Tptpll formation. Properties for Tptpmn are used in this analysis. It is valid to substitute the Tptpmn properties in place of Tptpll values because they are both part of the TSw2 thermal/mechanical unit (CRWMS M&O 2000v, p.13).

The U.S.Geological Survey measured the bulk density, water retention, and unsaturated hydraulic conductivity. These properties were measured in conjunction with the UFA measurements as described subsequently. The hydrologic and geotechnical properties for the crushed tuff are taken from U. S. Geological Survey (USGS) testing entitled *Water Retention and Unsaturated Hydraulic Conductivity Measurements for Various Size Fractions of Crushed, Sieved, Welded Tuff Samples Measured Using a Centrifuge* (DTN: GS980808312242.015). These are data sets as illustrated in Figures XIV-1 and XIV-2.

For materials sieved between 2.00 and 4.75 mm, used for hydraulic conductivity measurements, the measured dry bulk density was 1.15 g/cm^3 (DTN: GS980808312242.015) as calculated below. The grain density is 2.53 gm/cm^3. Calculate the porosity using the soil phase convention of setting the volume of the solids (Vs) equal to 1.0 cm^3, developing a formula for the bulk density, and then calculating the volume of the voids. The dry bulk density (ρ) is defined as:

$$\rho = G_s V_s / V_t \tag{XIV-1}$$

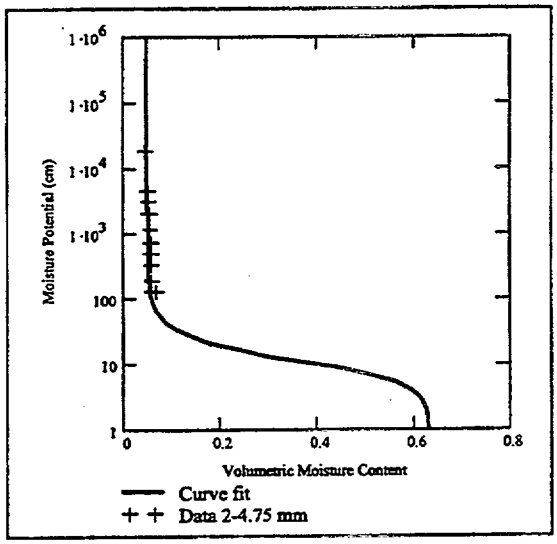

Figure XIV-1. Moisture Retention Relationship for the Invert

where

ρ	=	Dry bulk mass density (g/cm^3)
G_s	=	Specific gravity of solids
V_s	=	Solids volume (cm^3)
V_t	=	Total volume (cm^3)

Substituting in for the total volume which is equal to the volume of the solids and volume of the voids ($V_t = Vs + V_v$):

$$\rho = G_s V_s/(V_s+V_v) \tag{XIV-2}$$

where

V_v = Void volume (cm^3)

Substituting in the values for G_s, ρ, and V_s:

$$1.15 \text{ cm}^3 = 2.53 \text{ gm/cm}^3 \text{ } (1.0 \text{ cm}^3) / (1.0 \text{ cm}^3 + V_v) \tag{XIV-3}$$

Solve for V_v:

$$V_v = (2.53/1.15\text{-}1.0) \text{ cm}^3 \tag{XIV-4}$$

$$V_v = 1.200 \text{ cm}^3 \tag{XIV-5}$$

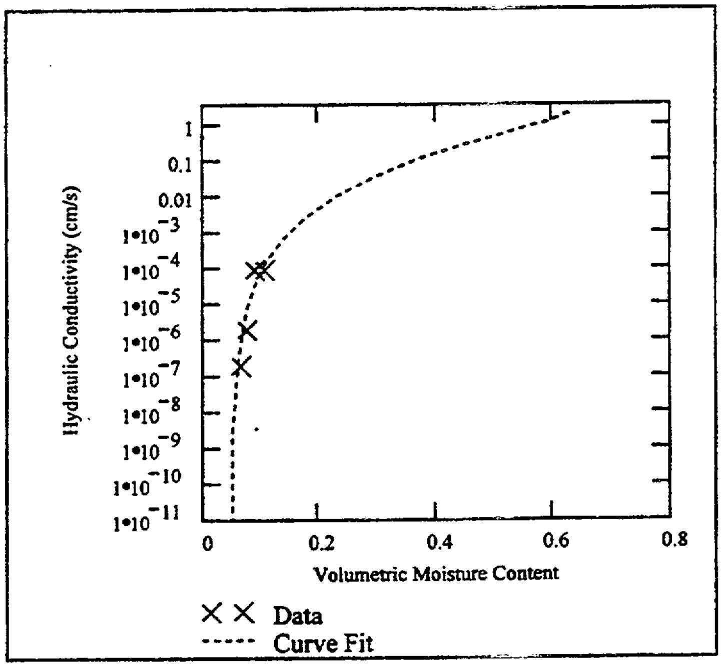

Figure XIV-2. Unsaturated Hydraulic Conductivity versus Volumetric Moisture Content for the Invert

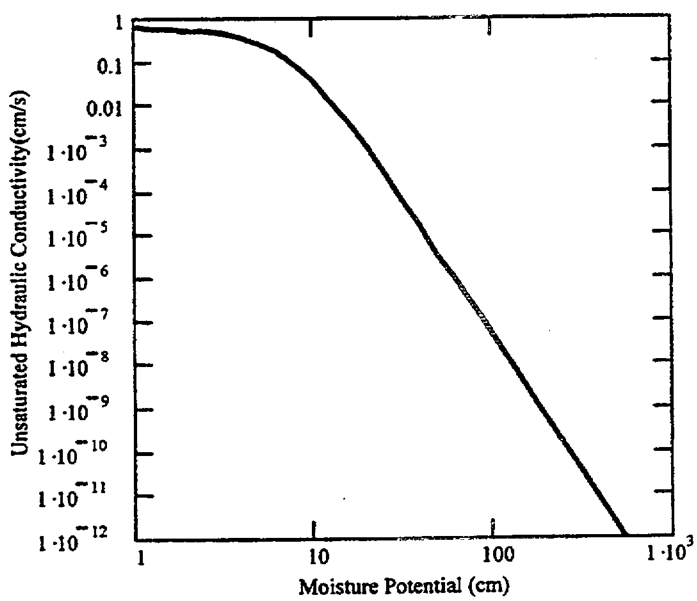

Figure XIV-3. Unsaturated Hydraulic Conductivity versus Moisture Potential for the Invert

Solve for the porosity (ϕ)

$$\phi = 1.209/(1.0+1.209) = 0.55 \tag{XIV-6}$$

XIV.2 Moisture Retention

Moisture retention measurements were performed on the crushed tuff using the Unsaturated Flow Apparatus (UFA) measurements (CRWMS M&O 1996, Appendix C).

The UFA consists of an ultracentrifuge with a constant ultra low flow pump that provides fluid to the sample through a rotating seal assembly and microdispersal system. The volumetric moisture content (θ) as a function of the moisture potential (ψ) can be determined by allowing the sample to drain until the moisture potential equals the centrifugal force per unit area divided by the unit weight in a state of equilibrium. The sample is then weighed to determine the volumetric moisture content (θ).

The moisture retention data obtained from the two methods can be plotted and a curve fitting performed for the retention model based upon the Van Genuchten two-parameter model (m=1-1/n) (Fetter 1993 p.172). Define the moisture potential (capillary pressure divided by weight density) versus moisture content relation:

$$\theta = \left[1 + (|\psi \cdot \alpha|^{n}\right]^{-m} \cdot (\theta_s - \theta_r) + \theta_r \tag{XIV-7}$$

where

n	=	van Genuchten curve-fitting parameter
m	=	van Genuchten curve-fitting parameter
α	=	van Genuchten or exponential curve-fitting parameters (cm^{-1})
θ	=	Volumetric moisture content
θ_I	=	Volumetric moisture content for the ith component of a soil
θ_r	=	Residual volumetric moisture content
θ_s	=	Saturated volumetric moisture content and
ψ	=	Moisture potential (cm)

Substituting the value of (m) into Equation (XIV-7) for the two-parameter model, gives

$$\theta = \left[1 + (|\psi \cdot \alpha|^{n}\right]^{-1-\frac{1}{n}} \cdot (\theta_s - \theta_r) + \theta_r \tag{XIV-8}$$

A *Microsoft Excel 97* spreadsheet calculation using the *Microsoft Excel 97* equation solver is used to optimize the model parameters by fitting the closed-form mathematical expression in Equation (XIV-8) to the retention data (Tables XIV-1, and XIV-2). These Excel files are saved as "TableXIV_1.xls" and "TableXIV_2.xls" under drainage directory in attached CD (Attachment XVI). The estimated curve-fitting parameters (Table XIV) are

$$\theta_r = 0.05$$

$$\alpha_i = 0.12 \text{ (1/cm)}$$

$$n_i = 2.75$$

Figure XIV-1 (DTN: GS980808312242.015) presents Equation (XIV-9) with the UFA data for the invert.

- To convert α_r to (1/Pa) divide by the density of water (1.0 gm /cm^3) times the acceleration of gravity:

$$0.12\text{cm}^{-1} \cdot \frac{1}{1.0\frac{\text{gm}}{\text{cm}^3} \cdot 981 \frac{\text{cm}}{\text{sec}^2}} = 1.223 \times 10^{-3} \frac{1}{\text{Pa}}$$

- From the definition of van Genuchten m (m=1-1/n) given above:

$$1 - \frac{1}{2.75} = 0.64$$

- The residual saturation equals the residual moisture content divided by the porosity (0.05/0.545) = 0.092. The satiated saturation is by definition.

Note that the measurements were performed near the residual moisture saturation. To establish the curve at higher moisture contents, the volumetric moisture content at saturation was estimated from the porosity. The volumetric moisture content θ_s equals the porosity of 0.63 which corresponds to the loose state. It should be noted that while the UFA testing was performed on the crushed tuff in a loose state (ϕ = 0.63) than what would be anticipated in the repository (ϕ = 0.55) allowing for consolidation over time, the moisture retention scaled to the saturation level would not be significantly different.

An alternate calculation was performed with the combined retention and unsaturated hydraulic conductivity data for the crushed tuff. The RETC program (van Genuchten et al. 1991) was used to optimize model parameters by fitting a closed form solution to the two-parameter relations (α_i, n_i) presented above. Attachment XV presents the results of this analysis which is in agreement with the EXCEL spreadsheet program using the Solver routine presented above.

XIV.3 Intrinsic Permeability

The saturated hydraulic conductivity (K_s) of the invert is estimated from the RETC curve fitting analysis presented in Attachment XV using the combined UFA unsaturated hydraulic conductivity (K_u) to moisture potential (ψ) and retention measurements. The calculated value from the RETC analysis is 0.60 cm/sec. This value corresponds to an approximate intrinsic permeability conversion value of 6.0×10^{-6} cm^2 or 6.0×10^{-8} m^2 (Freeze and Cherry, p.29).

Table XIV-1 van Genuchten Curve Fit ParameterResults for the Invert

Moisture Content at Saturation (qs)	0.63			
Residual Moisture Content (qr)	0.05			
a	117.00	bars^-1	0.12	cm^-1
n	2.75			
m	0.64			
Sum of Residuals	5.25E-04			

Note that the parameters are calculated using the EXCEL Equation Solver based upon the sum of the residuals as given above from Table XIV-2.

Table XIV-2 Retention Analysis Results for the Invert

Volumetric Moisture Content	Moisture Potential (bars)		Predicted Moisture Content	Residuals
0.068	0.121		0.057	1.29E-04
0.059	0.174		0.054	2.52E-05
0.058	0.309		0.052	3.49E-05
0.057	0.483		0.051	3.03E-05
0.056	0.696		0.051	2.24E-05
0.055	1.090		0.051	1.51E-05
0.053	1.930		0.051	3.83E-06
0.052	3.020		0.051	9.60E-07
0.050	4.350		0.051	1.02E-06
0.045	17.400		0.051	3.60E-05
0.060	0.121		0.057	1.14E-05
0.060	0.174		0.054	3.63E-05
0.059	0.309		0.052	4.77E-05
0.058	0.483		0.051	4.23E-05
0.058	0.696		0.051	4.54E-05
0.056	1.090		0.051	2.38E-05
0.054	1.930		0.051	8.74E-06
0.054	3.020		0.051	8.88E-06
0.052	4.350		0.051	9.79E-07
0.047	17.400		0.051	1.60E-05

Note: Volumetric moisture content and moisture potential are obtained from DTN GS980808312242.015 for Crushed Tuff
Equation (XIV-8) is used for calculating the predicted moisture content.
Residuals are calculated as the square of the difference between the actual volumetric moisture content and the predicted moisture content.

XIV.4 Relative Permeability

The UFA test apparatus described above can be used to determine the relationship between the unsaturated hydraulic conductivity (K_u) and volumetric moisture content through a direct application of Darcy's Law (CRWMS M&O 1996, Appendix C). By measuring the flow rates to 0.001 ml/hr and measuring the effluent collected from the sample in a volumetrically calibrated chamber that determines volumetric moisture content (θ), the unsaturated hydraulic conductivity can be determined from the ratio of the flow rate to the centrifugal force per unit volume (CRWMS M&O 1996, p. C-2).

The relationship of the unsaturated hydraulic conductivity with volumetric moisture content is given by (Jury et al. 1991, p.109):

$$K(\theta) = K_s \cdot \left(\frac{\theta - \theta_r}{\theta_s - \theta_r}\right)^{\frac{1}{2}} \cdot \left[1 - \left[1 - \left(\frac{\theta - \theta_r}{\theta_s - \theta_r}\right)^{\frac{1}{1-\frac{1}{n}}}\right]^{\left(1-\frac{1}{n}\right)}\right]^2$$

(XIV-9)

where

K_s = Saturated hydraulic conductivity (cm/sec)

The relative permeability function scales the saturated conductivity (K_S) to allow the unsaturated hydraulic conductivity function to be determined. Equation (XIV-10) with Van Genuchten parameters is used to plot the relationship crushed tuff as shown in Figure XIV-2.

The wetting-phase relative permeability as a function of moisture potential for this model is restated from Fetter (1993 p.182) and illustrated in Figure XIV-3. The unsaturated hydraulic conductivity (wetting-phase relative permeability times saturated hydraulic conductivity) as a function of moisture potential is given below.

$$K(\psi) = K_s \cdot \frac{\left[1 - \left(|\alpha \cdot \psi|\right)^{(n-1)} \cdot \left[1 + \left(|\alpha \cdot \psi|\right)^n\right]^{\left(-1+\frac{1}{n}\right)}\right]^2}{\left[\left[1 + \left(|\alpha \cdot \psi|\right)^n\right]^{\left[\frac{1}{2} - \frac{1}{(2 \cdot n)}\right]}\right]}$$

(XIV-10)

The relative permeability function scales the saturated conductivity (K_S) to allow the unsaturated hydraulic conductivity function to be determined. Equation (XIV-10) with Van Genuchten parameters (Section XIV.3) is used to plot the relationship for crushed as shown in Figure XIV-3.

XIV.5 Thermal Properties

Thermal properties for the invert that were used for the backfill case were initially identified. For dry crushed tuff, the thermal conductivity is about 0.58 to 0.74 W/m-°K, or an average value of 0.66 W/(m-°K) (Ryder et al. 1996, p.5-3). This value is similar to the dry sand thermal conductivity reported by de Marsily (1986, p.281) of 0.4-0.8 W/(m-°K).

The rock grain specific heat for crushed tuff is estimated to be 948 J/(kg*°K). The specific heat for the crushed tuff with a porosity of 0.55 and a bulk density of 1.15 g/cm^3 equals the specific heat of the grains since specific heat capacity depends on mass which is independent of volume. The volumetric heat (C_p) equals the specific heat (C_s) 948 J/(kg °K) times the bulk density (ρ) 1.15 g/cm^3. The thermal emissivity of the invert is assumed equal to the emissivity for quartz on a rough surface 0.93 (Holman 1997, p. 649).

Additional measurements (DTN: GS000048335103O.003) of geotechnical and thermal properties have been performed to characterize the thermal properties of crushed tuff as discussed in CRWMS M&O 2000q, Item 2). Also, it includes measurements of thermal properties of oven dry samples of crushed tuff using the Thermolink Probe. This device uses a dual-probe, short-duration, heat pulse technique to simultaneously measure the volumetric specific heat and thermal diffusivities of granular materials. The measurements were performed for a "fine" crushed tuff, and "4-10" Crushed Tuff. The average properties are summarized below for oven dry conditions at ambient temperature.

Additional physical properties measurements for the "4-10" Crushed Tuff (DTN: GS000683351030.006) were conducted according to the American Society for Testing and Materials Standard C1252 entitled "Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)." Twenty five samples were tested. These tests showed the average porosity was 50.26 ± 0.93 % with a corresponding dry bulk density of 1.26 ± 0.03 gm/cm^3. If this dry bulk density is applied to the measured volumetric specific heat for 4-10 Crushed Tuff, the calculated value for specific heat capacity is 740. J/(kg*K).

Table XIV-3. Summary of Thermolink Results for Crushed Tuff
(DTN: GS000483351030.003)

Material	Volumetric Specific Heat ($J/cm^3/^oK$)	Thermal Conductivity ($W/m/^oK$)	Thermal Diffusivity (mm^2/s)	Temperature (^oC)
4-10 Crushed Tuff	0.930 ± 0.074	0.16 ± 0.01	0.175 ± 0.013	17.3 ± 1.1
Fine Crushed Tuff Group 1	0.919 ± 0.061	0.14 ± 0.01	0.152 ± 0.004	23.8 ± 2.4
Fine Crushed Tuff Group 2	0.971 ± 0.036	0.15 ± 0.01	0.158 ± 0.007	20.1 ± 2.3

Note that measurements made on specific heat capacity for intact tuff show a strong temperature dependence. Information is presented by Brodsky et al. (1997, p.53) show that the specific heat capacity for TSw2 tuff is approximately 810 J/(kg*K) at a temperature of 60 C.

A review of models to predict thermal conductivity is presented by SEA (CRWMS M&O 2000q, pp.13-17). Crane et al. (1977) compared a number of models to the results of experimental studies. SEA's literature review suggested that two models provided somewhat better correlations. These included the model developed by Willhite, Kunii and Smith (1962), and the Dietz model. The Dietz model is a Fourier model for thermal conductivity of a packed bed. The Dietz model considered a special case of the packed bed-ahexagonal array of touching spheres. However, it was found that the resulting expression for the effective bed conductivity was only a weak function of bed geometry, allowing the expression to be applied to a variety of packings.

These models were evaluated by comparing the predicted values for thermal conductivity on a separate and independent set of data developed by Saxena et al. 1986. Saxena et al. 1986 performed thermal conductivity measurements on porous materials. Measurements of effective thermal conductivity of these materials were made using three different experimental methods via the thermal probe method. The thermal probe method reported by Saxena et al. consisted of a line heat source method in which a steel hypodermic needle of length 10 cm and outer diameter 0.125 cm is used as the source and sensor for temperature.

The measured data are regressed against the predicted data and illustrated in Figure XIV-4. The plot shows the ratio of the thermal conductivity to the continuous or gas phase thermal conductivity for measured data and predicted values for the Dietz Model. The Dietz model was found to produce a better result for this data. The Dietz Model is given by (CRWMS M&O 2000q, p.20):

$$\lambda_d(\lambda_g,\lambda_s) = 1.14\cdot\lambda_g\cdot\left(\frac{\lambda_s}{\lambda_g}\right)^{\frac{1}{2}}\cdot\frac{\frac{1}{2}\cdot K0\left[\left(\frac{40\cdot\lambda_g}{\lambda_s}\right)^{\frac{1}{2}}\right]}{K1\left[\left(\frac{40\cdot\lambda_g}{\lambda_s}\right)^{\frac{1}{2}}\right]}$$

(XIV-11)

where

λ_g = Thermal conductivity of the gas phase,
λ_d = Thermal conductivity of the solids phase,
K0= Zeroth order modified Bessel function of the second kind, and
K1 = First order modified Bessel function of the second kind.

The results of the analysis on the Saxena et al (1986) data over a range of porosities are presented in Figure XIV-4. Also, this figure shows a data point for crushed tuff using the grain thermal conductivity for TSw34 as discussed below. Note that the analysis shows some degree of variation that may be attributable to the higher porosity. CRWMS M&O 2000q, p.20, reports that good agreement was obtained for void fractions between 0.38 to 0.49.

The Dietz model (Equation XIV-11) can be applied to measured data for crushed tuff (TSw4) performed by the YMP. The value for the solids phase thermal conductivity for welded tuff is given by Table 4-5, of this report, as 1.56 W/(m*K). Considering the air thermal conductivity is given by Chapman (1974, p.593) as 0.026 W/(m*K) at 60 °C, the calculated value for thermal conductivity of crushed tuff is predicted to be 0.15 W/(m*K) which compares reasonably well with the measured values presented in Table XIV-3.

The Dietz model can be used to predict the thermal conductivity under saturated conditions by substituting the value of thermal conductivity for water into Equation (XIV-11). Considering the water thermal conductivity given by Chapman (1974, p. 586) at 60C, the value is 0.65 W/(m*K). Substituting in this value in Eq. (XIV-11) yields a value for thermal conductivity under saturated conditions of 1.03 W/(m*K).

The volumetric heat capacity under saturated conditions may be estimated by simple volumetric averaging. According to Jury et al. (1991, p. 179):

$$C_c = X_a\cdot C_a + X_w\cdot C_w + \sum_{j=1}^{N} X_{s_j}\cdot C_{s_j}$$

(Eq. XIV-12)

Where

C_c = Average volumetric heat capacity
X_a = Void fraction of air
X_w = Void fraction of water
X_{sj} = Void fraction of the jth solids component
C_a = Heat capacity per unit volume of the air
C_w =Heat capacity per unit volume of the water, and
C_{sj} = Heat capacity per unit volume of the jth solids component.

Note that NUFT will calculate the volume averaged specific heat capacity based upon the volume fractions and their respective volumetric heats for the solids, water, and air. The following calculation is provided for reference, and illustrates how specific heat, and thermal diffusivity would change when the degree of saturation is increased from zero to one.

Calculate the volumetric heat capacity for air. From Chapman (1974, p.593), the properties of air at 60 C (140 F) are given by:

$$Cp_a = 0.2409 \cdot \frac{BTU}{lb \cdot R} \qquad \rho_a = 0.06614 \cdot \frac{lb}{ft^3}$$

Converting to the SI system of units:

$$Cp_a = 1009 \cdot \frac{J}{kg \cdot K} \qquad \rho_a = 1.059 \cdot \frac{kg}{m^3}$$

Calculate the volumetric heat capacity for air:

$$C_a = Cp_a \cdot \rho_a \qquad C_a = 1069.0 \cdot \frac{J}{m^3 \cdot K}$$

Calculate the volumetric capacity of the tuff from Equation (XIV-12) by considering 4-10 crushed tuff that has a volumetric heat capacity of 0.930 J/(cm^3 K) for TSw4 (Table XIV-3) and an air void fraction of 0.51:

$$9.30 \cdot 10^5 = C_a \cdot X_a + (1 - X_a) \cdot C_s \qquad \text{(XIV-13)}$$

Solving for C_s, the value of 1.89 $*10^6$ J/(m^3 K) is obtained which is approximately twice the value for the porous crushed tuff since as noted by Jury et al. (1991, p.180), the volumetric heat capacity of air is small.

Consider now the properties of water. From Chapman (1974 p.586) at a temperature of 60C (140 F):

$$Cp_w = 0.998 \cdot \frac{BTU}{lb \cdot R} \qquad \rho_w = 61.39 \cdot \frac{lb}{ft^3}$$

Converting to SI units:

$$Cp_w = 4178 \cdot \frac{J}{kg \cdot K} \qquad \rho_w = 983.373 \cdot \frac{kg}{m^3}$$

The calculated volumetric heat capacity for water (C_w) is 4.11 * 10^6 J/(m^3 K). Substituting in Equation (XIV-13), the volumetric heat capacity under saturated conditions is given by:

$$X_w \cdot C_w + (1 - X_w) \cdot C_s = 3.01 \cdot 10^6 \cdot \frac{J}{m^3 \cdot K}$$

The volumetric heat capacity is increased by an approximate factor of three. The mass density under saturated conditions is calculated from the dry density of 1.26 gm/cm^3 using the standard soil mechanics convention of setting the volume of the solids to 1 cm^3. Solving for the volume of voids:

$$V_v = \frac{\phi}{1 - \phi} \qquad \text{(XIV-14)}$$

The total volume is 2.01 cm^3. Calculate the weight of solids (W_S) based upon the dry density of 1.26 gm/cm^3:

$$W_s = 1.26 \cdot \frac{gm}{cm^3} \cdot 2.01 \cdot cm^3 = 2.54 \cdot gm$$

Calculate the weight of the water equal the mass density of the water times the void volume:

$$W_w = 0.983 \cdot \frac{gm}{cm^3} \cdot 1.01 \cdot cm^3 = 0.99 gm$$

Calculate the saturated unit density:

$$\rho_s = \frac{W_s + W_s}{V_t} \qquad \text{(XIV-15)}$$

$$\rho_s = \frac{2.54 \cdot gm + 1.01 \cdot gm}{2.01 \cdot cm^3} = 1.76 \cdot \frac{gm}{cm^3}$$

The mass specific heat capacity may also be expressed as (Jury et al. 1991, p.179):

$$C = \rho\, C_p \qquad \text{(XIV-16)}$$

Solving for C_p under saturated conditions, the calculated value for Cp is $1.71 \cdot 10^3$ J/(kg*K).

The thermal diffusivity under saturated conditions is estimated from the thermal diffusivity relationship (Jury et al. 1991, p. 178):

$$\alpha = \lambda / C \qquad \text{Eq. (XIV-17)}$$

The calculated thermal diffusivity under saturated conditions is 0.34 mm^2/s. In comparing this thermal diffusivity to the dry case, the thermal diffusivity is increased by a factor of 2.

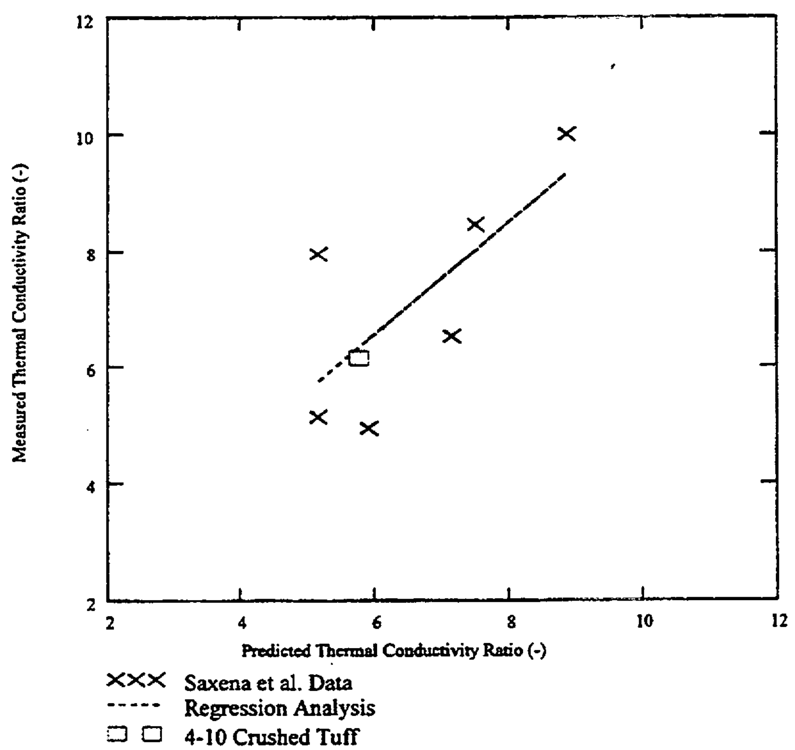

Figure XIV-4 Comparison of Experimental Results with Calculated Thermal Conductivity for the Dietz Model

Item 5

Draft evaluation of the range of properties for crushed tuff

$$\lambda_d(\lambda_g,\lambda_s) = 1.14 \cdot \lambda_g \cdot \left(\frac{\lambda_s}{\lambda_g}\right)^{\frac{1}{2}} \cdot \frac{\frac{1}{2} \cdot K0\left[\left(\frac{40 \cdot \lambda_g}{\lambda_s}\right)^{\frac{1}{2}}\right]}{K1\left[\left(\frac{40 \cdot \lambda_g}{\lambda_s}\right)^{\frac{1}{2}}\right]}$$

$$\lambda_g := 0.028 \cdot \frac{W}{m \cdot K}$$

$$\lambda_d(\lambda_g,\lambda_s) := 1.14 \cdot \lambda_g \cdot \left(\frac{\lambda_s}{\lambda_g}\right)^{\frac{1}{2}} \cdot \frac{K0\left[\left(\frac{40 \cdot \lambda_g}{\lambda_s}\right)^{\frac{1}{2}}\right]}{K1\left[\left(\frac{40 \cdot \lambda_g}{\lambda_s}\right)^{\frac{1}{2}}\right]}$$

$\lambda_s := 0.76 \cdot \frac{W}{m \cdot K}$ $\quad \lambda_d(\lambda_g,\lambda_s) = 0.122 \frac{W}{m \cdot K}$

$\lambda_s := 1.68 \cdot \frac{W}{m \cdot K}$ $\quad \lambda_d(\lambda_g,\lambda_s) = 0.163 \frac{W}{m \cdot K}$

$$\lambda_g := 0.644 \cdot \frac{W}{m \cdot K}$$

$\lambda_s := 0.76 \cdot \frac{W}{m \cdot K}$ $\quad \lambda_d(\lambda_g,\lambda_s) = 0.737 \frac{W}{m \cdot K}$

$\lambda_s := 1.68 \cdot \frac{W}{m \cdot K}$ $\quad \lambda_d(\lambda_g,\lambda_s) = 1.058 \frac{W}{m \cdot K}$

$C_{pw} := 1 \cdot \frac{cal}{cm^3 \cdot \frac{gm}{cm^3} \cdot K}$ $\quad C_{pw} = 4.187 \times 10^3 \frac{J}{kg \cdot K}$

$\rho_g := 2.53 \cdot \frac{gm}{cm^3}$ $\quad \rho_w := 1.0 \cdot \frac{gm}{cm^3}$

$$HeCoef := \begin{pmatrix} 0.8586 & 1.1745 & 1.0366 \\ 3.4954\cdot10^{-4} & 1.8813\cdot10^{-4} & 2.7015\cdot10^{-4} \\ 5.5807\cdot10^{-3} & 3.4676\cdot10^{-3} & 6.9353\cdot10^{-3} \\ 3.9099\cdot10^{-8} & 9.2565\cdot10^{-8} & 4.8589\cdot10^{-8} \\ -1.9925 & -1.3223 & -3.8365 \\ 1.7945\cdot10^{-4} & 1.1150\cdot10^{-4} & 2.2300\cdot10^{-4} \\ -1.5786\cdot10^{-4} & -4.1386\cdot10^{-4} & -1.4391\cdot10^{-4} \end{pmatrix}$$

$$\begin{pmatrix} A \\ B \\ C \\ D \\ E \\ F \\ G \end{pmatrix} := HeCoef^{\langle 0 \rangle} \qquad \begin{pmatrix} A \\ B \\ C \\ D \\ E \\ F \\ G \end{pmatrix} = \begin{pmatrix} 0.859 \\ 3.495\times10^{-4} \\ 5.581\times10^{-3} \\ 3.91\times10^{-8} \\ -1.992 \\ 1.795\times10^{-4} \\ -1.579\times10^{-4} \end{pmatrix}$$

$$C_{pg}(T) := \left(A + B\cdot T + C\cdot T^{\frac{1}{2}} + D\cdot T^2 + E\cdot T^{\frac{-1}{2}} + F\cdot T^{-1} + G\cdot T^{-2}\right)\cdot\frac{1000J}{kg\cdot K}$$

$$C_{ct}(\phi_T, S) := \rho_g\cdot 1\cdot(1-\phi_T)\cdot C_{pg}(330) + \rho_w\cdot 1\cdot\phi_T\cdot S\cdot C_{pw}$$

$$C_{pg}(330) = 969.902\,\frac{J}{kg\cdot K}$$

Consider the range of variability in matrix porosity, and intergrain porosity.

$\phi_T := 0.36$

$$C_{ct}(\phi_T, 0.0) = 1.57 \times 10^6 \frac{J}{m^3 \cdot K}$$

$$C_{ct}(\phi_T, 1.0) = 3.078 \times 10^6 \frac{J}{m^3 \cdot K}$$

$\phi_T := 0.56$

$$C_{ct}(\phi_T, 0.0) = 1.08 \times 10^6 \frac{J}{m^3 \cdot K}$$

$$C_{ct}(\phi_T, 1.0) = 3.424 \times 10^6 \frac{J}{m^3 \cdot K}$$

Now consider the permeability based upon the intergranular porosity.

$$k(d_m, \phi_I) := \frac{d_m^{\,2}}{180} \cdot \frac{(0.28)^3}{(1-0.28)^2} \qquad \rho_w = 1 \times 10^3 \frac{kg}{m^3} \qquad \mu := 4.89 \cdot 10^{-4} \cdot N \cdot \frac{s}{m^2}$$

$$k(2 \cdot mm, 0.28) = 9.41 \times 10^{-10} m^2 \qquad \frac{\rho_w \cdot g}{\mu} \cdot k(2 \cdot mm, 0.28) = 1.887 \frac{cm}{sec}$$

$$k(4 \cdot mm, 0.42) = 3.764 \times 10^{-9} m^2 \qquad \frac{\rho_w \cdot g}{\mu} \cdot k(4 \cdot mm, 0.42) = 7.549 \frac{cm}{sec}$$

Item 6

Draft version of *Committed Materials in Repository Drifts*, CAL-GCS-GE-000002 REV 00A (in checking)

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT CALCULATION COVER SHEET	1. QA: QA Page: 1 Of: 28

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10. Revision No.	11. Description of Revision
00A	Check Copy.

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FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ASTM	American Society for Testing and Materials
CRWMS M&O	Civilian Radioactive Waste Management System Management and Operating Contractor
DOE	U.S. Department of Energy
DTN	Data tracking number
I.D.	Inside Diameter
O.D.	Outside Diameter
WWF	Welded Wire Fabric

1. PURPOSE

The objective of this calculation is to estimate the quantity and chemical compositions of committed materials in repository drifts.

The scope of the calculation is to estimate the unit amounts (mass per meter) and the major chemical compositions of engineered materials in emplacement drifts. The information for other openings such as main access drifts, etc. will not be included in this calculation. The major reason is that the proper material information for non-emplacement drifts are not available this time. Information about thickness of materials will also be provided. Regarding the cooler repository concept, it is not expected to have a significant impact on the information presented in this calculation.

This work activity has been evaluated in accordance with the AP-2.21Q procedure, *Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities*, Revision 0, ICN 0, and is subject to QA controls (CRWMS M&O 2000a, Addendum C). The calculation is developed in accordance with the AP-3.12Q procedure, *Calculations*, Revision 0, ICN 2, and prepared in accordance with the *Technical Work Plan for Subsurface Design Section FY 01 Work Activities* (CRWMS M&O 2000a, Addendum C).

2. METHOD

Methods used in this calculation include literature review of both project and external documents, interactive meetings with affected groups (for example, the PDA and NFE, etc.) and consultation with experts, and some arithmetic calculations.

3. ASSUMPTIONS

The following assumptions are used in this calculation.

3.1 EMPLACEMENT DRIFTS

3.1.1 Material Configurations

3.1.1.1 The steel invert, rail and rail support will be estimated based on the configuration in "Steel Invert with Ballast" in *Emplacement Drift Invert - Low Steel Evaluation* (CRWMS M&O 2000b, Fig. 1, p. 20). The calculation for this assembly is used in Section 5 - Calculation, and does not require confirmation.

Rationale: The selected configuration will use the most structural steel of the three systems presented. Therefore, it will be an upper boundary for steel mass.

3.1.1.2 For the primary area of the repository footprint, 73.3% of the length of the emplacement drifts will be in rock identified as "tptpll" (CRWMS M&O 2000c, Table 18, p. 58), which is lithophysal.

Rationale: This percentage is the present best estimate between amounts of lithophysal and non-lithophysal material.

3.1.1.3 Ground support in the lithophysal area is estimated as W6X20 steel sets spaced at 1.5 meters (CRWMS M&O 2000d, p. 71) with welded wire fabric (WWF) supporting the crown from springline to springline (CRWMS M&O 2000d, Fig. 6-1, p. 75). This configuration is used in Section 5 - Calculation, and does not require confirmation.

Rationale: This is the best estimate for the latest prescribed design loads.

3.1.1.4 For the total primary area of the repository footprint, 26.7% of the emplacement drifts will be in rock classified as "tptpmn and tptpln" (CRWMS M&O 2000c, Table 18, p. 58), which are non-lithophysal.

Rationale: This percentage is the present best estimate between amounts of lithophysal and non-lithophysal material.

3.1.1.5 Ground support in the non-lithophysal area will have the W6X20 steel sets and welded wire fabric identified in sub-Section 3.1.1.3 plus the addition of an estimated six fully grouted rock bolts installed through an angle of 150° at the crown (CRWMS M&O 2000d, Fig. 6-2, p. 76). The spacing of the rock bolt rows along the length of the drift will be 1.5 meters, placing them midway between the steel sets (CRWMS M&O 2000d, p. 72). This configuration is used in Section 5 - Calculation, and does not require confirmation.

Rationale: This is the best estimate for the latest prescribed design loads.

3.1.1.6 Spacers and tie rods to laterally support the W6X20 steel sets will be 5/8" diameter rods installed in 1-1/4" diameter pipes spaced at 35° central angle around the perimeter of the steel sets (CRWMS M&O 1998a, p. 16). This configuration is used in Section 5 – Calculation, and does not require confirmation.

Rationale: The diameter of the drift for the Enhanced Characterization of the Repository Block (ECRB) is comparable to the proposed diameter of the emplacement drifts. Therefore, it is reasonable to use the same lateral support for the steel sets.

3.1.1.7 The required welded wire fabric will be estimated using the same loading pattern as used for the lagging computation for the ECRB ground support (CRWMS M&O 1998a, p. II-6). This is used in Section 5 – Calculation, and does not require confirmation.

Rationale: The diameter of the drift for the ECRB is comparable to the proposed diameter for the emplacement drifts. Therefore, it is reasonable to use the same loading.

3.1.1.8 The rock bolts are estimated to be 1-1/8" in diameter and are installed in 2-1/2" diameter holes (CRWMS M&O 1999, p. II-1). The length of the rock bolts is estimated to be 3 meters (CRWMS M&O 2000d, p. 72). This is used in Section 5 – Calculation, and does not require confirmation.

Rationale: Rock bolt dimensions give an upper boundary for rock bolt mass.

3.1.1.9 The maximum estimated volume of grout per rock bolt will be three times the volume of the annulus between the bolt and the hole to account for leakage in the jointed rock (CRWMS M&O 1999, p. II-1). This is used in Section 5 – Calculation, and does not require confirmation.

Rationale: Rock bolts are intended for use in emplacement drift areas that have jointed rock. Therefore, it is probable that grout will penetrate into the joints as it is installed under pressure.

3.1.1.10 It is assumed that the gantry rails (Fig. 1) will be 135 lb/yard crane rails (CRWMS M&O 2000b, Fig. 1, p. 20). This is used in Section 5 – Calculation, and does not require confirmation.

3.1.1.11 Rail fittings are estimated to be 10% of the rail mass (CRWMS M&O 2000f, p. 34). This is used in Section 5 – Calculation, and does not require confirmation.

3.1.1.12 The conductor is assumed to have a mass of 5.32 kilograms per meter (CRWMS M&O 2000f, p. 35).

3.1.1.13 Conductor bar fittings are assumed to have insulators with a mass of 0.15 kilograms per meter plus miscellaneous metal fittings with a mass of 0.2 kilograms per meter (CRWMS M&O 2000f, p. 35). This is used in Section 5 – Calculation, and does not require confirmation.

3.1.1.14 The communication cable is assumed to have a mass of 0.79 kilograms per lineal meter (CRWMS M&O 2000f, p. 32). This is used in Section 5 - Calculation, and does not require confirmation.

3.1.2 Material Composition and Chemistry

3.1.2.1 Organic Materials

3.1.2.1.1 It is assumed that rock bolt grout will contain superplasticizer, probably Rheobuild 1000 or equivalent which is 60% water and 40% Calcium Naphthalene Sultanate (CNS). CNS is composed (by weight) of: C-40.3%, H-3.3%, S-10.7%, O-32.2%, Ca-13.4% and Cl-0.1%. (CRWMS M&O 2000f, p. 32).

3.1.2.1.2 Communications Cable: The cable is low mass, but is made up of several components. It will have a polyethylene jacket (50% by weight) and a copper core (50%). The core is pure copper and no other information is available about the makeup of the jacket. (CRWMS M&O 2000f, p. 32).

3.1.2.2 Engineered Materials

3.1.2.2.1 It is assumed that steel sets and fittings (Fig. 1) will be ASTM A 36 (CRWMS M&O 2000d, p. 72) or ASTM A 572 (CRWMS M&O 2000f, p. 33). Although not specified, it can be assumed that these components will also contain traces of associated metals and halides (less than 0.1%) (CRWMS M&O 2000f, p. 33).

3.1.2.2.2 It is assumed that the pipe spacers and tie rods between the steel sets will be ASTM A 53 and ASTM A 307 respectively (CRWMS M&O 1998a, p. II-9). Although not specified, it can be assumed that these components will contain traces of associated metals and halides (less than 0.1%).

3.1.2.2.3 It is assumed that the transverse support beam (Fig. 1) will be ASTM A 709 (CRWMS M&O 2000b, p. 29). Although not specified, it can be assumed that these components will also contain traces of associated metals and halides (less than 0.1%).

3.1.2.2.4 It is assumed that the longitudinal support beams, guide beams, cap plate and runway beam (Fig. 1) will be ASTM A 242 (CRWMS M&O 2000b, pp. 30 & 31). Although not specified, it can be assumed that these components will also contain traces of associated metals and halides (less than 0.1%).

3.1.2.2.5 It is assumed that the welded wire fabric (WWF) is prepared to ASTM A 82 and will be fabricated as specified by ASTM A 185. These specifications do not give chemical composition. For analysis it can be assumed that the steel wire will contain the following elements in addition to Fe: C<1%; S<0.1%; P<0.1%. It can be assumed that the wire will also contain traces of associated metals and halides (less than 0.1%) (CRWMS M&O 2000f, p. 33).

3.1.2.2.6 It is assumed that rock bolts and associated heading plates and shell anchors are specified by ASTM F 432. Although not specified, it can be assumed that these components will also contain traces of associated metals and halides (less than 0.1%) (CRWMS M&O 2000f, p. 33)

3.1.2.2.7 It is assumed that rock bolt grout will be composed of the following (CRWMS M&O 2000f, p. 33):

Cement: Type K cement	1230 kg/m^3
Water:	550 kg/m^3
Silica Fume:	135 kg/m^3
Superplasticizer:	14 kg/m^3

Type K cement, silica fume, and superplasticizer are specified by ASTM C 845, C 1240, and C 494, respectively.

Halides - For analysis purposes this cement can be assumed to contain the halides F, Cl, Br, and I at a total concentration of less than 1% of dry weight (maximum). (CRWMS M&O 2000f, p. 34)

3.1.2.2.8 It is assumed that the invert ballast (Fig. 1) will consist of crushed, welded, Topopah Spring tuff which will be prepared from waste rock removed during emplacement drift, access drift, ventilation drift, shaft, and ramp construction. (CRWMS M&O 2000f, p. 34)

Whole rock mineralogical analysis may be abstracted from quantitative x-ray diffraction analysis. Representative analyses may be obtained from DTNs LADV831321AQ97.001 and LASX831321AQ96.002, and the host rock mineralogy is summarized in DTN LADB831321AN98.002. Fracture lining minerals are assumed to have a negligible contribution to overall composition. The host rock tends to be chemically homogeneous, so the available whole rock elemental analysis of the Topopah Spring vitrophyre (DTN LADV831322AN97.001 and LL981209705924.059) is appropriate for analyses of invert performance. Together these analyses include bromide, plus the following elements: Al, Ca, Fe, Mg, Mn, P, K, Si, Na, Ti, Cl, S, F, and Ba (CRWMS M&O 2000f, p. 34).

3.1.2.2.9 It is assumed that the rail material is specified by ASTM A 759. Although not specified, it can be assumed that these components will also contain traces of associated metals and halides (less than 0.1%). (CRWMS M&O 2000f, p. 34)

3.1.2.2.10 It is assumed that the allowance for rail fittings includes an allowance for end-to-end bonding, and cross bonding required to use the rail system as the ground for the DC power system to power the emplacement gantry. An assumption of 75% steel and 25% copper seems reasonable (CRWMS M&O 2000f, p. 34).

3.1.2.2.11 It is assumed that the conductor bar will be solid copper (CRWMS M&O 2000f, p. 35).

3.1.2.2.12 It is assumed that the insulators for the conductor fittings are ceramic with steel end fittings and hardware (CRWMS M&O 2000f, p. 35).

4. USE OF COMPUTER SOFTWARE AND MODELS

There was no computer software, nor models used in this calculation.

5. CALCULATION

This section presents the inputs and approaches used in this calculation. Some of the input data presented in this section are considered preliminary, and/or may not reflect the latest information.

5.1 EMPLACEMENT DRIFTS

5.1.1 INPUTS

5.1.1.1 The diameter of excavation will be nominally 5.5 meters (CRWMS M&O 2000d, p. 31).

5.1.1.2 The ground support in the emplacement drifts will be of carbon steel (steel sets and/or rock bolts and mesh) with cementitious grout (CRWMS M&O 2000d, p. 31).

5.1.1.3 The steel drift invert frame is independent of the ground control system (CRWMS M&O 2000b, p. 16).

5.1.1.4 Geometric Data for Materials in Emplacement Drift

The nominal thickness, width, and depth data of the steel materials for the emplacement drift are listed in Table 1.

Table 1. Nominal Thickness, Width, and Depth data of Steel Materials for Emplacement Drift[a]

Type	Member	Flange Width	Flange Depth	Web Thickness	Source of Data
Beams	W 6 x 20 W 8 x 67 W 12 x 53	152.9 210.3 253.9	9.27 23.75 14.61	6.60 12.95 8.76	AISC 1995, p. 1-32 AISC 1995, p. 1-32 AISC 1995, p. 1-28
Tie Rods & Pipes	Tie Rod Pipe	- -	- -	15.88 (diameter) 42.16 (O.D.) 3.56 (thickness)	AISC 1995, p. 1-108 AISC 1995, p. 1-93
Rock Bolts & Head plates	Rock Bolt Head plate	- 203x203	- -	30 (O.D.) 10.85 (thickness) 13 (thickness)	WFEC[b] 1997, p. 8 WFEC[b] 1997, p. 38
Welded Wire Fabric	WWF	76.2x76.2 (grid)	-	5.72 (diameter)	ACI 318-99, Appendix E, p. 386
Crane Rail[c]	135 lb/yd	87.31(head) 131.76 (base)	146.05	31.75	AISC 1995, p. 1-113

[a] All data dimension units are in mm.
[b] Williams Form Engineering Corporation.
[c] see Figure 1 for more detail.

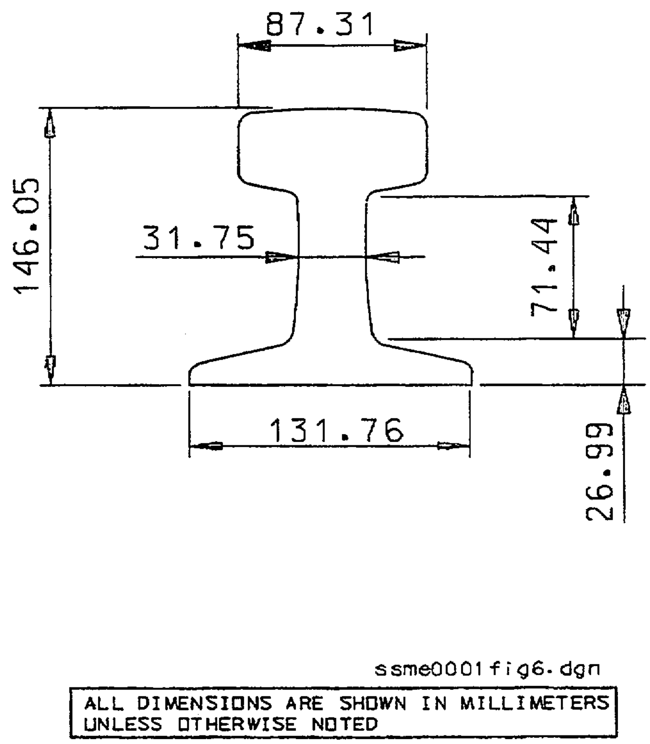

Figure 1. Dimension of 135 lb/yd Crane Rail

5.1.2 CALCULATION APPROACH

5.1.2.1 Steel Invert and Rail Support

5.1.2.1.1 Transverse Support Beam

Refer to Fig. 2

Radius of drift = 5.5 x 1000/2 = 2750 mm

Y_1 = 2750 - 806 = 1944 mm

Y_2 = 1944 + 12.06 x 25.4 = 2250.32 mm. (12.06 is depth of W12X53 in inches) (AISC 1995, p.1-28). (1 inch =25.4 mm)

$\theta_1 = \cos^{-1}$ (1944/2750) = 45.016°

(Top flange length)/2 = 2750 sin 45.016° = 1945.09 mm

$\theta_2 = \cos^{-1}$ (2250.32/2750) = 35.085°

(Bottom flange length)/2 = 2750 sin 35.085° = 1580.68 mm

Beam length = [(1945.09 + 1580.68)/2] 2 = 3525.77 mm

3525.77 mm x 0.03937mm/in. = 138.81 in. = 11.57 ft.

Beam mass. = 11.57 x 53 lb/ft. = 613.2 lb/unit

613.2 lb x 0.4536 kg/lb = 278.1 kg/unit

Transverse support beams are spaced at 1.5 m.

Therefore, transverse beam mass = 278.1/1.5 = 185.4 kg/meter

Estimate mass of stiffener brackets, anchor bolts, and connection bolts as being 25% of transfer support beam mass.
Estimated appurtenance mass = 0.25 x 185.4 = 46.4 kg/meter

Total = 185.4 + 46.4 = 231.8 kg/meter

5.1.2.1.2 Gantry Runway

Refer to Fig. 2.
The gantry runway is composed of W8X67 and 3/4" X 15" cap plate.
Mass of cap plate = (15/12) x 30.6 lb//ft. = 38.25 lb/ft. (AISC 1995, p.1-111)
Mass of runway = 2(67 + 38.25) = 210.5 lb/ft. 210.5 x 0.4536 kg/lb = 95.5 kg/ft
95.5 x 3.281 ft./meter = 313.3 kg/meter

5.1.2.1.3 Longitudinal Support Beams

Refer to Fig. 2.
There are 3 longitudinal support beams - each W6X20
Mass = 3 x 20 = 60 lb/ft. 60 x 0.4536 kg/lb = 27.2 kg/ft.
27.2 x 3.281 ft./meter = 89.2 kg/meter

5.1.2.1.4 Guide Beams

Refer to Fig. 2.
There are two guide beams - each W6X20
Mass = 2/3 x 89.2 = 59.5 kg/meter

5.1.2.1.5 Rail

Refer to Fig.2
The rail is 135 lb/yd. (1 yd. = 3 ft)
Mass = (2 x 135)/3 = 90 lb/ft.
90/60 x 89.2 = 133.8 kg/meter

5.1.2.1.6 Rail Fittings

Mass of rail fittings is estimated as 10% of rail mass. (Sub-Section 3.1.1.11)
Weight of rail fittings = 0.1 x 133.8 = 13.4 kg/m (sub-Section 3.1.2.2.9)
Mass of steel in rail fittings = 0.75 x 13.4 = 10.1 kg/m steel
Mass of copper in rail fittings = 0.25 x 13.4 = 3.4 kg/m copper (sub-Section 3.1.2.2.9)

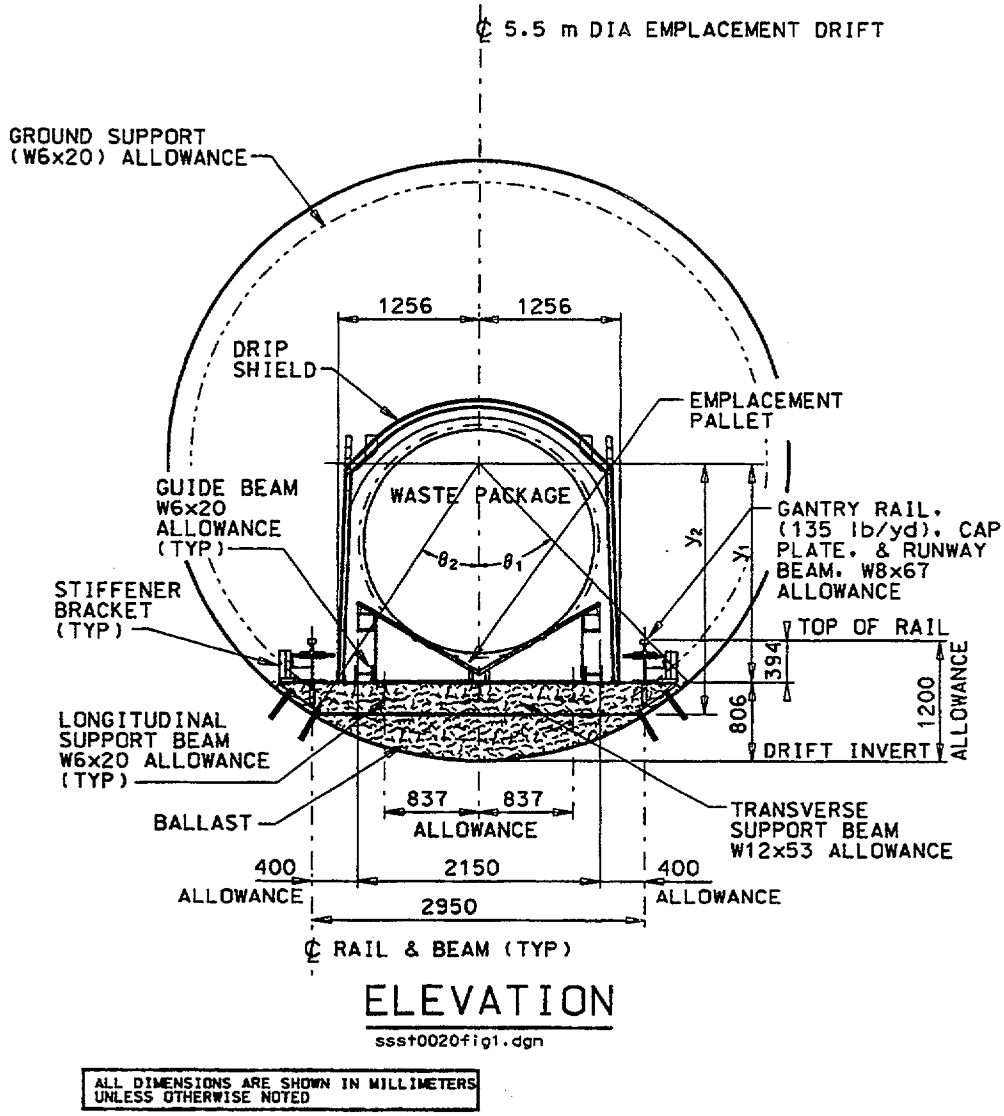

Figure 2. Steel Invert with Ballast - Elevation

5.1.2.2 Ground Support

5.1.2.2.1 Steel Sets

Refer to Figs. 2, 5 and 6.

Steel sets are W6X20 at 1.5 meter spacing. (Sub-Section 3.1.1.3)

Depth of W6X20 is 6.20" (AISC 1995, p.1-32)

Length = $\pi d = \pi[(5.5 \times 3.281$ ft./meter - 6.20/12)] = 55.07 ft.

Mass = 55.07 x 20 lb/ft. = 1101.4 lb/unit

Mass = 1101.4/1.5 = 734.3 lb/meter

734.3 lb/meter/ 2.205 lb/kg = 333 kg/meter

5.1.2.2.2 Pipe Spacers and Tie Rods

See sub-Section 3.1.1.6.

No. of rods and spacers = $360^\circ/35^\circ$ = 10.29

Use 11 lines of rods and spacers.

For 5/8" diameter rods, mass of rods = 1.044 lb/ft. x 11 = 11.48 lb/ft. (AISC 1995, p.1-108)

11.48 lb/ft. x 3.281 ft./meter = 37.67 lb/meter

37.67 lb/meter x 0.4536 kg/lb = 17.1 kg/m for tie rods

For 1-1/4" diameter pipes, mass of pipe = 2.27 lb/ft. x 11 = 24.97 lb/ft. (AISC 1995, p. 1-93)

24.97 x 3.281 = 81.93 lb/meter

81.93 x 0.4536 kg/lb = 37.2 kg/meter for pipe spacers

5.1.2.2.3 Welded Wire Fabric (WWF)

Refer to Figs. 5 and 6 and sub-Section 3.1.1.7

Loading Condition: (CRWMS M&O 1998, p. II-6)

ECRB span between steel sets will be modified from 5' 2" to 4' 11" to fit the emplacement drift spacing of steel sets (see Fig. 3).

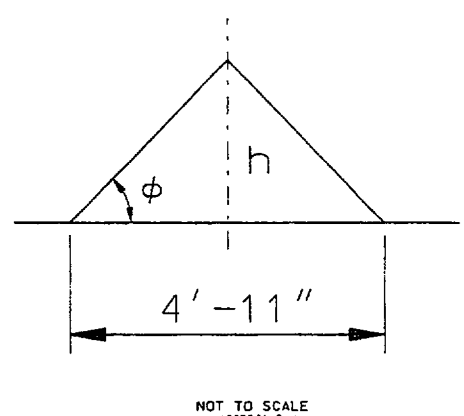

Figure 3. Sketch of WWF Loading Condition

Span = 1.5 meters = 4' 11"
Density (including seismic) = 199 lb/ft^3
h = (4.92/2)/(tan 45^o) = 2.46 ft. (see Fig. 3)
ω_{max} = 2.46 x 199 x 1.0 = 489.54 lb/ft^2
W = ω_{max}L/2 = 489.54 x 4.92/2 = 1204.27 lb/ft.width (perpendicular to drift centerline)

Total equivalent uniform load = 4W/3 = (4 x 1204.27)/3 = 1605.69 lb/ft width (AISC 1995, p.2-296)
1605.69 lb is total uniform load on an area 59" long and 12" wide.
Try W4 wire a @ 3" spacing. Area = 0.04 in^2 (ACI 318, Appendix E, p. 386)
Equivalent load/wire = (1605.69)(1/59)(1/12)(3) = 6.80 lb/in. (see Fig. 4)

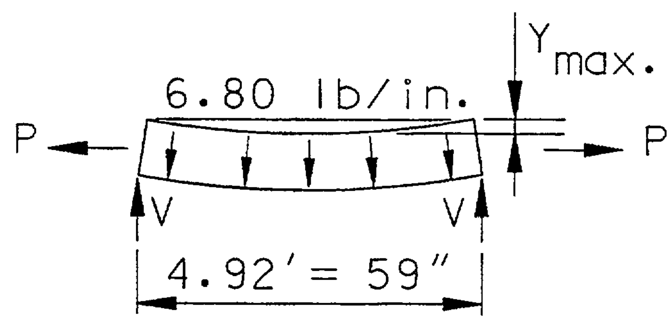

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Figure 4. Sketch of WWF Stress Condition

Y_{max} = l(3wl/64EA)$^{1/3}$ (Roark 1989, Table 12, Case 6, p. 179)
= 59x[(3 x 6.80 x 59)/(64 x 29 x 10^6 x 0.04)]$^{1/3}$
= 1.49 in. (AISC 1995, p. 1-117 for E value)

P = ωl^2/8Y_{max} = (6.80 x 59^2)/(8 x 1.49) = 1986 lb
V = ωl/2 = 6.80 x 59/2 = 201 lb
Tension = (1986^2 + 201^2)$^{1/2}$ = 1996 lb
Wire unit tension = 1996/0.04 = 49900 psi
Wire allowable tension = 0.60 x 65000 x 1.33 = 51870 psi > 49900 psi OK
Use of 0.60: (AISC 1995, p. 5-40, par. D-1).
Use of 65000 psi. (ASTM A 82, Table 2)
Use of 1.33: (AISC 1995, p. 5-30, par. A5.2)

Use 3X3 W4XW4 WWF There will be 4 wires/ft. in both directions.
Mass = (4 + 4) 0.136 lb/ft. = 1.088 lb/ft^2. (ACI 318-99, Appendix E, p. 386).
(1.088 lb/ft^2 x 0.4536 kg/lb)/ 0.0929 m^2/ft^2) = 5.31 kg/m^2
Wire fabric will be from springline to springline - 180^o.

Mass = (180/360)(π x 5.5 meters x 1 meter)(5.31 kg/m^2) = <u>45.9 kg/meter</u>

5.1.2.2.4 <u>Rock Bolts and Anchor Plates</u>

Refer to Fig. 6

Where rock bolts are required, 6 per row will be used across the crown through an arc of 150°. Diameter of rock bolts will be 1-1/8" with a length of 3.15 meters (3 meters in the hole with 0.15 meters projecting)(sub-Section 3.1.1.8). Longitudinal spacing will be 1.5 meters (sub-Section 3.1.1.5). Interior hole on centerline of bolt will be 0.325 in. in diameter (used for pumping grout) (Williams Form Engineering Corporation. 1997, p. 8)

Mass/bolt = 3.382 - (0.325^2/1.125^2)(3.382) = 3.10 lb/ft (AISC 1995, p. 1-108)
3.10 lb/ft x 3.15 meters x 3.281 ft/meter (AISC 1995, p. 6-12) = 32.04 lb/bolt
32.04 x 0.4536 kg/lb = 14.53 kg/bolt
Mass/meter = (14.53 x 6)/1.5 = 58.12 kg/meter
Anchor plates will be 6"X6"X1/4"
Mass of plates = 5.10/2 = 2.55 lb/plate (AISC 1995, p. 1-111) x 6 = 15.3lb/row
15.3 x 0.4536 kg/lb = 6.94 kg/row 6.94 x 1/1.5 = 4.63 kg/meter

Total mass of bolts and plates = 58.12 + 4.63 = <u>62.75 kg/meter</u>

5.1.2.2.5 <u>Grout for Rock Bolts</u>

1-1/8" bolts will be installed in 2-1/2" ϕ holes (sub-Section 3.1.1.8).
Volume of annulus = [(π x 2.5^2/4) - (π x 1.125^2/4)] x 3meters x 39.37 in/meter = 462.37 in^3. 462.37 in^3 x 1/39.37^3 = 0.0076 m^3
Assume two additional volumes for leakage (sub-Section 3.1.1.9).
Total volume = 3 x 0.0076 = 0.0228 m^3/bolt
Volume per meter = 6 x 0.0228/1.5 = 0.0912 m^3/meter
Mass of cement in grout mix = 1230 kg/m^3 (sub-Section 3.1.2.2.7)
Mass of cement = 0.0912 x 1230 = <u>112.2 kg/m</u>
Mass of silica fume = 0.0912 x 135 = 12.3 kg/meter (sub-Section 3.1.2.2.7)
Mass of superplasticizer = 0.0912 x 14 = 1.3 kg/meter (sub-Section 3.1.2.2.7)

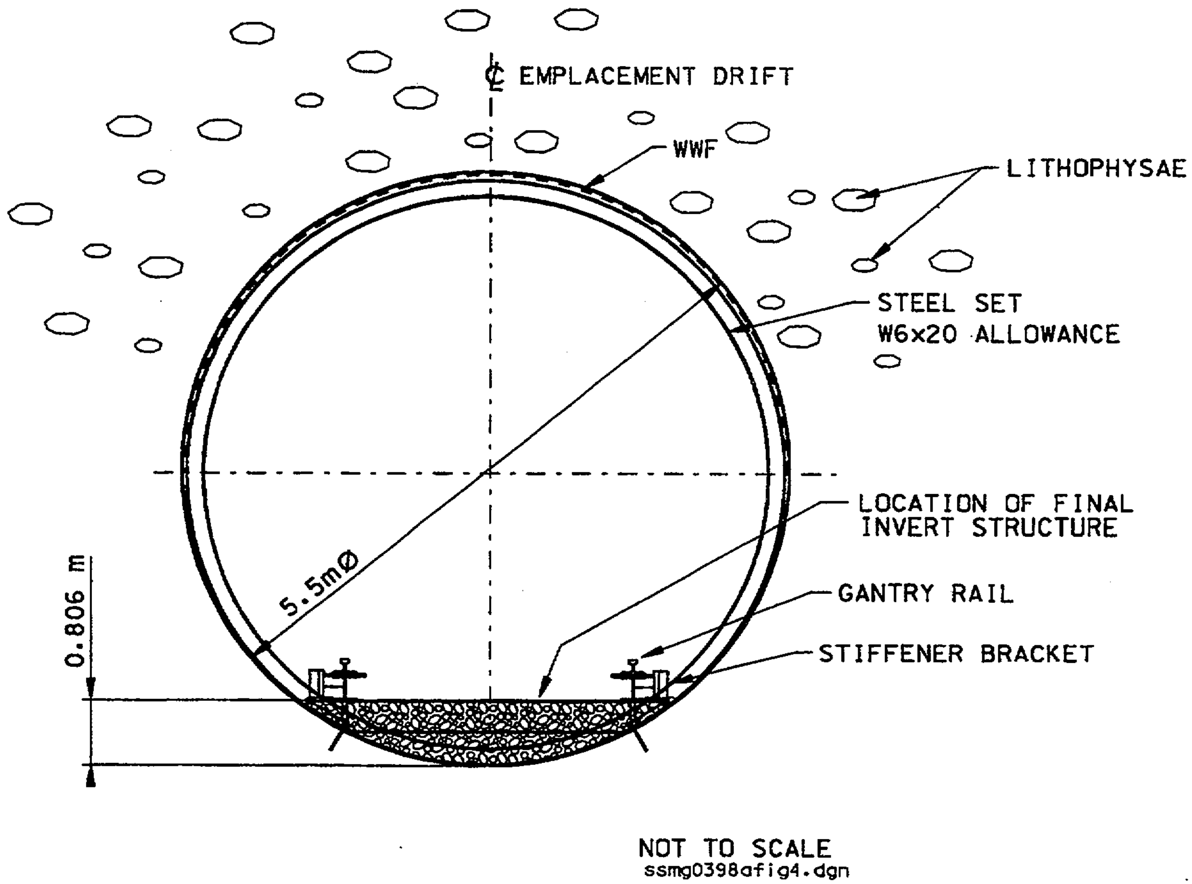

Figure 5. Steel Sets with Welded-Wire Fabric

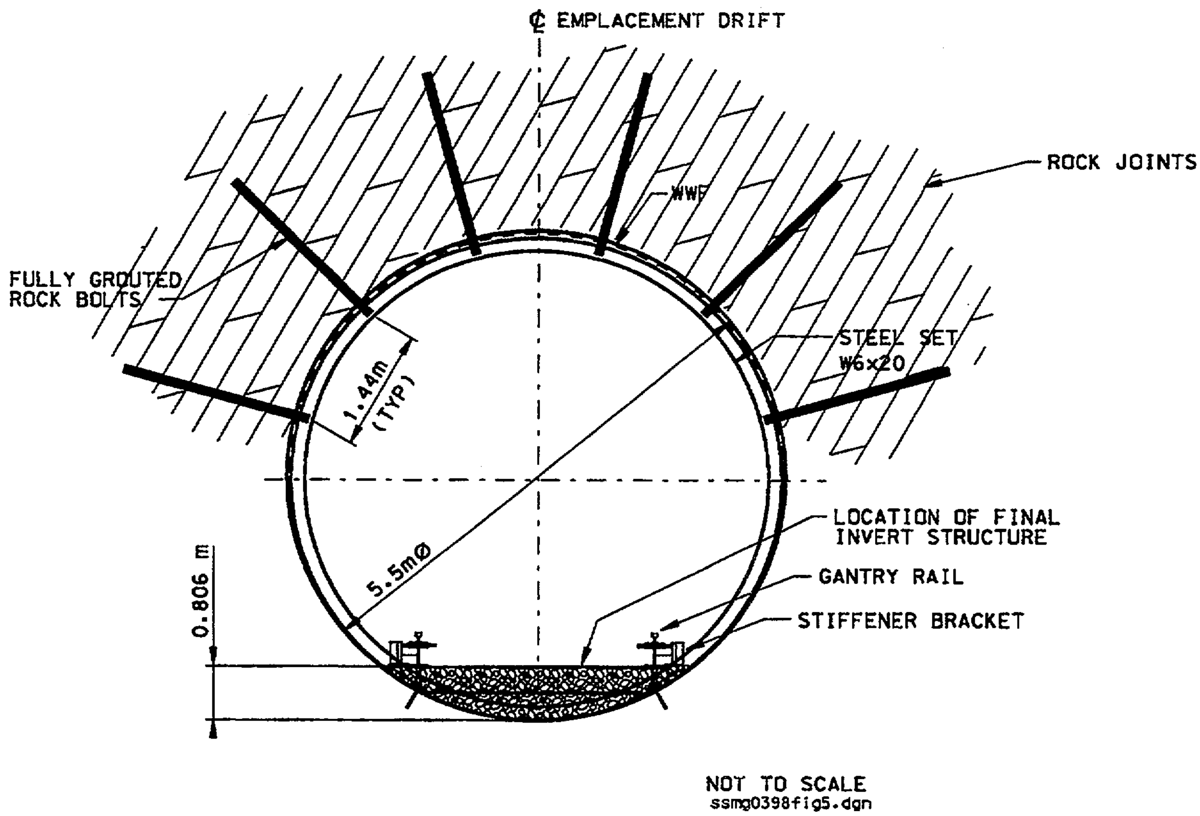

Figure 6. Fully Grouted Rock Bolts with Steel Sets

5.1.2.3 Invert Ballast and Miscellaneous Material

5.1.2.3.1 Invert Ballast

Refer to Fig. 2

$\theta_1 = 45.016^o$ (sub-Section 5.1.2.1.1)

Area of ballast invert = (Area of circle segment) - (Area of triangles)

Area of circle segment = $(2 \times 45.016^o/360^o)(\pi \times 5.5^2/4) = 5.942\ m^2$

Area of triangles = $1.945 \times 2 \times 1.944/2 = 3.781\ m^2$

Volume of ballast = $(5.942 - 3.781)\ 1 = \underline{2.161\ m^3/\text{meter}}$

Volume of encased steel is negligible.

5.1.2.3.2 Conductor Bar

Conductor bar is solid copper and has a mass of 5.32 kg/meter. (sub-Section 3.1.1.12)

5.1.2.3.3 Conductor Bar Fittings

Ceramic insulators: 0.15 kg/meter

Misc. metal fittings: 0.2 kg/meter (sub-Section 3.1.1.13)

5.1.2.3.4 Communications Cable

50% polyethylene jacket by weight

50% pure copper by weight

Total weight = 0.79 kg/m (sub-Section 3.1.1.14)

6. RESULTS

This section summarizes the results of the calculation. Some of the input data used are unqualified. Therefore, the confirmation of these unqualified data is required prior to the use of the results of the calculation for procurement, fabrication, or construction.

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.

6.1 EMPLACEMENT DRIFTS

6.1.1 Steel Invert and Rail Support

6.1.1.1 Transfer Support Beam and Appurtenances

Mass is 231.8 kg/meter (sub-Section 5.1.2.1.1)
Material is ASTM A 709 (sub-Section 3.1.2.2.3)

6.1.1.2 Gantry Runway

Mass is 313.3 kg/meter (sub-Section 5.1.2.1.2)
Material is ASTM A 242 (sub-Section 3.1.2.2.4)

6.1.1.3 Longitudinal Support Beams

Mass is 89.2 kg/meter (sub-Section 5.1.2.1.3)
Material is ASTM A 242 (sub-Section 3.1.2.2.4)

6.1.1.4 Guide Beams

Mass is 59.5 kg/meter (sub-Section 5.1.2.1.4)
Materials is ASTM A 242 (sub-Section 3.1.2.2.4)

6.1.1.5 Rail

Mass is 133.8 kg/meter (sub-Section 5.1.2.1.5)
Material is ASTM A 759 (sub-Section 3.1.2.2.9)

6.1.1.6 Rail Fittings

Mass of steel is 10.1 kg/meter (sub-Section 5.1.2.1.6)
Material specification is not identified.
Mass of copper is 3.4 kg/meter (sub-Section 5.1.2.1.6)
Material specification is not identified.

6.1.2 Ground Support

6.1.2.1 Steel Sets

Mass is 333 kg/meter (sub-Section 5.1.2.2.1)
Material is ASTM A 36 or A 572 (sub-Section 3.1.2.2.1)

6.1.2.2 Pipe Spacers

Mass is 37.2 kg/meter (sub-Section 5.1.2.2.2)
Material is ASTM A 53 (sub-Section 3.1.2.2.2)

6.1.2.3 Tie Rods

Mass is 17.1 kg/meter (sub-Section 5.1.2.2.2)
Material is ASTM A 307 (sub-Section 3.1.2.2.2)

6.1.2.4 Welded Wire Fabric (WWF)

Mass is 45.9 kg/meter (sub-Section 5.1.2.2.3)
Material is ASTM A 82 fabricated as specified in ASTM A 185 (sub-Section 3.1.2.2.5)

6.1.2.5 Rock Bolts and Anchor Plates

Mass is 62.75 kg/meter (sub-Section 5.1.2.2.4)
Material is ASTM F 432 (sub-Section 3.1.2.2.6)

6.1.2.6 Grout for Rock Bolts

Mass of cement is 112.2 kg/meter (sub-Section 5.1.2.2.5)
Material is ASTM C 845, Type K (sub-Section 3.1.2.2.7)

Mass of silica fume is 12.3 kg/meter (sub-Section 5.1.2.2.5)
Material is ASTM C 1240 (sub-Section 3.1.2.2.7)

Mass of superplasticizer is 1.3 kg/meter (sub-Section 5.1.2.2.5)
Material is ASTM C 494. (sub-Section 3.1.2.2.7)

6.1.3 Invert Ballast and Miscellaneous Material

6.1.3.1 Invert Ballast

Volume of Invert Ballast is 2.161 m^3/meter (sub-Section 5.1.2.3.1)
Composition of Invert Ballast is Crushed Tuff (sub-Section 3.1.2.2.8)

6.1.3.2 Conductor Bar

Mass of conductor bar is 5.32 kg/meter (sub-Section 5.1.2.3.2)
Material of conductor bar is solid copper (sub-Section 3.1.2.2.11)

7. REFERENCES

7.1 DOCUMENTS CITED

CRWMS M&O 1998a. *ECRB Cross Drift Ground Support - Structural Steel Analysis.* BABEE0000-01717-0200-00018 REV 02. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990503.0163.

CRWMS M&O 1998b. *Emplacement Drift Invert Structural Design Analysis.* BBDC00000-01717-0200-0001 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980625.0366.

CRWMS M&O 1999. *Evaluation of Alternative Materials for Emplacement Drift Ground Control.* BCAA00000-01717-0200-00013 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990720.0198.

CRWMS M&O 2000a. *Technical Work Plan For Subsurface Design Section FY 01 Work Activities.* TWP-MGR-MG-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001117.0053.

CRWMS M&O 2000b. *Emplacement Drift Invert - Low Steel Evaluation.* TDR-EDS-ST-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20001011.0001.

CRWMS M&O 2000c. *Site Recommendation Subsurface Layout.* ANL-SFS-MG-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000908.0276.

CRWMS M&O 2000d. *Ground Control for Emplacement Drifts for SR.* ANL-EBS-GE-000002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000414.0875.

CRWMS M&O 2000e. *FEIS Update To Engineering File - Subsurface Repository.* TDR-EBS-MD-000007 REV 00, ICN 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000612.0058.

CRWMS M&O 2000f. *Repository Subsurface Design Information to Support TSPA-SR.* Input Transmittal PA-SSR-99218.Tc. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000424.0690.

Roark, R.J. 1989. *Roark's Formulas for Stress and Strain.* 6th Edition. New York, New York: McGraw-Hill. TIC: 10191.

Williams Form Engineering Corporation 1997. Rock Anchor Systems, No. 397. Grand Rapids, Michigan. Williams Form Engineering Corporation. TIC: 245370.

7.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

ACI 318-99. 1999. *Building Code Requirements for Structural Concrete (ACI 318-99) and Commentary (ACI 318R-99).* Farmington Hills, Michigan: American Concrete Institute. TIC: 245142.

AISC (American Institute of Steel Construction) 1995. *Manual of Steel Construction, Allowable Stress Design.* 9th Edition, 2nd Revision, 2nd Impression. Chicago, Illinois: American Institute of Steel Construction. TIC: 240772.

AP-3.12Q, Rev. 0, ICN 3. *Calculations.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20001026.0084.

AP-2.21Q, Rev. 0, ICN 0. *Quality Determinations and Planning for Scientific, Engineering, and Regulatory Compliance Activities.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL.20000802.0003.

ASTM A 36/A 36M-97a. 1998. *Standard Specification for Carbon Structural Steel.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 243523.

ASTM A 53/A53M-99b. 1999. *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.* West Conschohocken, Pennsylvania: American Society for Testing and Materials. TIC: 247689.

ASTM A 82-97a. 1998. *Standard Specification for Steel Wire, Plain, for Concrete Reinforcement.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246400.

ASTM A 185-97. 1997. *Standard Specification for Steel Welded Wire Fabric, Plain, for Concrete Reinforcement.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246271.

ASTM A 242/ A 242M-98. 1998. *Standard Specification for High-Strength Low-Alloy Structural Steel.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 248531.

ASTM A 307-97. 1998. *Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 243522.

ASTM A 709/A 709M-00. 2000. *Standard Specification for Carbon and High-Strength Low-Alloy Structrual Steel Shapes, Plates, and Bars and Quenched-and-Tempered Alloy Structural Steel Plates for Bridges.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 248751.

ASTM A 759-85 (Reapproved 1992). *Standard Specification for Carbon Steel Crane Rails.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246309.

ASTM C 494-92. 1992. *Standard Specification for Chemical Admixtures for Concrete.* Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 241033.

ASTM C 845-96. 1996. *Standard Specification for Expansive Hydraulic Cement.* West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246401.

ASTM C 1240-99. 1999. *Standard Specification for Silica Fume for Use as a Mineral Admixture in Hydraulic-Cement Concrete, Mortar, and Grout*. West Conshohocken, Pennsylvania: American Society for Testing and Materials. TIC: 246205.

ASTM F 432-95. 1995. *Standard Specification for Roof and Rock Bolts and Accessories*. Philadelphia, Pennsylvania: American Society for Testing and Materials. TIC: 241007.