ENG.20080208.0001

BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: QA
2. Page 1

3. System Monitored Geologic Repository	4. Document Identifier 000-00A-MGR0-00300-000-00B

5. Title

Potential Repository Wastes – Inventory and Characteristics

6. Group

Engineering / Nuclear and Radiological

7. Document Status Designation

☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

Changes have been made to Sections 2.2 and 6.3.1 and Table 1.

Attachment A was not affected by this revision 00B.

Changes are identified by *Change Bars*.

Affected pages are coversheet, 3, 4, 7-11, 17, and 33, also all headers and footers.

Attachments	Total Number of Pages
Attachment A – Electronic attachment (One CD)	N/A
Attachment B – List of Files on Attached CD (Attachment A)	1
Attachment C – Modifications to the RW-859 2002 Database and Generation of Access Queries	6
Attachment D – Reference 2.2.12, E-mail from R. LeCounte to C. Sanders, July 16, 2007	1

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/ Accepted (Print/Sign/Date)
00A	Initial Issue	44	44	Quentin T. Newell Dorin P. Musat	David A. Ferris Kevin R. Doody	Kevin R. Doody	David B. Darling 01/08/08
00B	Edit Section 6.3.1 to remove redundant information in updated Ref. 2.2.11.	43	43	Tanya Sloma 2/7/08	Charlotta Sanders 02/07/2008	Kevin Doody 2/7/08	David Darling 2/7/08

DISCLAIMER

The analysis contained in this document was developed by Bechtel SAIC Company, LLC (BSC) and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

CONTENTS

FIGURES

TABLES

ACRONYMS

B&W	Babcock & Wilcox Company
BSC	Bechtel SAIC Company
BWR	boiling water reactor
CD	compact disc
CSNF	commercial spent nuclear fuel
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
GROA	Geologic Repository Operations Area
HLW	high-level (radioactive) waste
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LA	License Application
LWR	light water reactor
MOX	Mixed Oxide
MTHM	metric tons heavy metal
MTIHM	metric tons initial heavy metal
MTU	metric tons of uranium
PWR	pressurized water reactor
SAR	Safety Analysis Report
SNF	spent nuclear fuel
SRS	Savannah River Site
WVDP	West Valley Demonstration Project
WVNS	West Valley Nuclear Services Company

1. PURPOSE

10 CFR 63, 2007 (Reference 2.2.1, Section 21(c)(4)) requires a description of the kind, amount, and specifications of the radioactive material to be disposed in the geologic repository at Yucca Mountain.

The purpose of this analysis is to provide information on the inventory and characteristics of the different types of waste forms for the License Application (LA) Safety Analysis Report (SAR) Section 1.5.1.

The DOE has considered the following categories of nuclear waste forms for disposal at the Yucca Mountain repository: (Reference 2.2.19, Section S.2.2):

- Commercial Spent Nuclear Fuel (CSNF)
- High-Level radioactive Waste (HLW)
- U.S. Department of Energy (DOE) Spent Nuclear Fuel (SNF)
- Naval SNF
- Surplus weapons–grade plutonium
- Commercial greater-than-Class-C waste
- DOE special-performance-assessment-required waste.

The DOE will include the first four categories in its initial LA SAR to the U.S. Nuclear Regulatory Commission. According to the DOE's 68 FR 20134, *Surplus Plutonium Disposition Program* (Reference 2.2.4), the surplus weapons-grade plutonium will be irradiated as mixed oxide (MOX) fuel in the existing commercial nuclear reactors and disposed of as CSNF. In addition, a vitrification technology utilizing a lanthanide borosilicate glass appears to be a viable option for disposition of excess weapons-usable plutonium that is not suitable for processing into mixed oxide fuel (Reference 2.2.31, Section 2.0 p. 1). The Argonne National Laboratory-West (ANL-W) ceramic and metal HLW will not be included in the initial LA because these matrixes do not meet the requirement in *Waste Acceptance System Requirements Document* (Reference 2.2.27, Section 4.8.1[A]). These two waste forms and the last two categories will be considered for the later LA submittal depending on the DOE's determination.

This document covers CSNF, DOE SNF, and HLW waste forms. This analysis describes the physical, chemical, thermal, and nuclear characteristics of these wastes. Naval SNF is not covered in this document, and the Naval Nuclear Propulsion Program is providing information on naval SNF characteristics.

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2.1.2 IT-PRO-0011, Revision 7, *Software Management.* Las Vegas, NV: Bechtel SAIC Company ACC: DOC.20070905.0007.

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2.2 DESIGN INPUTS

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

2.2.2 10 CFR 71. 2007. Energy: Packaging and Transportation of Radioactive Material. ACC: MOL.20070829.0114. Internet Accessible [DIRS 181967].

2.2.3 10 CFR 72. 2007. Energy: Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste. Internet Accessible [DIRS 181968].

2.2.4 68 FR 20134. Surplus Plutonium Disposition Program. ACC: MOL.20050418.0145. [DIRS 167703]

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2.2.41 Not used.

Notes: Reference 2.2.8 is used as direct input for this analysis although it is not a QA: QA document. However, as this BSC generated document provides the most recent (2002) and best available data on the subject (discharged fuel assembly inventory), it is considered acceptable for the intended use. The referenced values are reliable and reasonable; therefore, based on engineering judgment, their use is justified.

References 2.2.14, 2.2.15, 2.2.24, 2.2.25, and 2.2.28 are used as direct input for this analysis although they are not QA: QA documents. However, as they are DOE generated documents and considered the best available data on the subject, they are considered acceptable for the intended use. The referenced values are reliable and reasonable; therefore, based on engineering judgment, their use is justified.

Reference 2.2.38 is used as direct input for this analysis although it is not a QA: QA document. Its use is justified as acceptable for the intended use, as they are a reliable source, the most current information, and the only available source.

References 2.2.16, 2.2.19, 2.2.30, 2.2.31, 2.2.37, and 2.2.40 are QA: N/A documents; however, they have not been used as direct input to produce results.

The use of Reference 2.2.12 (see Attachment D) as direct input in this document is considered acceptable for the intended use, as it comes directly from fuel manufacturer (AREVA), which is reliable and the only available source.

2.3 DESIGN CONSTRAINTS

None

2.4 DESIGN OUTPUTS

The information in this analysis will be used as supporting information in the LA SAR Section 1.5.1.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

There are no assumptions requiring verification in this analysis.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

There are no assumptions not requiring verification in this analysis.

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This analysis was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1). The types of waste forms are classified as a Safety Category item important to safety and important to waste isolation in the *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 2.2.9, p. 141). Therefore, the approved version of this document is designated as QA: QA.

4.2 USE OF SOFTWARE

Software is managed in accordance with procedure IT-PRO-0011, *Software Management* (Reference 2.1.2).

4.2.1 Baseline Software

No baseline software was used in this analysis.

4.2.2 Commercial Off-The-Shelf Software

4.2.2.1 MICROSOFT® Excel 2000 SR-1

The commercially available Microsoft® Excel 2000 SR-1 spreadsheet code, which is a component of Microsoft Office 2000, is used in this analysis. Usage of Microsoft® Office 2000 in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 2.1.2, Attachment 12).

The software specifications are:

- Program Name: Excel
- Version/Revision Number: Microsoft® Excel 2000 SR-1
- This software is installed on a personal computer running Microsoft® Windows 2000 (central processing unit number 151951)

Excel is used in this analysis to organize the data into tables, and display the results in tabular and graphical forms. Standard Excel functions were also used in this calculation to perform mathematical operations. No “macros” were used in Excel spreadsheets. The user defined formulas, inputs, and graphical representations were verified by visual inspection and computations were verified by hand calculations. They are documented in sufficient detail to allow an independent repetition of the computations. Microsoft® Excel is not required to be qualified because of its Level 2 usage (Reference 2.1.2 Attachment 12 p. 80).

4.2.2.2 MICROSOFT® Access 2000 SR-1

The commercially available Microsoft® Access 2000 SR-1 database program, which is a component of Microsoft® Office 2000, is used in this analysis. Usage of Microsoft® Office 2000 in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 2.1.2, Attachment 12).

The software specifications are:

- Program Name: Access
- Version/Revision Number: Microsoft® Access 2000 SR-1
- This software is installed on a personal computer running Microsoft Windows 2000 (central processing unit number 151951)

Access is used to access the information in the database. Standard functions of Microsoft® Access (i.e. selection of desired records, sorting, sum, count, avg., min and max function, query, etc.), are used in this analysis to find the desired data in the database, to display results in tabular form, or to export them to other applications (i.e. Microsoft® Excel). No “macros” were used to manipulate data in the above database. The user defined tables, queries, and results of the queries were verified by visual inspection and computational functions were verified by hand calculations. They are documented in sufficient detail to allow an independent repetition of the queries. Microsoft® Access is not required to be qualified because of its Level 2 usage (Reference 2.1.2 Attachment 12, p. 80).

4.3 ANALYSIS BACKGROUND METHODOLOGY

This analysis discusses the different types of waste forms to be stored at the repository at Yucca Mountain. The analysis covers the following wastes forms: commercial SNF, HLW, and DOE SNF. These waste forms along with naval spent nuclear are the kinds of wastes that the initial LA will cover. Characteristics of naval SNF are being provided by the Naval Nuclear Propulsion Program, and therefore are not covered in this analysis.

This analysis includes gathering the most up to date information on the characteristics of the different wastes forms to be stored at the repository at Yucca Mountain. This is done by researching, finding, and organizing the latest available data about the waste forms.

5. LIST OF ATTACHMENTS

	Number of Pages
Attachment A – Electronic Attachment (One CD)	N/A
Attachment B – List of Files on Attached CD (Attachment A)	1
Attachment C – Modifications to the RW-859 2002 Database and Generation of Access Queries	6
Attachment D – Reference 2.2.12, E-mail from R. LeCounte to C. Sanders, July 16, 2007	1

6. ANALYSIS

The initial LA covers CSNF, HLW, DOE SNF, and Naval SNF.

This section presents a range of parameters that describe the SNF, HLW, and DOE SNF waste forms. The associated tables and figures provide specific waste form parameters, classifications, and data.

6.1 SUMMARY OF SPENT NUCLEAR FUEL AND HIGH LEVEL WASTE INVENTORIES

The SNF (uranium dioxide pellets encased in zirconium alloy or stainless steel rods) and HLW (solid material - glass) are going to be received, staged, packaged, and emplaced at the repository. The "waste form" means the radioactive waste materials and any encapsulating or stabilizing matrix (including the canister) as defined in 10 CFR 63, 2007 (Reference 2.2.1, Section 2).

The waste forms included in the initial LA SAR are categorized into four groups:

- Commercial SNF
- HLW
- DOE SNF
- Naval SNF

The Geologic Repository Operations Area (GROA) is being designed to process and emplace SNF and HLW (Reference 2.2.33, Section 2). The repository capacity consists of 70,000 MTHM, comprised of 63,000 MTHM of CSNF and 7,000 MTHM of DOE wastes (Reference 2.2.27, Table 7.1). The DOE wastes consist of 2,333 MTHM of SNF (including Naval SNF) and 4,667 MTHM of vitrified HLW (Reference 2.2.27, Table 7.1).

Table 1 summarizes the quantities of the different waste forms including the historical (amount/date as of), projected, and proposed quantities, defined as follows:

- Proposed quantities represent the repository limits for the MTHM (the basis for the LA),
- Historical quantities represents permanently discharged assemblies (CSNF), already canistered naval SNF, and already poured HLW canisters,
- Projected quantities, included for completeness, represents:
    - the estimated quantities to be shipped to the repository (CSNF, DOE SNF, Naval SNF, and Total HLW value) or
    - total quantities to be produced (HLW per site values).

Table 1. Summary of SNF and HLW Inventories

Type		Units	Historical		Projected	Proposed Action MTHM Inventory
			Amount	Date As Of		
CSNF	PWR	MTIHM	30293[b]	2002		63000[a]
		Number of assemblies	70292[b]		221000[a,n]	
	BWR	MTIHM	16708[b]			
		Number of assemblies	93351[b]		See note n	
	TAD	MTIHM			62360[q]	
		Number of TAD canisters			7500[c]	
	Commercial HLW[v]	MTHM	640[a]	2007	640[a]	
		Number of assemblies	275[a]		275[a]	
HLW	Hanford	Total glass mass (kg)[x]	—		2.37E+07 - 3.85E+07[d,u]	4667[a]
		Number of canisters	—		7071 - 13205[d,u]	
		Equivalent MTHM	—		3535 - 6603[r,u]	
	Savannah River	Total glass mass (kg)[x]	4.14E+06[e]	2007	1.23E+07[g,u]	
		Number of canisters	2312[e]		6833[g,u]	
		Equivalent MTHM	—		3417[r,u]	
	West Valley[v] (count as CSNF)	Total glass mass (kg)[x]	5.50E+05[h]	2007	5.50E+05[h]	
		Number of canisters	275[a]		275[a]	
		Equivalent MTHM	640[a]		640[a]	
	INL/INTEC	Total glass mass (kg)[x]	—		1.86E+06[j,u]	
		Number of canisters	—		1190[j,u]	
		Equivalent MTHM	—		595[r,u]	
	Total HLW	Number of canisters	—		9334[r]	
		Equivalent MTHM	—		4667[a,t]	
DOE SNF		MTHM	—		2268[s]	2268[s]
		Number of canisters	—		3500[a,w]	
Naval SNF		MTHM	12[k]		65[L]	65[L]
		Number of canisters	—		400[m]	

Sources:
[a] Reference 2.2.27, Table 7.1;
[b] Attachment A database *Final2002modifiedDM-RW859.mdb*, query *6-2a*.
[c] Reference 2.2.25, p. 1
[d] Reference 2.2.11, Section 6.4
[e] Attachment A, spreadsheet *HLW.xls*, tab *SR*
[g] Reference 2.2.11, Section 6.5
[h] Reference 2.2.11, Section 6.6
[j] Reference 2.2.11, Section 6.7
[k] Reference 2.2.38 USN 1996, p. 44
[L] Reference 2.2.24, Table 5
[m] Reference 2.2.23, Section 3.1.2.I.

Notes:
[n] The value 221000 includes both PWR and BWR assemblies therefore it is reported only in PWR row.
[q] MTHM based on CSNF MTHM allotment less commercial HLW from West Valley
[r] Calculated based on the historical method (4667MTHM/0.5 MTHM per canister) Reference 2.2.30, Section 2.2.
[s] Based on 2333 MTHM[a] DOE SNF allotment less naval SNF
[t] Without West Valley HLW which is included in commercial allotment
[u] HLW values reflect the amount produced rather than quantities to be disposed of at Yucca Mountain monitored geological repository
[v] Included in HLW although it will be counted as CSNF toward repository limit
[w] the provided number of canisters is an estimate; the reference also provide a 2500 to 5000 range
[x] 1000 kg/metric ton

Remarks: During the burnup process, the mass of heavy metal is reduced by the fissions suffered by heavy metal atoms; therefore the MTHM/MTIHM ratio decreases with fuel burnup.
Equivalent MTHM is the assigned MTHM value used to count toward repository limit of 70000 MTHM.

6.2 COMMERCIAL SPENT NUCLEAR FUEL

Commercial SNF includes irradiated fuel discharged from pressurized water reactors (PWRs) and boiling water reactors (BWRs). The fuel used in these reactors consists of uranium dioxide pellets encased in zirconium alloy (Zircaloy) or stainless steel rods. The fuel assemblies vary in physical configuration, depending on the reactor type and the manufacturer.

The CSNF assemblies are categorized into 22 assembly classes, 16-PWR and 6-BWR, by the physical configuration of the assemblies, the design of the upper and lower core plates, and the control elements (Reference 2.2.37, p. 4; Reference 2.2.15, Appendix 2A, pp. 2A-3 and 2A-4).

The CSNF data is collected by a periodic mandatory survey, which is administered and compiled by the DOE Energy Information Administration (EIA) on behalf of OCRWM (Reference 2.2.8, p. 1). The latest available data covers all SNF discharged from commercial reactors as of December 31, 2002, and includes approximately 16,708 MTIHM (93,351 assemblies) of BWR and 30,293 MTIHM (70,292 assemblies) of PWR commercial SNF discharged from commercial nuclear power reactors (Attachment A, database *Final2002modifiedDM-RW859.mdb*, query *6-2a*). These spent fuel assemblies are currently stored in fuel pools and in storage casks at the reactor sites.

The current repository design concept focuses on using transportation, aging, and disposal (TAD) canisters for commercial SNF. The TAD canister-based repository relies on receiving most of the commercial SNF in TAD canisters (Reference 2.2.9,p. 4). Although the total number of TADs is not known; the repository is being designed to handle the SNF annual receipt rates whereby at least 90 percent of the SNF will be in TAD canisters and no more than 10 percent as uncanistered assemblies (Reference 2.2.23, pp. 6-7).

There is limited information on the TAD canister specifications because there is no final TAD design at this time. However, there are a few guidelines that TAD canisters must meet. The TAD canister shall conform to the dimensional envelope (e.g., tolerance stack-up, thermal expansion) that is based on a right-circular cylinder with a diameter of 66.5 inches and a length of 212.0 inches (Reference 2.2.26, p. 8). The TAD will have a capacity of 21 PWR assemblies or 44 BWR assemblies (Reference 2.2.26, p. 9). A TAD canister for PWR assemblies shall accept CSNF with less than 5% initial ^{235}U enrichment, below 80 GWd/MTU discharge burnup and an out-of-reactor cooling time of no less than 5 years (Reference 2.2.26, p. 9). A TAD canister for BWR assemblies shall accept CSNF with less than 5% initial ^{235}U enrichment, below 75 GWd/MTU discharge burnup and an out-of-reactor cooling time of no less than 5 years (Reference 2.2.26, p. 9). The TAD canister can have a thermal output value ranging up to 25 kW (Reference 2.2.26, p. 14). The combined neutron and gamma integrated average dose rate over the top surface of a loaded TAD canister shall not exceed 800 mrem/hr on contact for operations performed in the GROA (Reference 2.2.26, p. 14). In addition, the combined contact neutron and gamma maximum dose rate at any point on the top surface of a TAD canister shall not exceed 1000 mrem/hr for GROA operations (Reference 2.2.26, p. 14). Further information on the TAD can be found in the DOE 2007 *Transportation, Aging and Disposal Canister System Performance Specification* report (Reference 2.2.26).

Dual purpose canisters (DPC) are canisters that can be used for storage and/or shipment of commercial SNF. They are currently used by several utilities, and are licensed by the U.S. Nuclear Regulatory Commission for storage (according to 10 CFR Part 72, [Reference 2.2.3]) and shipment, (according to 10 CFR Part 71 [Reference 2.2.2]) of SNF. DPCs are stainless steel cylinders of welded construction.

6.2.1 Physical Characteristics of Commercial Spent Nuclear Fuel

Commercial SNF assemblies are categorized into assembly classes by physical configuration. The physical configuration is determined by the physical dimensions of fuel assemblies, the design of the lower and upper end fittings, and the design of the control elements. Within an assembly class all the assembly types are of similar size (and for PWRs the same array size). There are 134 individual fuel assembly types that have been discharged in these classes Attachment A, database *Final2002modifiedDM-RW859.mdb*, query *AssmType*.

Physical properties of fuel assemblies are described in DOE 1987, Appendix 2A (Reference 2.2.14). This reference includes properties of fuel assemblies like: masses, physical dimensions, materials of construction, physical characteristics of fuel pins, and assembly drawings. Table 2 presents a summary of initial uranium load, initial enrichment, and discharge burnup of the commercial SNF inventory.

Table 2. Summary of LWR Spent Fuel Characteristics as of December 31, 2002

		PWR	**BWR**	**Total**
Initial Uranium Loading	Average (kg/assembly)	431.0	179.0	N/A
	Maximum (kg/assembly)	546.6	197.6	N/A
	MTIHM (sum)	30293	16708	47001
Initial Enrichment	Average (wt% 235U)	3.45	2.77	N/A
	Maximum (wt% 235U)	4.95	4.24	N/A
Discharge Burnup	Average (MWd/MTU)	36242	28619	N/A
	Maximum (MWd/MTU)	69452	65149	N/A
Number of Assemblies (number)		70292	93351	163643

Source: Attachment A, database *Final2002modifiedDM-RW859.mdb*, query *6-2a*

In order to count toward the repository limit, commercial spent fuel values need be stated in terms of MTHM and not MTIHM. Calculations can be made (based on burnup) to find the MTHM value of spent fuel corresponding to the MTIHM value given for the fuel. This is done because during the burnup process, the mass of heavy metal is reduced by the fissions suffered by heavy metal atoms; therefore the MTHM/MTIHM ratio decreases with fuel burnup.

A source-term sensitivity study for PWR and BWR assemblies shows that the calculated source terms (based on same fuel loading, burnup, and cooling time) are not sensitive to the selection of a particular fuel assembly (Reference 2.2.6, Sections 6.3 and 6.4). Other factors such as burnable poison, moderator density, or specific power have greater effects on the source terms, but mainly in the heat and neutron outputs (Reference 2.2.6, p. 109).

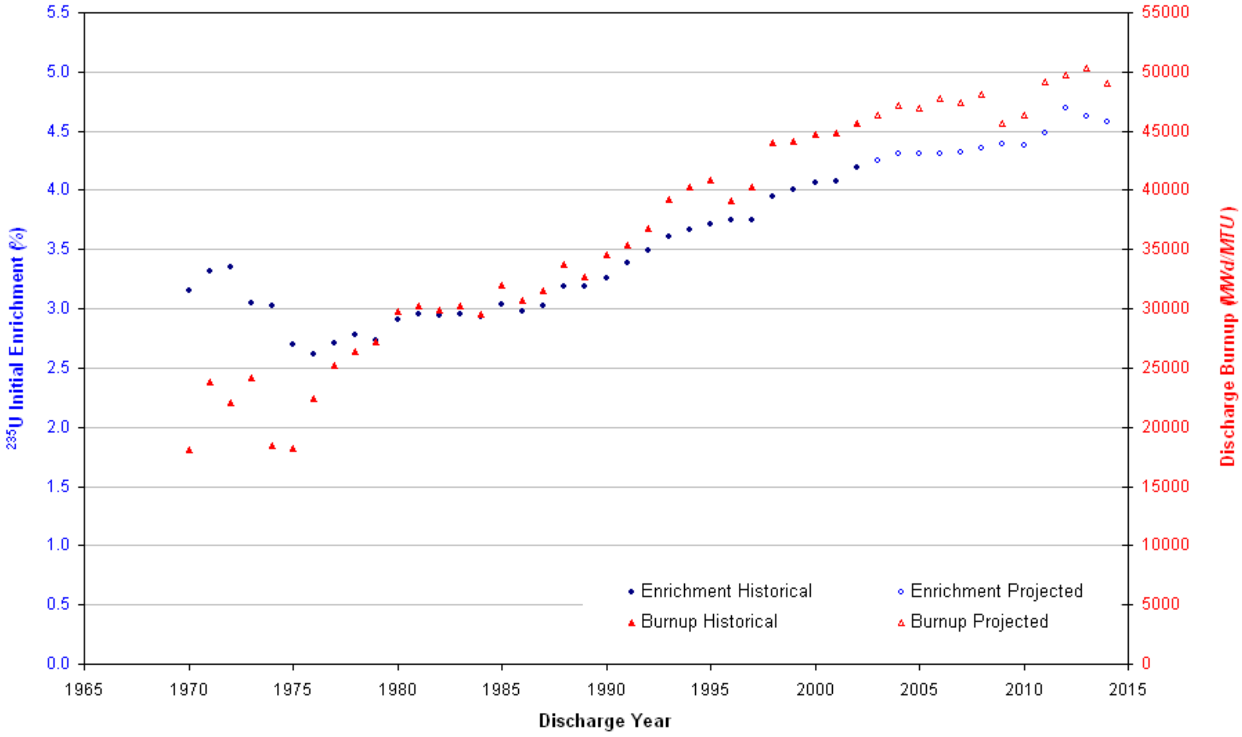
The Williams 2003, *Licensing Position-009, Waste Stream Parameters*, (Reference 2.2.40, Attachment, p. 1) gives the following characteristics for bounding CSNF assemblies (a) less than or equal to 5.0 percent ^{235}U enrichment, (b) less than or equal to 80 GWd/MTU burnup, and (c) greater than or equal to a 5 year out-of-reactor cooling time.

PWR

The Babcock and Wilcox (B&W) 15x15 Mark B fuel assembly was selected as the representative PWR assembly (Reference 2.2.7). The characteristics of the average and bounding PWR SNF assemblies used for source term generation (with an initial uranium loading of 475 kg) (Reference 2.2.7, Section 5.2 and 5.5) are:

- Average PWR assembly: B&W 15x15, 4.0 percent ^{235}U enrichment, 48 GWd/MTU, and 25-years cooling time
- Bounding PWR assembly: B&W 15x15, 5.0 percent ^{235}U enrichment, 80 GWd/MTU, and 5-years cooling time.

Figure 1 shows the evolution in time of ^{235}U initial enrichment and discharge burnup for PWR fuel assemblies. Both historical data and utility projection for the next five cycles are included.



Source: Attachment A, spreadsheet *EB.xls*
Note: This figure presents the average initial ^{235}U enrichment and average discharge burnup for all assemblies permanently discharged during a calendar year.

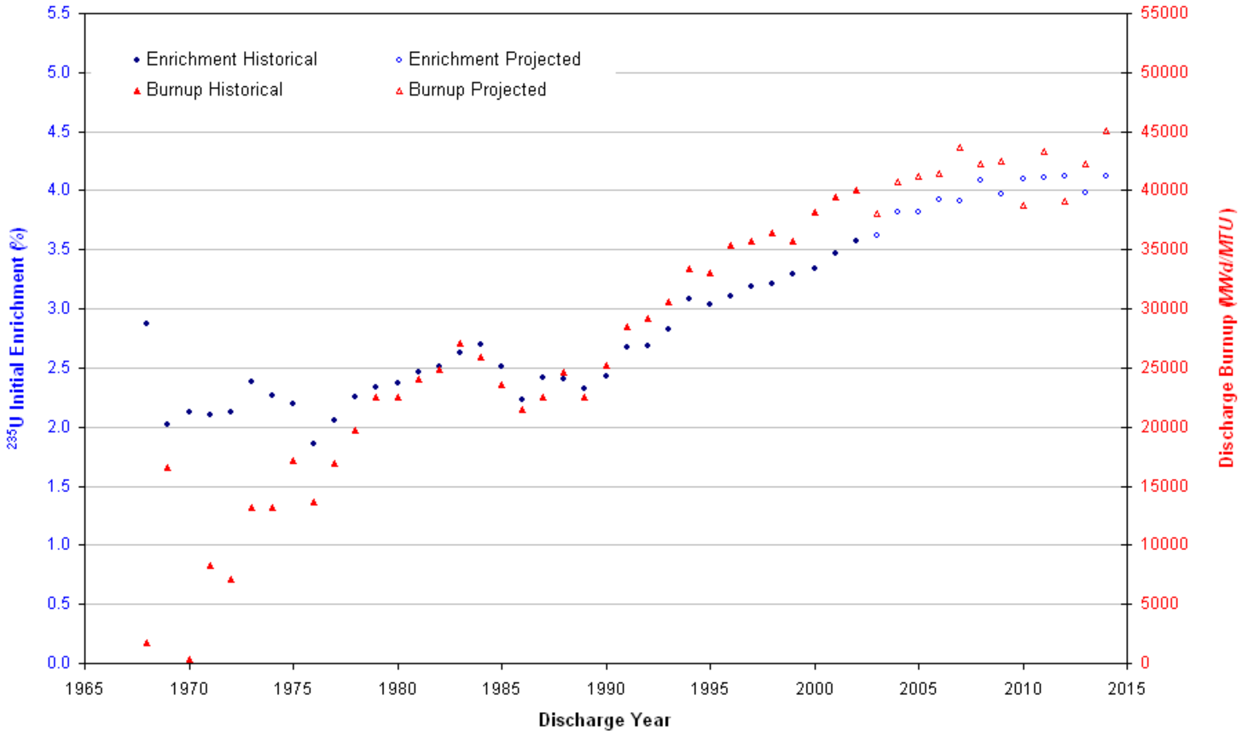
Figure 1. Initial Enrichment and Discharge Burnup Evolution for PWR Reactors as of December 31, 2002, and Facilities Program for the Next Five Cycles

BWR

The General Electric 2/3 8x8 fuel assembly has been chosen as the representative BWR assembly (Reference 2.2.5). The characteristics of the average and bounding BWR SNF representative assemblies used for source term generation (with an initial uranium loading of 200 kg) (Reference 2.2.5, Section 5.2 and 5.5.3) are:

- Average BWR Assembly: GE 2/3 8x8, 3.5 percent ^{235}U enrichment, 40 GWd/MTU, and 25 years cooling time
- Bounding BWR Assembly: GE 2/3 8x8, 5.0 percent ^{235}U enrichment, 75 GWd/MTU, and 5 years cooling time.

Figure 2 shows the evolution in time of ^{235}U initial enrichment and discharge burnup for BWR fuel assemblies. Both historical data and utility projection for the next five cycles are included.



Source: Attachment A, spreadsheet "EB.xls"
Note: This figure presents the average initial ^{235}U enrichment and average discharge burnup for all assemblies permanently discharged during a calendar year.

Figure 2. Initial Enrichment and Discharge Burnup Evolution for BWR Reactors as of December 31, 2002 and Facilities Program for the Next Five Cycles

Figures 1 and 2 were generated by averaging the discharged assembly characteristics (historical or projected) per calendar year and reactor type (see Attachment A, spreadsheet *EB.xls*).

Fuel Assembly Physical Characteristics and Dimensions

Table 3 shows the manufacturer and main characteristics of the fuel assembly types that are present in the reactors inventory as of December 31, 2002. Table 4 (for PWR SNF) and Table 5 (for BWR SNF) show, for each assembly type, the assembly class they belong and their physical characteristics (length, width, and cladding material). The physical dimensions of length and width are those of unirradiated assemblies.

Chemical Composition

CSNF consists of the uranium oxide fuel itself (including fission products), cladding, and hardware. Typical PWR and BWR fuels consist of uranium oxide fuel pellets with a zirconium alloy cladding, although some assemblies have stainless steel cladding (Reference 2.2.7, Sections 5.2 and 5.3, and Reference 2.2.5, Sections 5.2 and 5.4).

Crud Deposit

The crud source terms for PWR and BWR fuel assembly types were evaluated in previous calculations (Reference 2.2.7, Section 5.6 and Reference 2.2.5, Section 5.5.4, respectively). The crud source term comes from the activated corrosion products from the coolant deposited on the surface of the assembly. The activity of the crud on the surface of the BWR and PWR assemblies at time of discharge is determined by multiplying the calculated assembly surface area exposed to coolant by the ^{60}Co and some minor corrosion product activity per unit area of surface (Reference 2.2.7, Section 5.3.2 and 5.6).

After decaying for 5 years, the principal radionuclide species in the crud are ^{55}Fe and ^{60}Co. Initial crud activities for commercial SNF at the time of discharge from a reactor are presented in *Characteristics for the Representative Commercial Spent Fuel Assembly for Preclosure Normal Operations* (Reference 2.2.10, Table 17).

Commercial SNF assemblies have the following values for surface area per fuel assembly: (Reference 2.2.7, Section 5.6 and Reference 2.2.5, Section 5.5.4)

- PWR = 449,003 (cm^2/fuel assembly)
- BWR = 168,148 (cm^2/fuel assembly).

These surface areas are bounding values, based on assemblies with the largest surface areas, a South Texas PWR assembly, and an ANF 9X9 JP-4,5 BWR assembly (Reference 2.2.7, Section 5.6 and Reference 2.2.5, Section 5.5.4).

Table 3. Assembly Types and Their Main Characteristics as of December 31, 2002.

Reactor Type	Manufacturer Code	Assembly Code	Initial U (kg/assembly)		Enrichment (U-235 wt%)			Burnup (MWd/MTU)	
			Avg.	Max	Min.	Avg.	Max	Avg.	Max
BWR	not available	9X9IXQFA	170.713	170.800	3.25	3.25	3.25	39166	39248
BWR	AC	XLC10L	120.160	121.034	3.63	3.77	3.94	14419	21532
BWR	ANF	G2307A	181.574	183.797	2.56	2.64	2.65	24256	27826
BWR	ANF	G2308A	174.624	184.355	2.39	2.66	3.13	28814	36826
BWR	ANF	G2308AP	172.753	173.132	2.82	2.83	2.83	34366	34826
BWR	ANF	G2309A	168.097	169.520	2.78	3.10	3.15	35941	40818
BWR	ANF	G2309AIX	169.185	170.059	3.25	3.31	3.82	39151	43778
BWR	ANF	G4608AP	176.175	176.800	2.62	2.88	3.40	31248	35518
BWR	ANF	G4609A	172.970	174.700	0.72	3.42	3.73	36933	47000
BWR	ANF	G4609A5	176.147	177.000	2.90	3.28	3.55	36536	43555
BWR	ANF	G4609A9X	169.155	176.800	2.53	2.87	3.11	36880	43330
BWR	ANF	G4609AIX	174.788	177.000	3.00	3.58	3.94	24156	36777
BWR	ANF	G4609AX+	167.264	167.277	3.13	3.14	3.15	39239	40457
BWR	ANF	G4610A	176.900	176.900	3.94	3.94	3.94	38207	39000
BWR	ANF	G4610AIX	175.000	175.000	3.39	3.39	3.39	37706	38009
BWR	ANF	XBR09A	127.687	131.406	3.45	3.48	3.52	20981	22811
BWR	ANF	XBR11A	130.237	133.174	3.13	3.42	3.82	22716	34212
BWR	ANF	XDR06A	95.206	95.478	2.23	2.23	2.24	4907	5742
BWR	ANF	XHB06A	69.734	73.800	2.35	2.40	2.41	9037	22377
BWR	ANF	XLC10A	108.657	109.609	3.68	3.69	3.71	15017	20126
BWR	AREVA	ATRIUM10	176.900	176.900	3.94	3.94	3.94	38406	39000
BWR	ABB	G4610C	175.683	176.300	2.51	3.29	3.62	38133	42640
BWR	GE	G2307G2A	194.902	197.604	2.07	2.10	2.11	16775	24902
BWR	GE	G2307G2B	193.203	197.400	1.65	2.15	2.62	16384	29728
BWR	GE	G2307G3	187.419	189.105	1.96	2.41	2.60	25420	38861
BWR	GE	G2308G10	172.225	173.512	3.10	3.25	3.56	33988	43977
BWR	GE	G2308G4	183.991	185.496	2.19	2.51	2.76	26087	40523
BWR	GE	G2308G5	176.971	177.628	2.39	2.66	2.82	29009	33597
BWR	GE	G2308G7	178.520	179.400	2.96	2.97	2.99	31570	35894
BWR	GE	G2308G8A	175.695	179.584	2.55	3.09	3.40	34848	44933
BWR	GE	G2308G8B	172.590	178.000	2.96	3.19	3.39	36400	42518
BWR	GE	G2308G9	172.017	173.108	2.85	3.18	3.48	37268	42295
BWR	GE	G2308GB	177.983	180.060	2.62	2.80	3.39	32014	43381
BWR	GE	G2308GP	177.145	179.200	2.08	2.77	3.01	29317	38139
BWR	GE	G2309G11	165.650	169.500	3.10	3.56	3.78	40522	45117
BWR	GE	G4607G2	194.729	197.334	1.09	1.56	2.50	9362	11829
BWR	GE	G4607G3A	187.455	189.141	1.10	2.33	2.51	21058	32188
BWR	GE	G4607G3B	189.925	191.542	1.10	2.31	2.51	21948	30831
BWR	GE	G4608G10	177.778	186.094	2.63	3.24	3.70	36695	44343
BWR	GE	G4608G11	170.786	171.000	3.38	3.38	3.38	35194	42551
BWR	GE	G4608G12	180.873	181.484	3.69	3.71	3.99	32069	34462
BWR	GE	G4608G4A	183.931	185.221	2.19	2.62	2.99	24931	43430
BWR	GE	G4608G4B	186.709	187.900	2.10	2.31	2.76	21362	32941

Table 3. Assembly Types and Their Main Characteristics as of December 31, 2002. (Continued)

Reactor Type	Manufacturer Code	Assembly Code	Initial U (kg/assembly)		Enrichment (U-235 wt%)			Burnup (MWd/MTU)	
			Avg.	Max	Min.	Avg.	Max	Avg.	Max
BWR	GE	G4608G5	183.007	185.366	0.70	2.36	3.01	23964	38224
BWR	GE	G4608G8	179.801	185.854	2.95	3.19	3.40	34905	44640
BWR	GE	G4608G9	177.738	185.789	1.51	3.23	3.88	36492	47062
BWR	GE	G4608GB	184.636	186.653	0.71	2.53	3.25	26297	45986
BWR	GE	G4608GP	183.195	186.888	0.70	2.38	3.27	23112	42428
BWR	GE	G4609G11	170.123	178.136	1.46	3.56	4.14	40351	65149
BWR	GE	G4609G13	171.417	172.912	3.24	3.85	4.17	42045	53636
BWR	GE	G4610G12	176.100	182.141	3.12	3.98	4.20	44175	52735
BWR	GE	G4610G14	179.127	180.402	4.01	4.11	4.24	5868	8915
BWR	GE	XBR07G	131.500	133.000	2.88	2.88	2.88	1643	1690
BWR	GE	XBR08G	112.500	113.000	2.85	2.85	2.85	4546	7027
BWR	GE	XBR09G	137.088	141.000	3.51	3.58	3.62	15092	22083
BWR	GE	XBR11G	124.500	132.000	3.11	3.46	3.63	22802	24997
BWR	GE	XDR06G	111.352	111.352	1.47	1.47	1.47	23522	23522
BWR	GE	XDR06G3B	101.610	102.520	1.83	1.83	1.83	18632	27106
BWR	GE	XDR06G3F	102.049	102.876	2.25	2.25	2.25	22132	28138
BWR	GE	XDR06G5	105.857	112.257	2.26	2.26	2.26	21095	25886
BWR	GE	XDR07GS	59.000	59.000	3.10	3.10	3.10	29000	29000
BWR	GE	XDR08G	99.714	99.714	1.95	1.95	1.95	25287	25287
BWR	GE	XHB06G	76.355	77.000	2.35	2.43	2.52	17170	22876
BWR	GE	XHB07G2	76.325	77.100	2.08	2.11	2.31	18187	20770
BWR	NFS	XBR11N	128.991	134.414	2.16	2.83	3.51	18940	21850
BWR	UNC	XDR06U	102.021	103.441	1.83	2.24	2.26	17685	26396
BWR	WE	G4608W	156.696	171.403	2.69	2.85	3.01	28041	33140
PWR	ANF	C1414A	380.870	400.000	0.30	3.50	4.32	38899	50871
PWR	ANF	W1414A	378.274	406.840	0.71	3.42	4.50	37500	56328
PWR	ANF	W1414ATR	362.788	368.011	2.39	3.38	3.57	38168	46000
PWR	ANF	W1515A	428.888	434.792	2.01	3.00	3.60	33344	49859
PWR	ANF	W1515AHT	434.546	438.074	3.51	4.08	4.59	45441	56922
PWR	ANF	W1515APL	307.361	310.073	1.23	1.55	1.88	27971	37770
PWR	ANF	W1717A	413.845	460.540	2.43	4.19	4.77	45291	53958
PWR	ANF	XFC14A	353.345	358.811	3.50	3.57	3.80	37205	46048
PWR	ANF	XPA15A	396.674	408.040	1.50	3.17	4.05	34362	51486
PWR	ANF	XYR16A	233.555	237.300	3.49	3.78	4.02	29034	35088
PWR	B&W	B1515B	463.398	465.480	2.74	3.57	3.62	40407	50128
PWR	B&W	B1515B10	476.778	489.299	3.24	3.90	4.73	44417	56880
PWR	B&W	B1515B3	463.845	465.830	1.08	2.42	2.84	21036	32267
PWR	B&W	B1515B4	464.285	474.853	0.90	2.91	4.06	29534	57000
PWR	B&W	B1515B4Z	463.735	466.305	3.22	3.84	3.95	39253	51660
PWR	B&W	B1515B5	468.250	468.250	3.13	3.13	3.13	38017	39000
PWR	B&W	B1515B5Z	464.421	465.176	3.20	3.22	3.23	36016	42328
PWR	B&W	B1515B6	462.495	464.403	3.22	3.47	3.66	41790	49383
PWR	B&W	B1515B7	463.244	464.513	3.48	3.51	3.55	42059	48738
PWR	B&W	B1515B8	464.864	468.560	3.29	3.65	4.01	42692	54000
PWR	B&W	B1515B9	463.566	467.566	3.29	3.96	4.76	44097	53952
PWR	B&W	B1515BGD	429.552	430.255	3.92	3.92	3.92	49027	58310
PWR	B&W	B1515BZ	463.410	466.279	3.05	3.47	4.68	37441	54023

Table 3. Assembly Types and Their Main Characteristics as of December 31, 2002. (Continued)

Reactor Type	Manufacturer Code	Assembly Code	Initial U (kg/assembly)		Enrichment (U-235 wt%)			Burnup (MWd/MTU)	
			Avg.	Max	Min.	Avg.	Max	Avg.	Max
PWR	B&W	B1717B	456.722	457.929	2.64	2.84	3.04	29517	33904
PWR	B&W	W1414B	383.157	383.157	3.22	3.22	3.22	24398	24465
PWR	B&W	W1717B	455.799	466.688	2.00	3.84	4.60	40741	54014
PWR	B&W	XHN15B	409.913	415.060	3.00	3.99	4.02	33776	37833
PWR	B&W	XHN15BZ	363.921	368.072	3.40	3.80	3.91	34278	42956
PWR	CE	C1414C	382.437	408.508	1.03	3.20	4.48	33597	56000
PWR	CE	C1616CSD	413.912	442.986	1.87	3.62	4.63	37916	63328
PWR	CE	C8016C	421.468	442.000	1.92	3.57	4.27	38490	56312
PWR	CE	XFC14C	362.313	376.842	1.39	2.96	3.95	32130	52125
PWR	CE	XPA15C	412.442	416.780	1.65	2.47	3.06	16020	33630
PWR	CE	XSL16C	381.018	394.400	1.72	3.44	4.28	38807	54838
PWR	CE	XYR16C	228.766	233.400	3.51	3.80	3.92	24282	35999
PWR	GA	XHN15HS	406.163	406.163	3.99	3.99	3.99	32151	32151
PWR	GA	XHN15HZ	362.863	362.863	3.26	3.26	3.26	18546	18546
PWR	NU	XHN15MS	405.979	406.992	3.66	3.66	3.66	28324	28324
PWR	NU	XHN15MZ	370.776	371.039	2.95	2.95	2.95	25643	25643
PWR	UNC	XYR16U	238.573	241.300	3.96	3.99	4.02	27461	31986
PWR	WE	B1515W	461.819	464.763	3.90	4.06	4.22	36993	49075
PWR	WE	C1414W	403.483	411.719	2.70	3.15	3.76	30039	37781
PWR	WE	W1414W	393.896	403.683	2.26	3.04	3.47	27315	39723
PWR	WE	W1414WL	399.092	405.809	2.27	3.07	3.41	31940	47932
PWR	WE	W1414WO	355.724	369.265	0.99	3.92	4.95	44730	69452
PWR	WE	W1515W	451.193	458.091	2.21	3.00	3.35	29324	41806
PWR	WE	W1515WL	455.236	465.600	1.85	2.98	3.80	30874	55385
PWR	WE	W1515WO	460.764	465.747	1.91	3.53	4.60	39071	56138
PWR	WE	W1515WV5	457.793	462.934	2.99	3.92	4.80	37556	53056
PWR	WE	W1717WL	461.323	469.200	1.60	3.12	4.40	32340	58417
PWR	WE	W1717WO	425.107	459.433	1.60	3.05	4.02	32690	53000
PWR	WE	W1717WP	417.069	417.878	3.73	4.59	4.81	50707	58237
PWR	WE	W1717WRF	455.497	456.735	4.00	4.18	4.42	45530	48037
PWR	WE	W1717WV	425.399	426.042	4.21	4.38	4.41	44263	48385
PWR	WE	W1717WV+	424.010	465.469	1.61	4.16	4.66	45430	61685
PWR	WE	W1717WV5	424.269	430.925	1.49	4.01	4.95	43872	56570
PWR	WE	W1717WVH	461.954	473.962	2.11	3.87	4.95	41081	55496
PWR	WE	W1717WVJ	461.518	465.200	3.71	3.99	4.40	43922	46847
PWR	WE	WST17W	540.480	546.600	1.51	3.38	4.41	35926	54399
PWR	WE	XFC14W	374.055	376.000	0.27	3.75	4.25	38521	51971
PWR	WE	XHN15W	415.557	421.227	3.02	3.59	4.00	27922	35196
PWR	WE	XHN15WZ	384.894	386.689	4.20	4.39	4.60	14321	19376
PWR	WE	XIP14W	191.152	200.467	2.83	4.12	4.36	16471	27048
PWR	WE	XSO14W	368.153	374.885	3.16	3.87	4.02	27232	39275
PWR	WE	XSO14WD	373.323	373.643	4.01	4.01	4.02	18259	18424
PWR	WE	XSO14WM	311.225	311.225	0.71	0.71	0.71	19307	19636
PWR	WE	XYR18W	273.350	274.100	4.94	4.94	4.94	25484	31755

Source: Attachment A, database *Final2002modifiedDM-RW859.mdb*, query *assembly characteristics*

Table 4. Physical Characteristics of PWR Assembly Classes

Assm Class	Array Size	Manuf. Code	Version	Assm.Code	Length (in.)	Width (in.)	Clad
B&W 15x15	15x15	B&W	B&W Mark B	B1515B	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B10	B1515B10	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B3	B1515B3	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B4	B1515B4	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B4Z	B1515B4Z	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B5	B1515B5	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B5Z	B1515B5Z	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B6	B1515B6	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B7	B1515B7	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B8	B1515B8	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark B9	B1515B9	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark BGD	B1515BGD	165.7	8.54	Zircaloy-4
	15x15	B&W	B&W Mark BZ	B1515BZ	165.7	8.54	Zircaloy-4
	15x15	WE	WE	B1515W	165.7	8.54	not available
B&W 17x17	17x17	B&W	B&W Mark C	B1717B	165.7	8.54	Zircaloy-4
CE 14x14	14x14	ANF	ANF	C1414A	157.0	8.10	Zircaloy-4
	14x14	CE	CE	C1414C	157.0	8.10	Zircaloy-4
	14x14	WE	WE	C1414W	157.0	8.10	Zircaloy-4
CE 16x16	16x16	CE	CE	C1616CSD	176.8	8.10	Zircaloy-4
CE System 80	16x16	CE	CE System 80	C8016C	178.3	8.10	Zircaloy-4
WE 14x14	14x14	ANF	ANF	W1414A	159.8	7.76	Zircaloy-4
	14x14	ANF	ANF Top Rod	W1414ATR	159.8	7.76	Zircaloy-4
	14x14	B&W	B&W	W1414B	159.8	7.76	not available
	14x14	WE	WE LOPAR	W1414WL	159.8	7.76	Zircaloy-4
	14x14	WE	WE OFA	W1414WO	159.8	7.76	Zircaloy-4
	14x14	WE	WE Std	W1414W	159.8	7.76	Zircaloy-4
WE 15x15	15x15	ANF	ANF	W1515A	159.8	8.44	Zircaloy-4
	15x15	ANF	ANF HT	W1515AHT	159.8	8.44	not available
	15x15	ANF	ANF Part Length	W1515APL	159.8	8.44	not available
	15x15	WE	LOPAR	W1515WL	159.8	8.44	Zircaloy-4
	15x15	WE	OFA	W1515WO	159.8	8.44	Zircaloy-4
	15x15	WE	WE Std	W1515W	159.8	8.44	Zircaloy
	15x15	WE	WE Vantage 5	W1515WV5	159.8	8.44	not available
WE 17x17	17x17	ANF	ANF	W1717A	159.8	8.44	Zircaloy-4
	17x17	B&W	B&W Mark B	W1717B	159.8	8.44	not available
	17x17	WE	WE	W1717WRF	159.8	8.44	not available
	17x17	WE	WE	W1717WVJ	159.8	8.44	not available
	17x17	WE	WE LOPAR	W1717WL	159.8	8.44	Zircaloy-4
	17x17	WE	WE OFA	W1717WO	159.8	8.44	Zircaloy-4
	17x17	WE	WE Pressurized	W1717WP	159.8	8.44	not available
	17x17	WE	WE Vantage	W1717WV	159.8	8.44	not available
	17x17	WE	WE Vantage +	W1717WV+	159.8	8.44	ZIRLO
	17x17	WE	WE Vantage 5	W1717WV5	159.8	8.44	Zircaloy-4
	17x17	WE	WE Vantage 5H	W1717WVH	159.8	8.44	not available

Table 4. Physical Characteristics of PWR Assembly Classes (Continued)

Assm Class	Array Size	Manuf. Code	Version	Assm.Code	Length (in.)	Width (in.)	Clad
South Texas	17x17	WE	WE	WST17W	199.0	8.43	Zircaloy-4
Ft. Calhoun	14x14	ANF	ANF	XFC14A	146.0	8.10	not available
	14x14	CE	CE	XFC14C	146.0	8.10	Zircaloy-4
	14x14	WE	WE	XFC14W	146.0	8.10	not available
Haddam Neck	15x15	B&W	B&W SS	XHN15B	137.1	8.42	SS-304
	15x15	B&W	B&W Zir	XHN15BZ	137.1	8.42	Zircaloy
	15x15	GA	Gulf SS	XHN15HS	137.1	8.42	SS
	15x15	GA	Gulf Zir	XHN15HZ	137.1	8.42	Zircaloy
	15x15	NU	NUM SS	XHN15MS	137.1	8.42	SS
	15x15	NU	NUM Zir	XHN15MZ	137.1	8.42	Zircaloy
	15x15	WE	WE	XHN15W	137.1	8.42	SS-304
	15x15	WE	WE Zir	XHN15WZ	137.1	8.42	not available
Indian Point-1	13x14	WE	WE	XIP14W	138.8	6.27	SS
Palisades	15x15	ANF	ANF	XPA15A	147.5	8.20	Zircaloy-4
	15x15	CE	CE	XPA15C	147.5	8.20	Zircaloy-4
St. Lucie-2	16x16	CE	CE	XSL16C	158.2	8.10	Zircaloy-4
San Onofre-1	14x14	WE	WE	XSO14W	137.1	7.76	SS-304
	14x14	WE	WE D	XSO14WD	137.1	7.76	not available
	14x14	WE	WE M	XSO14WM	137.1	7.76	not available
Yankee Rowe	15x16	ANF	ANF	XYR16A	111.8	7.62	Zircaloy-4
	15x16	CE	CE	XYR16C	111.8	7.62	Zircaloy-4
	15x16	UNC	UNC	XYR16U	111.8	7.62	not available
	17x18	WE	WE	XYR18W	111.8	7.62	SS

Source: Attachment A, database *Final2002modifiedDM-RW859.mdb*, query *char*
Note: Some characteristics of more recently discharged fuel (post 1999) have not yet been provided.

Table 5. Physical Characteristics of BWR Assembly Classes

Assm Class	Array Size	Manuf. Code	Version	Assm.Code	Length (in.)	Width (in.)	Clad
GE BWR/2,3	7x7	ANF	ANF	G2307A	171.2	5.44	Zircaloy-2
	8x8	ANF	ANF	G2308A	171.2	5.44	Zircaloy-2
	9x9	ANF	ANF	G2309A	171.2	5.44	Zircaloy-2
	9x9	ANF	ANF IX	G2309AIX	171.2	5.44	Zircaloy-2
	8x8	ANF	ANF Pressurized	G2308AP	171.2	5.44	Zircaloy-2
	8x8	GE	GE-10	G2308G10	171.2	5.44	Zircaloy-2
	9x9	GE	GE-11	G2309G11	171.2	5.44	Zircaloy-2
	7x7	GE	GE-2a	G2307G2A	171.2	5.44	Zircaloy-2
	7x7	GE	GE-2b	G2307G2B	171.2	5.44	Zircaloy-2
	7x7	GE	GE-3	G2307G3	171.2	5.44	Zircaloy-2
	8x8	GE	GE-4	G2308G4	171.2	5.44	Zircaloy-2
	8x8	GE	GE-5	G2308G5	171.2	5.44	Zircaloy-2
	8x8	GE	GE-7	G2308G7	171.2	5.44	not available
	8x8	GE	GE-8a	G2308G8A	171.2	5.44	Zircaloy-2
	8x8	GE	GE-8b	G2308G8B	171.2	5.44	Zircaloy-2
	8x8	GE	GE-9	G2308G9	171.2	5.44	Zircaloy-2
	8x8	GE	GE-Barrier	G2308GB	171.2	5.44	Zircaloy-2
	8x8	GE	GE-Pressurized	G2308GP	171.2	5.44	Zircaloy-2
	N/A	N/A	not available	9X9IXQFA	171.2	5.44	not available
GE BWR/4-6	9x9	ANF	ANF	G4609A	176.2	5.44	Zircaloy-2
	10x10	ANF	ANF	G4610A	176.2	5.44	not available
	9x9	ANF	ANF 9-5	G4609A5	176.2	5.44	Zircaloy-2
	9x9	ANF	ANF 9X	G4609A9X	176.2	5.44	Zircaloy-2
	9x9	ANF	ANF IX	G4609AIX	176.2	5.44	Zircaloy-2
	10x10	ANF	ANF IX	G4610AIX	176.2	5.44	not available
	9x9	ANF	ANF X+	G4609AX+	176.2	5.44	not available
	8x8	ANF	ANF-Pressurized	G4608AP	176.2	5.44	Zircaloy-2
	N/A	AREVA	not available	ATRIUM10	176.2	5.44	Zircaloy-2 [a]
	10x10	ABB	CE	G4610C	176.2	5.44	not available
	8x8	GE	GE-10	G4608G10	176.2	5.44	Zircaloy-2
	8x8	GE	GE-11	G4608G11	176.2	5.44	not available
	9x9	GE	GE-11	G4609G11	176.2	5.44	Zircaloy-2
	8x8	GE	GE-12	G4608G12	176.2	5.44	not available
	10x10	GE	GE-12	G4610G12	176.2	5.44	Zircaloy-2
	9x9	GE	GE-13	G4609G13	176.2	5.44	Zircaloy-2
	10x10	GE	GE-14	G4610G14	176.2	5.44	not available
	7x7	GE	GE-2	G4607G2	176.2	5.44	Zircaloy-2
	7x7	GE	GE-3a	G4607G3A	176.2	5.44	Zircaloy-2
	7x7	GE	GE-3b	G4607G3B	176.2	5.44	Zircaloy-2
	8x8	GE	GE-4a	G4608G4A	176.2	5.44	Zircaloy-2
	8x8	GE	GE-4b	G4608G4B	176.2	5.44	Zircaloy-2
	8x8	GE	GE-5	G4608G5	176.2	5.44	Zircaloy-2
	8x8	GE	GE-8	G4608G8	176.2	5.44	Zircaloy-2
	8x8	GE	GE-9	G4608G9	176.2	5.44	Zircaloy-2
	8x8	GE	GE-Barrier	G4608GB	176.2	5.44	Zircaloy-2
	8x8	GE	GE-Pressurized	G4608GP	176.2	5.44	Zircaloy-2
	8x8	WE	WE	G4608W	176.2	5.44	Zircaloy-2

Table 5. Physical Characteristics of BWR Assembly Classes (Continued)

Assm Class	Array Size	Manuf. Code	Version	Assm.Code	Length (in.)	Width (in.)	Clad
Big Rock Point	9x9	ANF	ANF	XBR09A	84	6.52	Zircaloy-2
	11x11	ANF	ANF	XBR11A	84	6.52	Zircaloy-2
	7x7	GE	GE	XBR07G	84	6.52	not available
	8x8	GE	GE	XBR08G	84	6.52	not available
	9x9	GE	GE	XBR09G	84	6.52	Zircaloy-2
	11x11	GE	GE	XBR11G	84	6.52	Zircaloy-2
	11x11	NFS	NFS	XBR11N	84	6.52	not available
Dresden-1	6x6	ANF	ANF	XDR06A	134.4	4.28	Zircaloy-2
	6x6	GE	GE	XDR06G	134.4	4.28	Zircaloy-2
	7x7	GE	GE SA-1	XDR07GS	134.4	4.28	not available
	8x8	GE	GE PF Fuels	XDR08G	134.4	4.28	not available
	6x6	GE	GE Type III-B	XDR06G3B	134.4	4.28	not available
	6x6	GE	GE Type III-F	XDR06G3F	134.4	4.28	not available
	6x6	GE	GE Type V	XDR06G5	134.4	4.28	not available
	6x6	UNC	UNC	XDR06U	134.4	4.28	not available
Humboldt Bay	6x6	ANF	6x6 ANF	XHB06A	95	4.67	Zircaloy
	6x6	GE	GE	XHB06G	95	4.67	Zircaloy-2
	7x7	GE	GE Type II	XHB07G2	95	4.67	Zircaloy
LaCrosse	10x10	AC	AC	XLC10L	102.5	5.62	SS348H
	10x10	ANF	ANF	XLC10A	102.5	5.62	SS348H

Source: Attachment A, database *Final2002modifiedDM-RW859.mdb*, query *char*
[a] Reference 2.2.12 — see Attachment D
Note: Some characteristics of more recently discharged fuel (post 1999) have not yet been provided.

6.2.2 Thermal Characteristics of Commercial Spent Nuclear Fuel

The thermal power for the average and bounding PWR and BWR assemblies are shown in Table 6 at their particular cooling time.

Table 6. Thermal Power of the Representative Average and Bounding PWR and BWR Fuel Assemblies

	Thermal Power (Watts/Assembly)			
	PWR		**BWR**	
	Average 25 years 48 GWd/MTU [a]	**Bounding 5 years 80 GWd/MTU** [b]	**Average 25 years 40 GWd/MTU** [c]	**Bounding 5 years 75 GWd/MTU** [d]
Activation Products	5	93	1	14
Fission Products	389	1610	133	540
Actinides and Daughters	207	772	53	225
Total	601	2475	186	779

Source: Attachment A
[a] spreadsheet *CSNF.xls*, tab *STPWRAvg*
[b] spreadsheet *CSNF.xls*, tab *STPWRMax*
[c] spreadsheet *CSNF.xls*, tab *STBWRAvg*
[d] spreadsheet *CSNF.xls*, tab *STBWRMax*

6.2.3 Nuclear Characteristics of Commercial Spent Nuclear Fuel

The radionuclides in CSNF are categorized into three groups: fission products, actinides, and activation products. In general, freshly discharged CSNF contains more than 100 radionuclides that are considered fission products. Uranium isotopes and transuranic elements make up the actinides, and radioactive isotopes created by neutron activation (of reactor components, fuel assembly materials, and impurities in cooling water or in the fuel pellets) make up the activation products. The exact radionuclide inventory of a particular spent fuel assembly depends on the reactor type, initial fuel composition, amount of time the fuel was irradiated, and elapsed time since its removal from the reactor core.

The radionuclide inventories of the representative PWR and BWR assemblies (B&W 15x15 Mark B and General Electric BWR 2/3 8x8, respectively) are presented in Table 7 for the average and bounding cases. The inventory includes radionuclides from the fuel section, the top and bottom end fittings, the plenum region, and the crud. Those radionuclides important for preclosure safety analysis and total system performance assessment are included.

Table 7. Nuclide Radioactivity of the Average and Bounding PWR and BWR Fuel Assemblies

Nuclide	Radioactivity (Curies/Assembly)			
	PWR		BWR	
	Average 25 years 48 GWd/MTU [a]	**Bounding 5 years 80 GWd/MTU [b]**	**Average 25 years 40 GWd/MTU [c]**	**Bounding 5 years 75 GWd/MTU [d]**
^{3}H	1.14×10^{2}	4.95×10^{2}	3.95×10^{1}	1.77×10^{2}
^{14}C	3.32×10^{-1}	5.35×10^{-1}	1.75×10^{-1}	3.16×10^{-1}
^{36}Cl	6.80×10^{-3}	1.05×10^{-2}	2.93×10^{-3}	4.99×10^{-3}
^{55}Fe	6.94×10^{0}	1.28×10^{3}	3.27×10^{0}	5.85×10^{2}
^{60}Co	3.14×10^{2}	6.00×10^{3}	4.71×10^{1}	8.97×10^{2}
^{59}Ni	2.09×10^{0}	2.96×10^{0}	5.03×10^{-1}	7.80×10^{-1}
^{63}Ni	2.52×10^{2}	4.52×10^{2}	5.87×10^{1}	1.16×10^{2}
^{79}Se	4.57×10^{-2}	7.35×10^{-2}	1.59×10^{-2}	2.89×10^{-2}
^{85}Kr	1.13×10^{3}	5.79×10^{3}	3.81×10^{2}	2.03×10^{3}
^{90}Sr	2.72×10^{4}	6.52×10^{4}	9.54×10^{3}	2.52×10^{4}
^{90}Y	2.72×10^{4}	6.53×10^{4}	9.54×10^{3}	2.52×10^{4}
^{93}Zr	8.94×10^{-1}	1.41×10^{0}	3.39×10^{-1}	6.03×10^{-1}
^{93m}Nb	1.29×10^{1}	4.87×10^{1}	4.74×10^{-1}	1.22×10^{0}
^{94}Nb	8.40×10^{-1}	1.37×10^{0}	1.87×10^{-2}	3.39×10^{-2}
^{99}Tc	8.99×10^{0}	1.34×10^{1}	3.20×10^{0}	5.35×10^{0}
^{106}Ru	1.23×10^{-2}	1.33×10^{4}	3.00×10^{-3}	3.29×10^{3}
^{106}Rh	1.23×10^{-2}	1.33×10^{4}	3.00×10^{-3}	3.29×10^{3}
^{107}Pd	8.41×10^{-2}	1.60×10^{-1}	2.65×10^{-2}	5.70×10^{-2}
^{113m}Cd	7.66×10^{0}	4.31×10^{1}	2.26×10^{0}	1.39×10^{1}
^{121m}Sn	1.59×10^{0}	3.58×10^{0}	5.99×10^{-1}	1.48×10^{0}
^{126}Sn	3.85×10^{-1}	6.83×10^{-1}	1.27×10^{-1}	2.52×10^{-1}
^{125}Sb	9.71×10^{0}	2.14×10^{3}	2.89×10^{0}	6.21×10^{2}
^{126}Sb	5.39×10^{-2}	9.57×10^{-2}	1.78×10^{-2}	3.53×10^{-2}
^{126m}Sb	3.85×10^{-1}	6.83×10^{-1}	1.27×10^{-1}	2.52×10^{-1}
^{125m}Te	2.38×10^{0}	5.21×10^{2}	7.06×10^{-1}	1.52×10^{2}
^{129}I	2.20×10^{-2}	3.60×10^{-2}	7.43×10^{-3}	1.36×10^{-2}
^{134}Cs	2.52×10^{1}	4.05×10^{4}	6.32×10^{0}	1.16×10^{4}
^{135}Cs	3.50×10^{-1}	6.34×10^{-1}	1.39×10^{-1}	2.82×10^{-1}
^{137}Cs	4.11×10^{4}	1.05×10^{5}	1.39×10^{4}	3.87×10^{4}
^{137m}Ba	3.88×10^{4}	9.89×10^{4}	1.31×10^{4}	3.65×10^{4}
^{144}Ce	1.18×10^{-4}	5.80×10^{3}	2.89×10^{-5}	1.38×10^{3}
^{144}Pr	1.18×10^{-4}	5.80×10^{3}	2.89×10^{-5}	1.38×10^{3}
^{147}Pm	1.19×10^{2}	2.29×10^{4}	3.98×10^{1}	7.46×10^{3}
^{151}Sm	2.11×10^{2}	3.19×10^{2}	5.39×10^{1}	8.22×10^{1}
^{152}Eu	1.31×10^{0}	4.54×10^{0}	5.29×10^{-1}	1.69×10^{0}
^{154}Eu	6.71×10^{2}	6.15×10^{3}	1.80×10^{2}	1.83×10^{3}
^{155}Eu	5.16×10^{1}	1.80×10^{3}	1.64×10^{1}	6.37×10^{2}
^{208}Tl	7.56×10^{-3}	1.64×10^{-2}	1.72×10^{-3}	6.10×10^{-3}
^{227}Ac	1.61×10^{-5}	—	—	—
^{230}Th	1.48×10^{-4}	3.33×10^{-5}	6.09×10^{-5}	2.05×10^{-5}
^{231}Pa	2.97×10^{-5}	4.18×10^{-5}	1.39×10^{-5}	2.94×10^{-5}

Table 7. Nuclide Radioactivity of the Average and Bounding PWR and BWR Fuel Assemblies (Continued)

Nuclide	Radioactivity (Curies/Assembly)			
	PWR		BWR	
	Average 25 years 48 GWd/MTU [a]	Bounding 5 years 80 GWd/MTU [b]	Average 25 years 40 GWd/MTU [c]	Bounding 5 years 75 GWd/MTU [d]
^{232}U	2.05×10^{-2}	5.97×10^{-2}	4.64×10^{-3}	2.00×10^{-2}
^{233}U	4.07×10^{-5}	2.42×10^{-5}	1.14×10^{-5}	—
^{234}U	6.77×10^{-1}	5.21×10^{-1}	2.49×10^{-1}	2.26×10^{-1}
^{235}U	7.36×10^{-3}	3.28×10^{-3}	2.62×10^{-3}	9.40×10^{-4}
^{236}U	1.72×10^{-1}	2.23×10^{-1}	6.26×10^{-2}	9.55×10^{-2}
^{237}U	5.90×10^{-1}	1.91×10^{0}	1.62×10^{-1}	5.40×10^{-1}
^{238}U	1.48×10^{-1}	1.42×10^{-1}	6.32×10^{-2}	6.07×10^{-2}
^{236}Np	—	3.45×10^{-5}	—	—
^{237}Np	2.47×10^{-1}	4.01×10^{-1}	6.89×10^{-2}	1.33×10^{-1}
^{238}Np	2.87×10^{-2}	4.58×10^{-2}	9.75×10^{-3}	1.53×10^{-2}
^{239}Np	2.20×10^{1}	6.00×10^{1}	5.35×10^{0}	1.93×10^{1}
^{236}Pu	1.01×10^{-3}	3.46×10^{-1}	1.67×10^{-4}	6.96×10^{-2}
^{237}Pu	—	1.03×10^{-11}	—	1.64×10^{-12}
^{238}Pu	2.29×10^{3}	6.80×10^{3}	5.85×10^{2}	2.11×10^{3}
^{239}Pu	1.77×10^{2}	1.83×10^{2}	5.35×10^{1}	5.36×10^{1}
^{240}Pu	3.18×10^{2}	4.01×10^{2}	1.14×10^{2}	1.48×10^{2}
^{241}Pu	2.47×10^{4}	8.00×10^{4}	6.78×10^{3}	2.25×10^{4}
^{242}Pu	1.64×10^{0}	3.34×10^{0}	5.09×10^{-1}	1.26×10^{0}
^{241}Am	1.98×10^{3}	8.79×10^{2}	5.58×10^{2}	2.66×10^{2}
^{242m}Am	6.39×10^{0}	1.02×10^{1}	2.17×10^{0}	3.40×10^{0}
^{242}Am	6.36×10^{0}	1.01×10^{1}	2.16×10^{0}	3.39×10^{0}
^{243}Am	2.20×10^{1}	6.00×10^{1}	5.35×10^{0}	1.93×10^{1}
^{242}Cm	5.27×10^{0}	3.56×10^{1}	1.79×10^{0}	1.13×10^{1}
^{243}Cm	1.03×10^{1}	4.19×10^{1}	2.48×10^{0}	1.12×10^{1}
^{244}Cm	1.36×10^{3}	1.40×10^{4}	2.56×10^{2}	3.95×10^{3}
^{245}Cm	3.07×10^{-1}	1.79×10^{0}	4.04×10^{-2}	3.54×10^{-1}
^{246}Cm	1.04×10^{-1}	1.21×10^{0}	1.45×10^{-2}	2.97×10^{-1}
^{248}Cm	—	1.40×10^{-4}	—	2.38×10^{-5}
^{249}Cf	7.75×10^{-5}	3.90×10^{-3}	—	4.73×10^{-4}
^{251}Cf	—	1.96×10^{-4}	—	2.29×10^{-5}
Sum	1.68×10^{5}	5.64×10^{5}	5.53×10^{4}	1.90×10^{5}

Source: Attachment A
[a] spreadsheet *CSNF.xls*, tab *STPWRAvg*
[b] spreadsheet *CSNF.xls*, tab *STPWRMax*
[c] spreadsheet *CSNF.xls*, tab *STBWRAvg*
[d] spreadsheet *CSNF.xls*, tab *STBWRMax*

Note: The radionuclide activities not provided in table were eliminated by the ORIGEN-S code; therefore, not reported in the output files.

6.3 HIGH-LEVEL RADIOACTIVE WASTE

HLW is the highly radioactive material resulting from the reprocessing of SNF. DOE stores defense HLW that it produced at Hanford, SRS, and INL. Commercial reprocessing was done at WVDP, and therefore HLW is also stored at this site (Reference 2.2.19, Appendix A, p. A-36).

6.3.1 Physical Characteristics of High-Level Waste

An overview of the physical characteristics of HLW is provided in Reference 2.2.11, Section 6.3.

Additionally, Reference 2.2.11, Tables 2, 6, 10, and 14 provide the chemical compositions of each HLW glass type.

6.3.2 Thermal Characteristics of High-Level Waste

The thermal output from each site (total per HLW type and maximum per canister basis) are provided in Reference 2.2.11, Tables 25 and 24, respectively.

6.3.3 Nuclear Characteristics of High-Level Waste

For each HLW glass type, the total radionuclide inventories and the radionuclide inventories for the bounding canisters are provided in Reference 2.2.11, Tables B-1 and 18, respectively.

6.4 DOE SPENT NUCLEAR FUEL

DOE SNF comes from a variety of sources. Some DOE SNF is the spent fuel remaining from the fuel used for weapons. The DOE reprocessed most of its SNF in facilities at INL, the Hanford Site, and the Savannah River Site (SRS). The government of the United States decided to stop reprocessing, and therefore some SNF remains at those sites. Most of the SNF came from the N-Reactor at the Hanford Site, which was a dual-purpose reactor designed to produce plutonium for nuclear weapons and to generate electricity for commercial use. However, smaller amounts of SNF associated with nuclear weapons production are stored at the SRS (Reference 2.2.19, Appendix A p. A-21 and A-22).

Presently, most of the DOE SNF is stored at three primary locations including: the Hanford Site, the SRS, and INL. DOE will ship all of its remaining SNF from other sites to one of the three primary sites for storage and preparation for ultimate disposition (Reference 2.2.19, Appendix A, pp. A-21 and A-22, Reference 2.2.16, Table 3.2).

6.4.1 Physical Characteristics of DOE Spent Nuclear Fuel

Reference 2.2.24, Sections 3 and 4, provide information on the physical characteristics of DOE SNF.

6.4.2 Thermal Characteristics of DOE Spent Nuclear Fuel

Reference 2.2.24, Table 4, shows the thermal power of DOE SNF. The *Waste Acceptance System Requirements Document* limits the total heat generation rate in DOE SNF canisters to 1,970 watts (Reference 2.2.27, Section 4.3.9).

6.4.3 DOE Spent Nuclear Fuel Radionuclide Inventory

Reference 2.2.24, Table 3, provides the total DOE SNF radionuclide inventory for the nominal and bounding fuel inventories for both years 2010 and 2030.

6.5 NAVAL SPENT NUCLEAR FUEL

The Naval Nuclear Propulsion Program is providing information and characteristics on the naval SNF; therefore, naval SNF is not covered in this document. Classified details regarding the naval waste form are presented in the Naval Nuclear Propulsion Program Technical Support Document, which is part of the license application submitted under separate cover.

7. CONCLUSIONS

This analysis provided information on the different types of waste forms to be stored at the repository at Yucca Mountain. The analysis covered three different waste forms including: CSNF, DOE SNF, and HLW. Naval SNF was not covered in this document since the Naval Nuclear Propulsion Program will be providing the characteristics of the naval SNF waste form. This analysis provides the main characteristics (e.g. radionuclide inventory and thermal output) of the different waste forms. A description of the TAD canister was also covered in this analysis.

ATTACHMENT B

LIST OF FILES ON ATTACHED CD (ATTACHMENT A)

Attachment B lists the files that are on the compact disc (CD) (Attachment A), which contains the modified Microsoft® Assess databases, and the Microsoft® Excel spreadsheets.

```
 Volume in drive D is 080107_0859
 Volume Serial Number is 410E-8ACB

 Directory of D:\

01/03/2008  07:39 PM        21,089,280 CSNF.xls
12/06/2007  08:32 AM         1,548,800 EB.xls
01/03/2008  07:39 PM        64,176,128 Final2002modifiedDM-RW859.mdb
12/20/2007  01:11 PM            14,336 HLW.xls
               4 File(s)    86,828,544 bytes

     Total Files Listed:
               4 File(s)    86,828,544 bytes
               0 Dir(s)              0 bytes free
```

ATTACHMENT C

Modifications to the RW-859 2002 Database and Generation of Access Queries

The following modifications were made to the *Final2002RW859ACC97.mdb*, table *fuelfreshcorr* which is the RW-859 2002 database (Reference 2.2.8 BSC 2005).

The *Final2002RW859ACC97.mdb* RW-859 2002 database is written in Access 1997. BSC uses Access 2000 so the file *Final2002RW859ACC97.mdb* was first converted to an Access 2000 file and then modified with the following changes:

- The assembly type of "G460864B" of the Brunswick 1 reactor was changed from "G460864B" to "G4608G4B." The assembly type "G460864B" is not a valid assembly type. This change was based on comparing the assembly ID numbers in the 2002 and 1998 databases, which matched exactly meaning that the fuel assemblies are the same. Therefore. the assembly code was changed in the 2002 database to what it was in the 1998 database.
- The assembly type of "G4608G8B" of the Fitzpatrick reactor was changed from "G4608G8B" to "G2308G8B." This change was based on comparing the assembly ID numbers in the 2002 and 1998 databases, which matched exactly meaning that the fuel assemblies are the same. Therefore the assembly code was changed in the 2002 database to what it was in the 1998 database.
- The assembly type of "G4806G10" of the Perry reactor was changed from "G4806G10" to "G4608G10." The assembly type "G4806G10" is not a valid assembly type. This change was based on the assembly type "G4806G10" having the same assembly ID format, same characteristics (initial uranium content, initial enrichment, and max burnup) as the assembly type "G4608G10," and coming from the same reactor.
- The assembly with ID of "NJ053C" for assembly type of "N/A" of the Three Mile Island 1 reactor with was changed from "N/A" to "B1515B8." This assembly started out as a skeleton assembly but is used to hold pins from various assemblies (comments table 2002 database). The change is based on a best fit of the other assembly types for this reactor and on the characteristics of the assembly (initial uranium, enrichment, and burnup).
- The assembly with ID of "SKLTN" of the Peach Bottom 3 reactor was deleted from the database. This was based on the assembly being a skeleton assembly.
- The assemblies "VY369" and "VY370" of the Peach Bottom 2 reactor were deleted from the database. This was based on these two assemblies not having an assembly type indicated, and the initial uranium loading, initial enrichment, and maximum burnup being much lower than any other assembly from that reactor.

The following tables were added to the RW-859 2002 database with information to be used in the new queries:

- Table *Assm Class* creates a correlation between the assembly class to reactor type (i.e., PWR or BWR) and physical dimension of the assembly.

Table C-1 presents the information from the database *Final2002modifiedDM-RW859.mdb*, Table *Assm Class*

Table C-1. Table *Assm Class* Created in Database *Final2002modifiedDM-RW859.mdb*

Assembly Class	Type	Length (in)	Width (in)
Big Rock Point	BWR	84.0	6.52
Dresden-1	BWR	134.4	4.28
GE BWR/2,3	BWR	171.2	5.44
GE BWR/4-6	BWR	176.2	5.44
Humboldt Bay	BWR	95.0	4.67
LaCrosse	BWR	102.5	5.62
B&W 15x15	PWR	165.7	8.54
B&W 17x17	PWR	165.7	8.54
CE 14x14	PWR	157.0	8.10
CE 16x16	PWR	176.8	8.10
CE 16x16 System 80	PWR	178.3	8.10
Ft. Calhoun	PWR	146.0	8.10
Haddam Neck	PWR	137.1	8.42
Indian Point-1	PWR	138.8	6.27
Palisades	PWR	147.5	8.20
San Onofre-1	PWR	137.1	7.76
South Texas	PWR	199.0	8.43
St. Lucie-2	PWR	158.2	8.10
WE 14x14	PWR	159.8	7.76
WE 15x15	PWR	159.8	8.44
WE 17x17	PWR	159.8	8.44
Yankee Rowe	PWR	111.8	7.62

Source: Reference 2.2.28, Supplementary Tables, Table 1D.

- Table *Assm Type/Class* creates a correlation between the assembly type to assembly class, array size, clad material, manufacturer, and a brief description of the assembly.

Table C-2 presents the information from the database *Final2002modifiedDM-RW859.mdb*, Table *Assm Type/Class*

Table C-2. Table *Assm Type/Class* Created in Database *Final2002modifiedDM-RW859.mdb*

Assm Class	Array Size	Description	Manufacturer	Manufacturer Code	Clad	Assm Type Code
B&W 15x15	15x15	B&W Mark B	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B
B&W 15x15	15x15	B&W Mark B10	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B10
B&W 15x15	15x15	B&W Mark B3	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B3
B&W 15x15	15x15	B&W Mark B4	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B4
B&W 15x15	15x15	B&W Mark B4Z	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B4Z
B&W 15x15	15x15	B&W Mark B5	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B5
B&W 15x15	15x15	B&W Mark B5Z	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B5Z
B&W 15x15	15x15	B&W Mark B6	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B6
B&W 15x15	15x15	B&W Mark B7	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B7
B&W 15x15	15x15	B&W Mark B8	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B8
B&W 15x15	15x15	B&W Mark B9	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515B9
B&W 15x15	15x15	B&W Mark BGD	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515BGD
B&W 15x15	15x15	B&W Mark BZ	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1515BZ
B&W 15x15	15x15	WE	Westinghouse	WE	N/A	B1515W
B&W 17x17	17x17	B&W Mark C	Bobcock & Wilcox	B&W	Zircaloy-4 [c]	B1717B
Big Rock Point	11x11	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	XBR11A
Big Rock Point	9x9	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	XBR09A
Big Rock Point	11x11	GE	General Electric	GE	Zircaloy-2 [c]	XBR11G
Big Rock Point	7x7	GE	General Electric	GE	N/A	XBR07G
Big Rock Point	8x8	GE	General Electric	GE	N/A	XBR08G
Big Rock Point	9x9	GE	General Electric	GE	Zircaloy-2 [c]	XBR09G
Big Rock Point	11x11	NFS	Nuclear Fuel Services	NFS	N/A	XBR11N
CE 14x14	14x14	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	C1414A
CE 14x14	14x14	CE	Combustion Engineering	CE	Zircaloy-4 [c]	C1414C
CE 14x14	14x14	WE	Westinghouse	WE	Zircaloy-4 [c]	C1414W
CE 16x16	16x16	CE	Combustion Engineering	CE	Zircaloy-4 [c]	C1616CSD
CE 16x16 System 80	16x16	CE System 80	Combustion Engineering	CE	Zircaloy-4 [c]	C8016C
Dresden-1	6x6	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	XDR06A
Dresden-1	6x6	GE	General Electric	GE	Zircaloy-2 [b]	XDR06G
Dresden-1	7x7	GE SA-1	General Electric	GE	N/A	XDR07GS
Dresden-1	8x8	GE PF Fuels	General Electric	GE	N/A	XDR08G
Dresden-1	6x6	GE Type III-B	General Electric	GE	N/A	XDR06G3B
Dresden-1	6x6	GE Type III-F	General Electric	GE	N/A	XDR06G3F
Dresden-1	6x6	GE Type V	General Electric	GE	N/A	XDR06G5
Dresden-1	6x6	UNC	United Nuclear Corporation	UNC	N/A	XDR06U
Ft. Calhoun	14x14	ANF	Advanced Nuclear Fuel	ANF	N/A	XFC14A
Ft. Calhoun	14x14	CE	Combustion Engineering	CE	Zircaloy-4 [c]	XFC14C
Ft. Calhoun	14x14	WE	Westinghouse	WE	N/A	XFC14W
GE BWR/2,3	7x7	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G2307A
GE BWR/2,3	8x8	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G2308A

Table C-2. Table *Assm Type/Class* Created in Database *Final2002modifiedDM-RW859.mdb* (Continued)

Assm Class	Array Size	Description	Manufacturer	Manufacturer Code	Clad	Assm Type Code
GE BWR/2,3	9x9	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G2309A
GE BWR/2,3	9x9	ANF IX	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G2309AIX
GE BWR/2,3	8x8	ANF Pressurized	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G2308AP
GE BWR/2,3	8x8	GE-10	General Electric	GE	Zircaloy-2 [c]	G2308G10
GE BWR/2,3	9x9	GE-11	General Electric	GE	Zircaloy-2 [c]	G2309G11
GE BWR/2,3	7x7	GE-2a	General Electric	GE	Zircaloy-2 [c]	G2307G2A
GE BWR/2,3	7x7	GE-2b	General Electric	GE	Zircaloy-2 [c]	G2307G2B
GE BWR/2,3	7x7	GE-3	General Electric	GE	Zircaloy-2 [c]	G2307G3
GE BWR/2,3	8x8	GE-4	General Electric	GE	Zircaloy-2 [c]	G2308G4
GE BWR/2,3	8x8	GE-5	General Electric	GE	Zircaloy-2 [c]	G2308G5
GE BWR/2,3 [d]	8x8 [d]	GE-7 [d]	General Electric [d]	GE [d]	N/A	G2308G7
GE BWR/2,3	8x8	GE-8a	General Electric	GE	Zircaloy-2 [c]	G2308G8A
GE BWR/2,3	8x8	GE-8b	General Electric	GE	Zircaloy-2 [c]	G2308G8B
GE BWR/2,3	8x8	GE-9	General Electric	GE	Zircaloy-2 [c]	G2308G9
GE BWR/2,3	8x8	GE-Barrier	General Electric	GE	Zircaloy-2 [c]	G2308GB
GE BWR/2,3	8x8	GE-Pressurized	General Electric	GE	Zircaloy-2 [c]	G2308GP
GE BWR/2,3 [d]	N/A	N/A	N/A	N/A	N/A	9X9IXQFA
GE BWR/4-6	10x10 [d]	ANF [d]	Advanced Nuclear Fuel [d]	ANF [d]	N/A	G4610A
GE BWR/4-6	9x9	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G4609A
GE BWR/4-6	9x9	ANF 9-5	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G4609A5
GE BWR/4-6	9x9	ANF 9X	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G4609A9X
GE BWR/4-6	10x10	ANF IX	Advanced Nuclear Fuel	ANF	N/A	G4610AIX
GE BWR/4-6	9x9	ANF IX	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G4609AIX
GE BWR/4-6	9x9	ANF X+	Advanced Nuclear Fuel	ANF	N/A	G4609AX+
GE BWR/4-6	8x8	ANF-Pressurized	Advanced Nuclear Fuel	ANF	Zircaloy-2 [c]	G4608AP
GE BWR/4-6	10x10	CE [d]	ABB Atom	ABB	N/A	G4610C
GE BWR/4-6	8x8	GE-10	General Electric	GE	Zircaloy-2 [c]	G4608G10
GE BWR/4-6	8x8 [d]	GE-11 [d]	General Electric [d]	GE [d]	N/A	G4608G11
GE BWR/4-6	9x9	GE-11	General Electric	GE	Zircaloy-2 [c]	G4609G11
GE BWR/4-6	10x10	GE-12	General Electric	GE	Zircaloy-2 [c]	G4610G12
GE BWR/4-6	8x8 [d]	GE-12 [d]	General Electric [d]	GE [d]	N/A	G4608G12
GE BWR/4-6	9x9	GE-13	General Electric	GE	Zircaloy-2 [c]	G4609G13
GE BWR/4-6	10x10 [d]	GE-14 [d]	General Electric [d]	GE [d]	N/A	G4610G14
GE BWR/4-6	7x7	GE-2	General Electric	GE	Zircaloy-2 [c]	G4607G2
GE BWR/4-6	7x7	GE-3a	General Electric	GE	Zircaloy-2 [c]	G4607G3A
GE BWR/4-6	7x7	GE-3b	General Electric	GE	Zircaloy-2 [c]	G4607G3B
GE BWR/4-6	8x8	GE-4a	General Electric	GE	Zircaloy-2 [c]	G4608G4A
GE BWR/4-6	8x8	GE-4b	General Electric	GE	Zircaloy-2 [c]	G4608G4B
GE BWR/4-6	8x8	GE-5	General Electric	GE	Zircaloy-2 [c]	G4608G5
GE BWR/4-6	8x8	GE-8	General Electric	GE	Zircaloy-2 [c]	G4608G8
GE BWR/4-6	8x8	GE-9	General Electric	GE	Zircaloy-2 [c]	G4608G9
GE BWR/4-6	8x8	GE-Barrier	General Electric	GE	Zircaloy-2 [c]	G4608GB
GE BWR/4-6	8x8	GE-Pressurized	General Electric	GE	Zircaloy-2 [c]	G4608GP
GE BWR/4-6	N/A	N/A	AREVA [a]	AREVA	Zircaloy-2 [a]	ATRIUM10
GE BWR/4-6	8x8	WE	Westinghouse	WE	Zircaloy-2 [c]	G4608W
Haddam Neck	15x15	B&W SS	Bobcock & Wilcox	B&W	SS-304 [c]	XHN15B
Haddam Neck	15x15	B&W Zir	Bobcock & Wilcox	B&W	Zircaloy [c]	XHN15BZ
Haddam Neck	15x15	Gulf SS	Gulf	GA	SS	XHN15HS
Haddam Neck	15x15	Gulf Zir	Gulf	GA	Zircaloy	XHN15HZ
Haddam Neck	15x15	NUM SS	Numec	NU	SS	XHN15MS

Table C-2. Table *Assm Type/Class* Created in Database *Final2002modifiedDM-RW859.mdb* (Continued)

Assm Class	Array Size	Description	Manufacturer	Manufacturer Code	Clad	Assm Type Code
Haddam Neck	15x15	NUM Zir	Numec	NU	Zircaloy	XHN15MZ
Haddam Neck	15x15	WE	Westinghouse	WE	SS-304 [c]	XHN15W
Haddam Neck	15x15	WE Zir	Westinghouse	WE	N/A	XHN15WZ
Humboldt Bay	6x6	6x6 ANF	Advanced Nuclear Fuel	ANF	Zircaloy	XHB06A
Humboldt Bay	6x6	GE	General Electric	GE	Zircaloy-2 [c]	XHB06G
Humboldt Bay	7x7	GE Type II	General Electric	GE	Zircaloy	XHB07G2
Indian Point-1	13x14	WE	Westinghouse	WE	SS	XIP14W
LaCrosse	10x10	AC	Allis Chalmer	AC	SS348H [c]	XLC10L
LaCrosse	10x10	ANF	Advanced Nuclear Fuel	ANF	SS348H [c]	XLC10A
Palisades	15x15	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	XPA15A
Palisades	15x15	CE	Combustion Engineering	CE	Zircaloy-4 [c]	XPA15C
San Onofre-1	14x14	WE	Westinghouse	WE	SS-304 [c]	XSO14W
San Onofre-1	14x14 [d]	WE D [d]	Westinghouse [d]	WE [d]	N/A	XSO14WD
San Onofre-1	14x14 [d]	WE M [d]	Westinghouse [d]	WE [d]	N/A	XSO14WM
South Texas	17x17	WE	Westinghouse	WE	Zircaloy-4 [c]	WST17W
St. Lucie-2	16x16	CE	Combustion Engineering	CE	Zircaloy-4 [c]	XSL16C
WE 14x14	14x14	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	W1414A
WE 14x14	14x14	ANF Top Rod	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	W1414ATR
WE 14x14	14x14	B&W	Bobcock & Wilcox	B&W	N/A	W1414B
WE 14x14	14x14	WE LOPAR	Westinghouse	WE	Zircaloy-4 [c]	W1414WL
WE 14x14	14x14	WE OFA	Westinghouse	WE	Zircaloy-4 [c]	W1414WO
WE 14x14	14x14	WE Std	Westinghouse	WE	Zircaloy-4 [c]	W1414W
WE 15x15	15x15	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	W1515A
WE 15x15	15x15 [d]	ANF [d]	Advanced Nuclear Fuel [d]	ANF [d]	N/A	W1515AHT
WE 15x15	15x15	ANF Part Length	Advanced Nuclear Fuel	ANF	N/A	W1515APL
WE 15x15	15x15	LOPAR	Westinghouse	WE	Zircaloy-4 [c]	W1515WL
WE 15x15	15x15	OFA	Westinghouse	WE	Zircaloy-4 [c]	W1515WO
WE 15x15	15x15	WE Std	Westinghouse	WE	Zircaloy	W1515W
WE 15x15	15x15	WE Vantage 5	Westinghouse	WE	N/A	W1515WV5
WE 17x17	17x17	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	W1717A
WE 17x17	17x17	B&W Mark B	Bobcock & Wilcox	B&W	N/A	W1717B
WE 17x17	17x17	WE	Westinghouse	WE	N/A	W1717WRF
WE 17x17	17x17	WE	Westinghouse	WE	N/A	W1717WVJ
WE 17x17	17x17	WE LOPAR	Westinghouse	WE	Zircaloy-4 [c]	W1717WL
WE 17x17	17x17	WE OFA	Westinghouse	WE	Zircaloy-4 [c]	W1717WO
WE 17x17	17x17	WE Pressurized	Westinghouse	WE	N/A	W1717WP
WE 17x17	17x17	WE Vantage	Westinghouse	WE	N/A	W1717WV
WE 17x17	17x17	WE Vantage +	Westinghouse	WE	ZIRLO [c]	W1717WV+
WE 17x17	17x17	WE Vantage 5	Westinghouse	WE	Zircaloy-4 [c]	W1717WV5
WE 17x17	17x17	WE Vantage 5H	Westinghouse	WE	N/A	W1717WVH
Yankee Rowe	15x16	ANF	Advanced Nuclear Fuel	ANF	Zircaloy-4 [c]	XYR16A
Yankee Rowe	15x16	CE	Combustion Engineering	CE	Zircaloy-4 [c]	XYR16C
Yankee Rowe	15x16	UNC	United Nuclear Corporation	UNC	N/A	XYR16U
Yankee Rowe	17x18	WE	Westinghouse	WE	SS	XYR18W

Source: Attachment A, *Final2002modifiedDM-RW859.mdb*, Table *tblFuelFreshCORR* and Reference 2.2.28, Supplementary Tables, Table 1D.

[a] Reference 2.2.12 — see Attachment D

[b] Reference 2.2.14, Appendix 2A, p. 2A-213

[c] Reference 2.2.15, Appendix 2A, pp. 2A-7 through 2A-47

Note: [d] Information based on assembly code codification

While reference 2.2.28, Table 1-D provides assembly types used by utilities, only those that have been discharged or otherwise characterized for repository burial are provided in Table C-2 for inventory purposes. The assemblies not yet discharged or not considered part of the YMP inventory are not provided in Table C-2. Also, there are few new assembly types not described in reference 2.2.28; Table 1-D. Therefore, there is not a one to one correspondence between the assembly types provided in Table C-2 and Table 1-D of reference 2.2.28.

The following queries were added to the new database:

- Query *6-2a* extracts count of the assemblies and the average and maximum values for uranium load, initial ^{235}U enrichment, and discharge burnup for each fuel type (i.e., PWR or BWR).

- Query *assembly characteristics* extracts all information per assembly type to be presented in Table 3.

- Query *AssmClass* provides the count of discharged assemblies by assembly class.

- Query *AssmType* provides the count of discharged assemblies by assembly type.

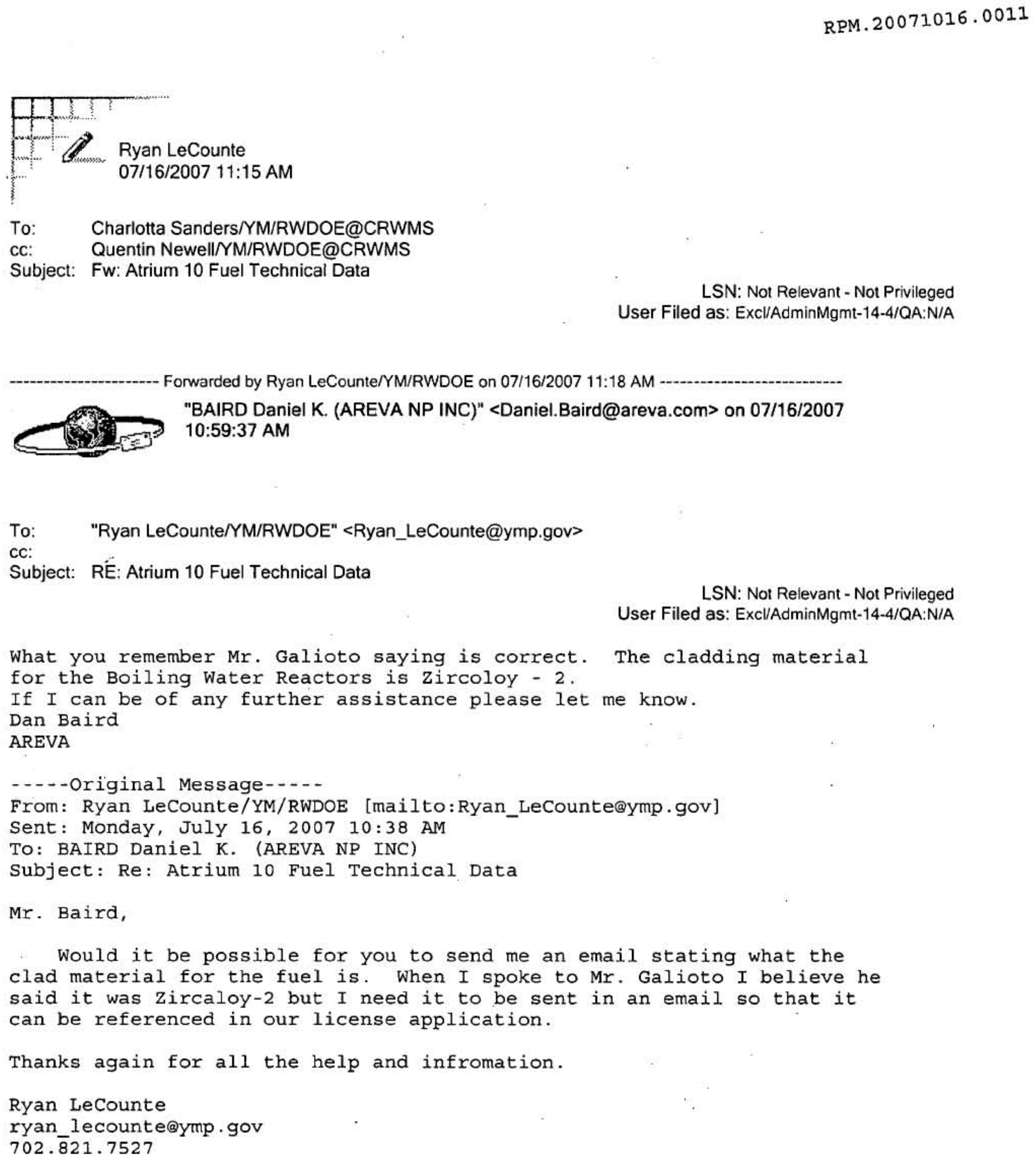
- Query *Hist* extracts information regarding historical discharges per yearly basis to be presented in a graphical form in Figure 1 and Figure 2.

- Query *Proj* extracts information regarding projected discharges per yearly basis to be presented in Figure 1 and Figure 2.

- Query *char* extracts the main characteristics of fuel assemblies by type to be presented in Table 4 and Table 5.

ATTACHMENT D

Reference 2.2.12, E-mail from R. LeCounte to C. Sanders, July 16, 2007



RPM.20071016.0011

Ryan LeCounte
07/16/2007 11:15 AM

To: Charlotta Sanders/YM/RWDOE@CRWMS
cc: Quentin Newell/YM/RWDOE@CRWMS
Subject: Fw: Atrium 10 Fuel Technical Data

LSN: Not Relevant - Not Privileged
User Filed as: Excl/AdminMgmt-14-4/QA:N/A

---------------------- Forwarded by Ryan LeCounte/YM/RWDOE on 07/16/2007 11:18 AM ---------------------------

"BAIRD Daniel K. (AREVA NP INC)" <Daniel.Baird@areva.com> on 07/16/2007 10:59:37 AM

To: "Ryan LeCounte/YM/RWDOE" <Ryan_LeCounte@ymp.gov>
cc:
Subject: RE: Atrium 10 Fuel Technical Data

LSN: Not Relevant - Not Privileged
User Filed as: Excl/AdminMgmt-14-4/QA:N/A

What you remember Mr. Galioto saying is correct. The cladding material for the Boiling Water Reactors is Zircoloy - 2.
If I can be of any further assistance please let me know.
Dan Baird
AREVA

-----Original Message-----
From: Ryan LeCounte/YM/RWDOE [mailto:Ryan_LeCounte@ymp.gov]
Sent: Monday, July 16, 2007 10:38 AM
To: BAIRD Daniel K. (AREVA NP INC)
Subject: Re: Atrium 10 Fuel Technical Data

Mr. Baird,

Would it be possible for you to send me an email stating what the clad material for the fuel is. When I spoke to Mr. Galioto I believe he said it was Zircaloy-2 but I need it to be sent in an email so that it can be referenced in our license application.

Thanks again for all the help and infromation.

Ryan LeCounte
ryan_lecounte@ymp.gov
702.821.7527