OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

1. QA: N/A

2. Calculation Title
Commercial Spent Nuclear Fuel Assembly Waste Volume and Weight Estimation for 63,000 MTU

MOL.19990812.0356

3. Document Identifier (including Revision Number)
CAL-MGR-ME-000001 REV 00

4. Total Attachments	5. Attachment Numbers - Number of pages in each
1	I - 1

	Print Name	Signature	Date
6. Originator	Bradford A. Colton	Bradford AC	7/21/99
7. Checker	Jabo S. Tang	Jabo S. T	7/21/99
8. Lead	John R. Massari	[signature]	7/22/99

9. Remarks

Revision History

10. Revision No.	11. Description of Revision
00	Initial Issuance

CONTENTS

Page

1. PURPOSE

The purpose of this calculation is to create a high-level estimation of the weights and volume of the commercial spent nuclear fuel (SNF) assemblies, at the time of repository receipt, that will comprise 63,000 metric tons of uranium (MTU) waste. The results of this calculation are for informational purposes only and are not intended to be used as input to design documents. This calculation was prepared in accordance with procedure AP-3.12Q REV 00 ICN 0, *Calculations*.

2. METHOD

As this calculation is considered a high-level estimation, only two specific assemblies will be chosen to represent the commercial SNF assemblies. One assembly will be a pressurized water reactor (PWR) assembly and the other will be a boiling water reactor (BWR) assembly. From source term tables, generated in Refs. 4 and 6, radionuclide information will be extracted for the two representative assemblies. Radionuclide information from the two assemblies will be projected to the 63,000 MTU based on the distribution of PWR and BWR assemblies assumed in the Viability Assessment (VA) design basis waste stream.

3. ASSUMPTIONS

3.1 It is assumed that the densities used to determine waste volume will be based on 95% of the theoretical densities. When fuel pellet densities are listed, generally there is a specification as to what percent of theoretical density was obtained. The foundation of this assumption is from Ref. 10, Sections 2.1.2.2 and 2.1.2.3, which reflects that fuel pellet volumes range from 94 to 95 percent of their theoretical density. While this may not be true for waste components, the basis of this assumption is to attempt to approximate a more realistic volume. This assumption will be applied to all waste volumes at the end of the calculation as an adjustment in Section 5.7.

3.2 It is assumed that one representative PWR assembly and one BWR assembly will adequately reflect the weights and volumes for those types of assemblies over the entire 63,000 MTU of commercial assembly waste. The basis of this assumption is that while the quantity of a specific radionuclide may be extremely important for a particular application, for this estimate of weight and volume, these variations should not significantly affect the results. This assumption is used throughout this calculation.

3.3 The weight value for hardware is assumed to remain unchanged between pre-irradiation and post-irradiation. This assumption is based on the fact that the radionuclide tables provided in Refs. 5 and 7 only specify the weight of the hardware elements that were activated. The pre-irradiation weights can be found within the text of Refs. 4 and 6. This assumption should have little impact on the results of this calculation as the hardware weight will change insignificantly due to irradiation. This assumption is used in Section 5.1.

3.4 For volume calculations, it is assumed that the fission products and actinides produced in the fuel region of an SNF assembly will be exclusively in the form of oxides. While this will not be true for all fission products or actinides, the basis of this assumption is to provide a reasonable simplification to determine volumes for this estimation. This assumption is used throughout this calculation.

3.5 To produce the oxides in Assumption 3.4, oxygen is assumed to provide 12% of the total compound weight. This assumption is based on the fact that for plutonium oxide and uranium oxide, oxygen varies from between 11.68% and 11.94% weight percent for the uranium and plutonium isotopes presented in the radionuclide tables of Refs. 5 and 7. This may underestimate or overestimate the oxide weights, but the basis of this assumption is to provide a reasonable simplification to determine oxygen weight and oxide compound volumes for this estimation. This assumption is used in Sections 5.4 through 5.6.

3.6 For hardware weight and volume, it is assumed that the elements of chromium, iron, nickel, tin and zirconium will adequately reflect the hardware weight and volume of the representative PWR or BWR assembly. As can be seen on p. 16 of Ref. 4, these five elements comprise a significant majority of the hardware material weights, therefore this simplification should not significantly affect the estimation of hardware weight. The basis of this assumption is to provide a reasonable simplification to determine hardware weight and volume for this estimation. This assumption is used in Section 5.4.

3.7 It is assumed that representing stainless steel clad assemblies as zircaloy clad assemblies will insignificantly affect this estimation. The basis of this assumption is to provide a reasonable simplification to determine weights for this estimation. Since stainless steel clad assemblies compromise less than one percent of the total commercial assemblies, this assumption should have a little effect on the results. This assumption is used throughout.

3.8 It is assumed that the densities of the fission product oxides (see Assumption 3.4) can be adequately represented by the average of the densities of cesium oxide and strontium oxide. The basis of this assumption is, as cesium and strontium are major components of the fission products, using their oxide densities to represent the fission product oxide density provides a reasonable simplification for this estimation. This assumption is used in Section 5.1 and 5.5.

3.9 It is assumed that the densities of the actinide oxides (see Assumption 3.4) can be adequately represented by the density of uranium oxide. As the masses of the actinides are generally similar to uranium, this assumption is expected to have an insignificant affect on the results of this calculation. The basis for this assumption is to provide an reasonable simplification for this estimation. This assumption is used in Section 5.1 and 5.6.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE APPROVED FOR QA WORK

None.

4.2 SOFTWARE ROUTINES

Other than Microsoft Excel 97, no software routines were used for this calculation. Excel was used to perform simple mathematical functions and to create the pie charts in Section 6.

4.3 MODELS

None.

5. CALCULATION

This calculation is based partially on unqualified inputs. The references that provide unqualified inputs are Refs. 1, 2, 3 and 10. Reference 9 is handbook and is therefore considered as accepted data. All other references are qualified.

The calculations presented in the tables of this section were performed in Microsoft Excel 97 and results presented in this calculation are summaries from the Excel spreadsheet with values rounded for presentation. Because the Excel spreadsheet calculations carry more significant digits than presented in this document, values presented in the tables may not be precisely obtained by hand-calculations based on the rounded values presented in this document.

5.1 DENSITIES

Table 5-1 lists the density values that were used for this calculation.

Table 5-1. Density Values

	g/cm^3	Reference
Cesium Oxide	4.25	9, p. 4-52
Chromium	7.2	9, p. 4-53
Fission Products [1]	4.45	Not Applicable
Iron	7.86	9, p. 4-64
Nickel	8.9	9, p. 4-78
"Other Actinide" Oxides [2]	10.96	Not Applicable
Plutonium Oxide	11.46	9, p. 4-83
Strontium Oxide	4.70	9, p. 4-103
Tin [3]	7.28	9, p. 4-107
Uranium Oxide	10.96	9, p. 4-110
Zircaloy-2	6.55	8, p. 41
Zircaloy-4	6.56	8, p. 44
Zirconium	6.49	9, p. 4-113

[1] This density is based on an average of cesium oxide and strontium oxide (see Assumption 3.8)
[2] This density is based on uranium oxide (see Assumption 3.9)
[3] This density is based on white tin

5.2 PERCENTAGE OF PWR WASTE VERSUS BWR WASTE

Table 5-2 summarizes information concerning the initial mass of uranium, number of assemblies and number of waste packages (WPs) from Attachment LXVI of the *Preliminary Design Basis for WP Thermal Analysis*, Ref. 1. The information in the attachment of Ref. 1 is based on the "Case 1" waste stream forecast presented in the *Waste Quantity, Throughput and Mix Study*, Ref. 2. The Case 1 waste stream was used as the design basis waste stream for the VA design.

Table 5-2. VA Design Basis Waste Stream Information for Commercial SNF

WP Design Type	MTU	Number of Assemblies	Number of WPs
21 PWR - No Absorbers	12961.4	30317	1444
21 PWR - Absorber Plates	23896.88	55455	2641
21 PWR - Control Rods	976.81	2520	120
12 PWR - Absorber Plates	2118.54	4674	390
12 PWR - Long (South Texas)	969.37	1800	150
44 BWR - No Absorbers	5334.16	30587	696
44 BWR - Absorber Plates	16547.84	92689	2107
24 BWR - Thick Absorber Plates	163.5	993	42
BWR Junk Bin	0	0	N/A
PWR Junk Bin	35.2	81	N/A
PWR Long (South Texas) Junk Bin	0	0	N/A
Total	63003.7	219116	7590

Table 5-3 further summarizes information presented in Table 5-2.

Table 5-3. Initial Mass of Uranium Percentages

	Initial Mass of Uranium	MTU Percentage
PWR	40958.2	65.0%
BWR	22045.5	35.0%

5.3 SELECTION OF REPRESENTATIVE BWR AND PWR ASSEMBLIES

The intent of this estimation was not to determine every minute detail of radionuclides contained in commercial SNF assemblies to be sent to the repository, but to determine some general weight and volume characteristics of the waste. To this end, these characteristics will simply be determined by one representative PWR SNF assembly and one representative BWR SNF assembly. Average assembly characteristics for the VA design basis waste stream were documented in Key Assumption 004 of the *Controlled Design Assumption Document* (CDA), Ref. 3, p. 3-15, and are presented in Table 5-4.

Table 5-4. Average Assembly Characteristics from CDA

	PWR	BWR
Average Age (i.e., time since discharge)	25.9 years	27.2 years
Average Assembly Burnup	39.56 GWd/MTU	32.24 GWd/MTU
Average Initial U-235 Enrichment	3.69 wt%	3.00 wt%

The radionuclide tables used for this calculation do not have the specific average points listed in Table 5-4. Therefore, the closest points from the radionuclide tables were chosen for the basis of the representative assemblies to be used in this calculation. Those representative assemblies are identified in Table 5-5.

Table 5-5. Representative Assembly Characteristics

	PWR	BWR
Average Age (i.e., time since discharge)	25.0 years	25.0 years
Average Assembly Burnup	40.00 GWd/MTU	30.00 GWd/MTU
Average Initial U-235 Enrichment	3.50 wt%	3.00 wt%
Initial Mass of Uranium per Assembly	0.475 MTU	0.200 MTU
Assembly Class	Babcock & Wilcox Mark B 15x15	General Electric 2/3 8x8

Note that the CDA average characteristics in Table 5-4 did not include initial mass of uranium per assembly or assembly class, although they are listed in Table 5-5. These initial uranium masses are taken from the source term generation analyses, Ref. 6, p. 5 and Ref. 4, p. 5 for PWR and BWR, respectively, and are considered bounding values for initial mass of uranium per assembly. These bounding values are used for the basis of the radionuclides calculated in the source term generation analyses, Ref. 4 and Ref. 6, and are used here for the representative assemblies. Because of the use of these bounding values, the number of assemblies comprising the 63,000 MTU of waste must be modified from what is presented in Table 5-2.

If applying these bounding values for initial mass of uranium per assembly to the PWR and BWR assemblies shown in Table 5-2 for the VA design basis waste stream, it would result in an overall uranium weight greater than 63,000 MTU. To compensate for this, the forecast number of assemblies from the VA design basis waste stream will not be used for calculating fission products or actinides. Instead, the number of assemblies used for this calculation will be obtained by dividing the respective amount of the 63,000 MTU for PWR and BWR waste by the MTU per assembly from the representative assemblies. The result of this calculation is shown in Table 5-6.

Table 5-6. Number of Assemblies

	PWR	BWR	Total
Number of assemblies based on respective MTU [1]	86228	110228	196456
Number of assemblies forecast in the VA design basis waste stream (taken from Table 5-2)	94847	124269	219116

[1] This value is derived by dividing the MTU from Table 5-3 by the MTU per assembly from Table 5-5

The assembly classes listed in Table 5-5 are the only assembly classes evaluated in the source term generation documents. The identification of the assembly classes can be found on p. 9 of Ref. 6 and p. 10 of Ref. 4 for PWR and BWR respectively. Based on which set of assembly numbers are chosen from Table 5-6, this can underestimate or overestimate the hardware results of this estimate.

For consistency, the calculations of hardware weight will also be based on the "Number of assemblies based on the respective MTU" value from Table 5-6. As this value contains 11.5% fewer assemblies than the forecast number of assemblies to arrive for the VA design, based on the figures in Table 5-6, it would tend to underestimate the hardware weights. On the other hand, the hardware weight of the representative assemblies are based on a somewhat average assembly hardware weight for PWR assemblies and a heavier than average hardware for BWR assemblies. Therefore, the underestimation should be less than 11.5%, while the use of the number of assemblies from the VA design basis waste stream would result in an overestimation. See p. 2.1.2.2-1 and p. 2.1.2.3-1 in Ref. 10 for hardware weight comparisons for PWR and BWR, respectively.

5.4 HARDWARE WEIGHT AND VOLUME DETERMINATION

To calculate the hardware weights, elemental weights of the light elements from four assembly regions must be determined and summed. The four assembly regions are: top end-fitting, plenum, fuel and bottom end-fitting. Tables 5-7 and 5-8 summarize the hardware elements for these regions. Information provided in the tables is obtained from Ref. 6, p. 14 and Attachment III, and Ref. 4, p. 36 and Attachment II, for PWR and BWR, respectively, with the scaling factor removed. The scaling factor was applied in the source generation analysis to the weight of hardware to account for the lower neutron flux levels in order to obtain correct values for activation products in the hardware.

As noted in Assumption 3.3, the hardware weights will be based on pre-irradiation values. Based on Assumption 3.6, only chromium, iron, nickel, tin and zirconium weights are used to determine hardware weight.

Tables 5-9 and 5-10 further summarize the information presented in Tables 5-7 and 5-8 and present volume calculations for the hardware elements. Table 5-11 summarizes the hardware information that represents 63,000 MTU of waste.

Table 5-7. PWR Hardware Elements and Distribution

	Kilograms per Assembly				
Element	Top End-Fitting	Plenum	Fuel	Bottom End-Fitting	Totals
Cr	2.0447	0.2017	1.1552	1.7977	5.20
Fe	6.0667	0.1743	1.0663	5.454	12.76
Ni	1.9513	0.5633	2.9649	1.5997	7.08
Sn	0.0000	0.0100	1.6099	0.0020	1.62
Zr	0.0000	0.698	112.4372	0.1473	113.28
Total					139.94

Table 5-8. BWR Hardware Elements and Distribution

	Kilograms per Assembly				
Element	Top End-Fitting	Plenum	Fuel	Bottom End-Fitting	Totals
Cr	0.4680	0.3784	0.1302	0.9069	1.88
Fe	1.4232	0.5692	0.1468	3.2804	5.42
Ni	0.5923	1.2527	0.2495	0.4412	2.54
Sn	0.0139	0.0869	1.1402	0.0091	1.25
Zr	0.9768	6.0934	79.9798	0.6394	87.69
Total					98.78

Table 5-9. PWR Assembly Weight and Volume of Hardware Elements

Element	Weight per Assembly, kg	Density, kg/m^3	Volume per Assembly, m^3
Cr	5.20	7200	0.000722
Fe	12.76	7860	0.001624
Ni	7.08	8900	0.000795
Sn	1.62	7280	0.000223
Zr	113.28	6490	0.017455
Totals	139.94		0.020819

Table 5-10. BWR Assembly Weight and Volume of Hardware Elements

Element	Weight per Assembly, kg	Density, kg/m^3	Volume per Assembly, m^3
Cr	1.88	7200	0.000262
Fe	5.42	7860	0.000690
Ni	2.54	8900	0.000285
Sn	1.25	7280	0.000172
Zr	87.69	6490	0.013511
Totals	98.78		0.014919

Table 5-11. Hardware Summary for PWR and BWR

	Number of Assemblies	Weight per Assembly, kg	Total Weight for 63,000 MTU, kg	Volume per Assembly, m^3	Total Volume for 63,000 MTU, m^3
PWR	86228	139.94	12067108.5	0.020819	1795.2
BWR	110228	98.78	10888134.5	0.014919	1644.5
Totals			22955242.9		3439.7

5.5 FISSION PRODUCTS

The fission products are extracted from the electronic files contained in Refs. 7 and 5, for PWR and BWR, respectively. Unlike the hardware, fission products are only present in the fuel region. In Ref. 7, the file that contains the fuel region information, for the representative PWR assembly identified in Table 5-5, is "Waste.Stream.E5.R1.B4." For the representative BWR assembly, the information was extracted from the file "3.0%.30GWd.fuel.cut" in Ref. 5. Table 5-12 summarizes the fission product weights obtained from these files. Number of assemblies is taken from Table 5-6.

Table 5-12. Fission Product Weight

	Number of Assemblies	Fission Product Weight per Assembly, g	Total Weight for 63,000 MTU, kg
PWR	86228	1.95E+04	1681446.0
BWR	110228	6.07E+03	669084.0
Total			2350530.0

When referring to the weight of the fission products, the values from Table 5-12 will be used. For volume calculations, in accordance with Assumptions 3.4 and 3.5, all fission products will be considered to be in the form of oxides. Table 5-13 reflects the weight and volume for the fission product oxides. Density values are from Table 5-1 and are based on Assumption 3.8.

Table 5-13. Fission Product Oxides

	Number of Assemblies	Total Weight for 63,000 MTU, kg	Fission Product Density, kg/m^3	Total Volume for 63,000 MTU, m^3
PWR	86228	1910734.1	4450	429.4
BWR	110228	760322.7	4450	170.9
Totals		2671056.8 [1]		600.2

[1] Total oxygen weight added is 320526.8 kg in accordance with Assumption 3.5

5.6 ACTINIDES

Similar to the fission products, actinides only exist in the fuel region. The actinide weights are extracted from the electronic files contained in Refs. 7 and 5, for PWR and BWR, respectively. In Ref. 7, the file that contains the fuel region information, for the representative PWR assembly identified in Table 5-5, is "Waste.Stream.E5.R1.B4." For the representative BWR assembly, the information was extracted from the file "3.0%.30GWd.fuel.cut" in Ref. 5. Table 5-14 summarizes the actinide weights obtained from the files. Table 5-15 summarizes the total actinide weights for the entire 63,000 MTU, and Tables 5-16 and 5-17 summarize the volumes.

Table 5-14. Actinides per Assembly

	PWR	BWR
Total Actinides, g	4.56E+05	1.94E+05
Pu-236, g	0.00E+00	Not Applicable
Pu-238, g	9.46E+01	2.06E+01
Pu-239, g	2.83E+03	9.16E+02
Pu-240, g	1.28E+03	4.32E+02
Pu-241, g	2.16E+02	5.83E+01
Pu-242, g	3.24E+02	7.99E+01
U-232, g	6.22E-04	1.20E-04
U-233, g	3.26E-03	8.77E-04
U-234, g	9.57E+01	3.56E+01
U-235, g	3.62E+03	1.59E+03
U-236, g	2.25E+03	7.66E+02
U-237, g	0.00E+00	Not Applicable
U-238, g	4.45E+05	1.90E+05
Other Actinides (total actinides minus Pu and U), g	2.90E+02	1.02E+02

Table 5-15. Actinide Weight Summary

	Number of Assemblies	Plutonium Weight per Assembly, g	Total Plutonium Weight for 63,000 MTU, kg	Uranium Weight per Assembly, g	Total Uranium Weight for 63,000 MTU, kg	"Other Actinide" Weight per Assembly, g	Total "Other Actinide" Weight for 63,000 MTU, kg
PWR	86228	4744.6	409117.4	450965.7	38885870.7	290.0	25006.1
BWR	110228	1506.8	166091.6	192391.6	21206941.4	102.0	11243.3
Totals			575208.9		60092812.1		36249.4

Table 5-16. Actinide Volume Summary for Plutonium and Uranium Oxides

	Total Plutonium Oxide Weight for 63,000 MTU, kg	Plutonium Oxide Density, kg/m^3	Total Plutonium Oxide Volume for 63,000 MTU, m^3	Total Uranium Oxide Weight for 63,000 MTU, kg	Uranium Oxide Density, kg/m^3	Total Uranium Oxide Volume for 63,000 MTU, m^3
PWR	464906.1	11460	40.6	44188489.4	10960	4031.8
BWR	188740.4	11460	16.5	24098797.0	10960	2198.8
Totals	653646.5 [1]		57.0	68287286.5 [2]		6230.6

[1] Total oxygen weight added is 78437.6 kg in accordance with Assumption 3.5
[2] Total oxygen weight added is 8194474.4 kg in accordance with Assumption 3.5

Table 5-17. Actinide Volume Summary for "Other Actinide" Oxides

	Total "Other Actinide" Oxide Weight for 63,000 MTU, kg	"Other Actinide" Oxide Density, kg/m^3	Total "Other Actinide" Oxide Volume for 63,000 MTU, m^3
PWR	28416.0	10960	2.6
BWR	12776.4	10960	1.2
Totals	41192.5 [1]		3.8

[1] Total oxygen weight added is 4943.1 kg in accordance with Assumption 3.5

5.7 ADJUSTMENT FOR THEORTICAL DENSITIES

As noted in Assumption 3.1, the densities calculated will be adjusted to account for inefficiencies in materials reaching their theoretical density. The material volumes calculated in Sections 5.4 through 5.6 are summarized in Table 5-18 for the entire 63,000 MTU. Table 5-18 also includes the adjustment to account for inefficiencies in reaching theoretical density.

Table 5-18. Volume Adjustment for 63,000 MTU of Waste

	Unadjusted Volume, m^3	Adjusted Volume (95% Theoretical Density), m^3
Hardware (Cr, Fe, Ni, Sn, Zr)	3439.7	3620.7
Plutonium Oxide	57.0	60.0
Uranium Oxide	6230.6	6558.5
Fission product and other actinide oxides	604.0	635.8
Totals	10331.3	10875.1

5.8 63,000 MTU SUMMARY / SINGLE WASTE PACKAGE ESTIMATION

The average weight and volume of waste contained in an average WP will be based on dividing the total weights and volumes expected for the 63,000 MTU by the number of WPs resulting from the VA design basis waste stream. The number of WPs is 7590, from Table 5-2. Tables 5-19 and 5-20 show the summary results for the 63,000 MTU, while Tables 5-21 and 5-22 show the information for a single average WP. A conversion to English units is also provided in the tables.

Table 5-19. Component Weights for 63,000 MTU of Waste

	Weight, kg	Weight, (English) tons	Weight Fraction
Hardware (Cr, Fe, Ni, Sn, Zr, O)	31553624.8	34781.6	33.4%
Plutonium	575208.9	634.1	0.6%
Uranium	60092812.1	66240.3	63.5%
Fission products and other actinides	2386779.3	2630.9	2.5%
Totals	94608425.2	104286.9	

Table 5-20. Component Volumes for 63,000 MTU of Waste

	Volume, m^3	Volume, ft^3	Volume Fraction
Hardware (Cr, Fe, Ni, Sn, Zr)	3620.7	127864.4	33.3%
Plutonium oxide	60.0	2120.3	0.6%
Uranium oxide	6558.5	231611.9	60.3%
Fission product and other actinide oxides	635.8	22452.5	5.8%
Totals	10875.1	384049.1	

Table 5-21. Component Weights for Waste in an Average Waste Package

	Weight, kg	Weight, (English) tons	Weight Fraction
Hardware (Cr, Fe, Ni, Sn, Zr, O)	4157.3	4.6	33.4%
Plutonium	75.8	0.1	0.6%
Uranium	7917.4	8.7	63.5%
Fission products and other actinides	314.5	0.3	2.5%
Totals	12464.9	13.7	

Table 5-22. Component Volumes for Waste in an Average Waste Package

	Volume, m^3	Volume, ft^3	Volume Fraction
Hardware (Cr, Fe, Ni, Sn, Zr)	0.5	16.8	33.3%
Plutonium oxide	0.0	0.3	0.6%
Uranium oxide	0.9	30.5	60.3%
Fission product and other actinide oxides	0.1	3.0	5.8%
Totals	1.4	50.6	

6. RESULTS

The results of this calculation are summarized in Tables 5-19 through 5-22 and displayed graphically in Figures 6-1 through 6-4 for English units. The results are based on the VA commercial waste stream forecasts and the VA WP designs, which are unqualified. Many assumptions were made for simplification, so the results provided here should be considered as a general estimate and are not intended to reflect precise values. The results are for informational purposes and offer an insight into the general characteristics of commercial waste volumes and weights. The results from this calculation are not intended for use as input into documents supporting procurement, fabrication or construction and are not required to be identified and tracked as "to be verified" (TBV) in accordance with appropriate procedures.

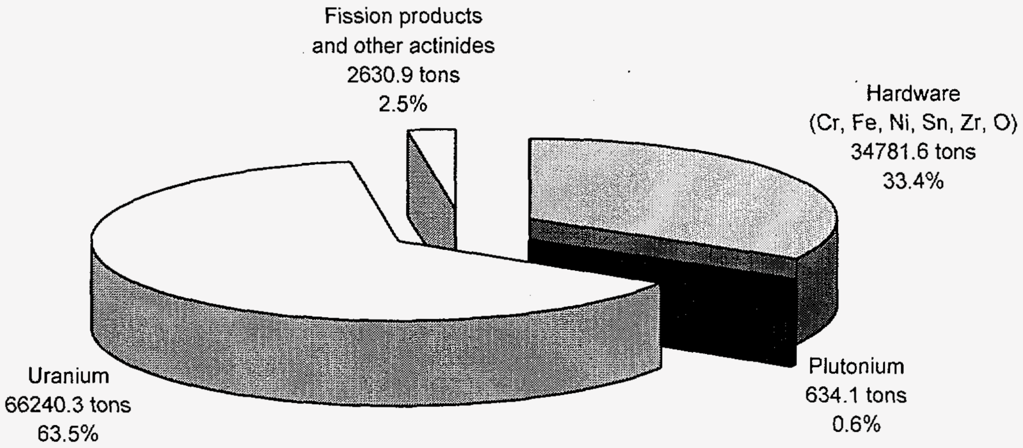

Figure 6-1. Weight Summary of Waste Components for 63,000 MTU Commercial Waste

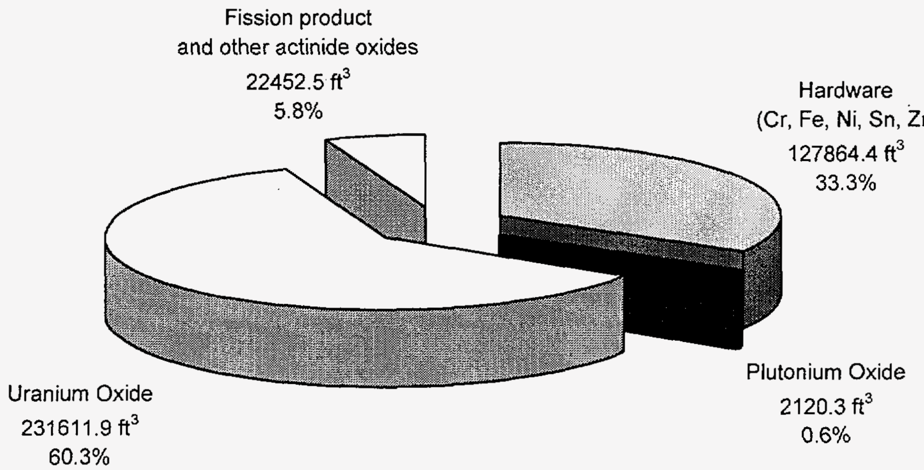

Figure 6-2. Volume Summary of Waste Components for 63,000 MTU Commercial Waste

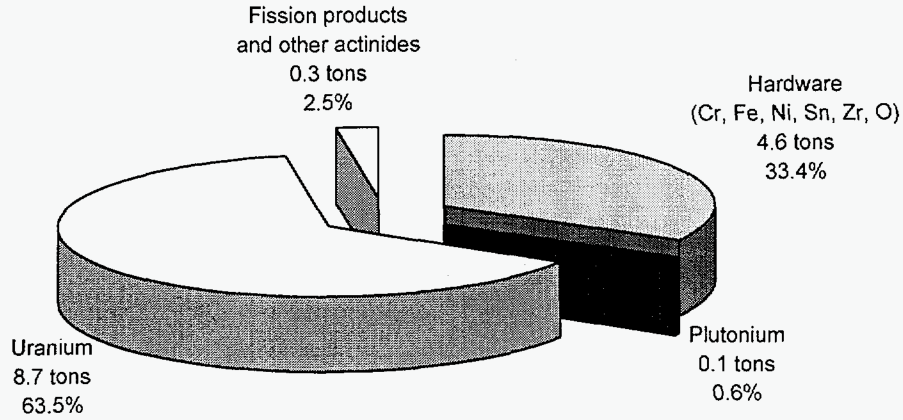

Figure 6-3. Weight Summary of Waste Components for an Average Commercial Waste Package

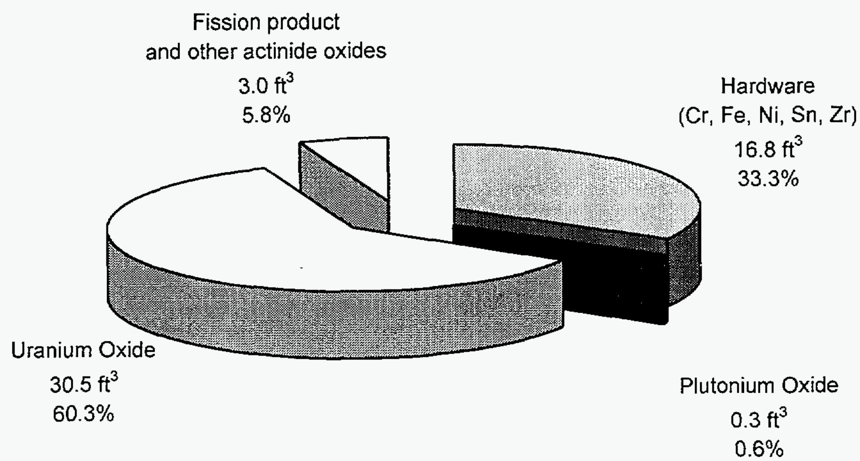

Figure 6-4. Volume Summary of Waste Components for an Average Commercial Waste Package

7. ATTACHMENTS

Attachments to this calculation are summarized in Table 7-1. Each attachment is identified by its specific number, title and number of pages.

Table 7-1. List of Attachments

Attachment Number	Title / Description	Number of Pages
I	Reference List	1

ATTACHMENT I
REFERENCE LIST

1. Civilian Radioactive Waste Management System (CRWMS) Management and Operating Contractor (M&O) 1997. *Preliminary Design Basis for WP Thermal Analysis*. BBAA00000-01717-0200-00019 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19980203.0529.

2. CRWMS M&O 1997. *Waste Quantity, Mix and Throughput Study Report*. B00000000-01717-5705-00059 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971210.0628.

3. CRWMS M&O 1998. *Controlled Design Assumptions Document*. B00000000-01717-4600-00032 REV 05. Las Vegas, Nevada: M&O. ACC: MOL.19980804.0481.

4. CRWMS M&O 1999. *BWR Source Term Generation and Evaluation*. BBAC00000-01717-0210-00006 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19990226.0319.

5. CRWMS M&O 1999. *BWR Source Term Generation and Evaluation*. BBAC00000-01717-0210-00006 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19981106.0117. [Process Discs related to MOL.19990226.0319]

6. CRWMS M&O 1999. *PWR Source Term Generation and Evaluation*. BBAC00000-01717-0210-00010 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19990215.0395.

7. CRWMS M&O 1999. *PWR Source Term Generation and Evaluation*. BBAC00000-01717-0210-00010 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19990225.0411. [Process Discs related to MOL.19990215.0395]

8. CRWMS M&O 1999. *Waste Package Materials Properties*. BBA000000-01717-0210-00017 REV 00. Las Vegas, Nevada: M&O. ACC: MOL.19990407.0172.

9. Lide, D.R., ed. 1991. *CRC Handbook of Chemistry and Physics, 72nd Edition, 1991-1992.* Boca Raton, Florida: CRC Press. TIC: 3595.

10. Stout, R.B. and Leider, H.R. 1997. *Waste Form Characteristics Report, Rev. 1.* UCRL-ID-108314. Livermore, California: Lawrence Livermore National Laboratory. TIC: 234546.