OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

1. QA: QA
Page: 1 Of: 35

2. Calculation Title
Waste Packages and Source Terms for the Commercial 1999 Design Basis Waste Streams

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

4. Total Attachments	5. Attachment Numbers – Number of pages in each
3	I - 2, II - 28, III - 3 compact discs

	Print Name	Signature	Date
6. Originator	Bradford A. Colton	Bradford A. Colton	02/14/00
7. Checker	Katherin L. Goluoglu	Katherin L. Goluoglu	2/14/00
8. Lead	Kathryn S. Knapp	Roxanna VanDellen for	2/14/00

9. Remarks

Revision History

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

CONTENTS

TABLES

1. PURPOSE

This calculation is prepared by the Monitored Geologic Repository Waste Package Requirements & Integration Department. The purpose of this calculation is to compile source term and commercial waste stream information for use in the analysis of waste package (WP) designs for commercial fuel. Information presented will consist of the number of WPs, source terms, metric tons of uranium, and the average characteristics of assemblies to be placed in each WP design. The source terms provide thermal output, radiation sources, and radionuclide inventories. The results of this calculation will support WP analysis for commercial fuel including Performance Assessment Operations calculations for nuclide releases. This calculation is prepared in accordance with AP-3.12Q, REV 00, ICN 0, *Calculations*.

2. METHOD

A software routine was created (see Section 4.2) for this calculation. The routine is used to (1) determine the WP design that can accommodate each assembly in the forecasted waste streams based on criticality level, (2) determine source terms for each assembly, and (3) use counters and averaging functions to determine other information of interest. See Section 4.2 for the full list of software routine functions.

When calculating WP numbers, this calculation presumes that WPs will have been completely loaded to full assembly capacity, with the exception of the last WP loaded for each design type. In order to meet limits for total heat generation of a WP, three options are possible: (1) store higher thermal output assemblies until they cool, (2) store higher thermal output assemblies until enough assemblies with cooler thermal outputs arrive to create a WP that meets the thermal limits, and (3) load WPs partially full. The WP numbers presented in this calculation support options 1 and 2.

3. ASSUMPTIONS

3.1 CRWMS M&O (1999c) developed source term information for a Babcock & Wilcox Mark B pressurized water reactor (PWR) assembly with an initial heavy metal loading of 475 kg (CRWMS M&O 1999c, p. 7). This assembly was chosen because it has characteristics that are generally representative of other PWR assemblies. It is assumed that source term values from this assembly can be applied to other PWR assemblies of different classes and initial uranium loadings by a simple ratio of initial uranium loading. The basis of this assumption is Section 3 of CRWMS M&O (1999c), which states that based on the development of the representative PWR assembly and engineering judgement, it is assumed that this representative PWR assembly can approximate other PWR assembly classes. This assumption is used in Sections 4.2 and 5.1.3.

3.2 CRWMS M&O (1999b) developed source term information for a General Electric 2/3 boiling water reactor (BWR) assembly with an initial heavy metal loading of 200 kg (CRWMS M&O 1999b, p. 8). This assembly was chosen because it has characteristics that are generally representative of other BWR assemblies. It is assumed that source term values from this assembly can be applied to other BWR assemblies of different classes and initial uranium loadings by a simple ratio of initial uranium loading. The basis of this assumption is Assumption 3.1 on page 5 of CRWMS M&O (1999b), which states that based on the development of the representative BWR assembly and engineering judgement, it is assumed that this representative BWR assembly can approximate other BWR assembly classes. This assumption is used in Sections 4.2 and 5.1.3.

3.3 CRWMS M&O (1997, pp. 25-26), developed a longer WP to accommodate the South Texas PWR assemblies, which were designed for a 14-foot reactor core rather than the standard 12-foot reactor core. The WP design that accommodates South Texas assemblies is the 12 PWR Absorber Plate-Long WP (see WP Bin 3 in Table 3). While the 12 PWR Absorber Plate-Long WP will accommodate other assemblies, either PWR or BWR that will not meet loading constraints of other WPs, it is assumed that only South Texas assemblies will be loaded into it. The basis of this assumption is that while additional assembly types have the potential to be placed into a 12 PWR Absorber Plate-Long WP, it is preferred to wait until those assemblies are better characterized as the total number of WPs required for disposal should not significantly be affected by this assumption. This assumption will underestimate the total number of 12 PWR Absorber Plate-Long WPs. See Assumption 3.4 for additional constraints concerning assemblies that could potentially be loaded into this WP. This assumption is used in Section 4.2.

3.4 It is assumed that the Combustion Engineering 16 x 16 and 16 x 16 System 80 assemblies will either arrive without non-fuel components or that the non-fuel components will be removed at the repository. This assumption is required to facilitate placing these assemblies into a 21 PWR WP instead of a 12 PWR Absorber Plate-Long WP. It is currently unknown how many of these assemblies will arrive with non-fuel components. For the assemblies that may contain non-fuel components, a study will need to be performed to determine if it is more cost-effective to place the assembly in the 12 PWR Absorber Plate-Long WP or remove the components for separate disposal and place the assemblies into a 21 PWR WP. The basis of this assumption is the same as for Assumption 3.3. This assumption is used in Section 4.2.

3.5 It is assumed that Big Rock Point assemblies will be placed one each into a basket position of a 21 PWR Absorber Plate WP (see WP Bin 1 in Table 3) because Big Rock Point BWR Spent Nuclear Fuel (SNF) assemblies have a larger assembly square cross-sectional area than other BWR assemblies. The basis of this assumption is Section 7.1.2 of CRWMS M&O (1997), which identified that these assemblies will be disposed of in PWR WPs. This assumption is used in Section 4.2.

3.6 The current repository thermal design features an upper limit for total heat generation of a WP. To accommodate this, pre-emplacement thermal “blending” of waste may be performed. Blending requires that high heat output assemblies be loaded with low heat output assemblies, such that the WP's heat output falls within a set range. An analysis has not been performed to determine if any specific criteria will be required when blending high and low heat output assemblies. For this calculation, it is assumed that no thermal criteria will be violated when loading a WP with assemblies with large variances in heat generation rate as long as the mix of assemblies placed into a WP are below the maximum allowable limit. For the Viability Assessment, WP designs were developed to hold assemblies with higher heat-generation rates while maintaining cladding temperature limits. This assumption is based on the analysis of previous WP designs. This assumption is used in Section 5.1.1.

3.7 If an arriving assembly has structurally failed, it is assumed that the assembly will be placed into a disposable canister that can be loaded in the same WP design as if the assembly was intact. The basis of this assumption is the *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel* (CRWMS M&O 1999a, p. C-5) which states that "It can be assumed that all of these canisters [unsealed canisters of failed fuel] will be screened-end containment vessels essentially identical to those currently in use and dimensionally compatible with an uncanistered assembly." Specific historical or projected failed assemblies are not presented in the transmittal of the waste arrival cases (CRWMS M&O 1999d). This assumption is used in Section 4.2.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE (QA) WORK

None used.

4.2 SOFTWARE ROUTINES

Microsoft Excel 97 spreadsheet program was used to perform simple calculations that are documented in Section 5 and Attachment II. Additionally, these files have been placed as an electronic media attachment to this calculation, Attachment III.

4.2.1 BIN.EXE

Software Routine Name: BIN.EXE
Software Routine Version: 00
Software Routine Developed Using: C89, Version HP92453-01, C programming language compiler on a Hewlett-Packard HP-UX operating system, Release 10.20

The BIN.EXE software routine performs the following four functions:

1. For each assembly in the design basis waste stream, BIN.EXE looks up and interpolates, if necessary, source term values from source term input files extracted from CRWMS

M&O (1999b, 1999c). For the interpolation, eight points must bracket the source terms of interest. These eight points represent values in the source tables at locations relative to the point of interest as follows:

Point 1: pre-time, pre-enrichment, pre-burnup
Point 2: pre-time, pre-enrichment, post-burnup
Point 3: pre-time, post-enrichment, pre-burnup
Point 4: pre-time, post-enrichment, post-burnup
Point 5: post-time, pre-enrichment, pre-burnup
Point 6: post-time, pre-enrichment, post-burnup
Point 7: post-time, post-enrichment, pre-burnup
Point 8: post-time, post-enrichment, post-burnup

To obtain the value of interest, seven interpolations are necessary. The first set of interpolations is along the plane for burnup and is performed between Points 1 and 2, then Points 3 and 4, then Points 5 and 6, then Points 7 and 8. The resulting values can be considered a, b, c, and d, respectively. The second set of interpolations is along the enrichment plane, interpolating between values a and b, then values c and d. The resulting values can be considered ab and cd, respectively. The final interpolation in the time plane is between ab and cd, which results in the value of interest.

All interpolations use the following equation:

$$value = (value2)\left(\frac{assy}{post-assy}\right)^{\frac{\ln\left(\frac{value2}{value1}\right)}{\ln\left(\frac{post-assy}{pre-assy}\right)}}$$

where,

- Value is the resulting value from the interpolation.
- Value1 and value2 are the values that are being interpolated between, which occur at the locations of pre-plane and post-plane, respectively.
- Assy represents the value of a assembly characteristic, such as burnup, enrichment, or age.
- Pre-assy represents the lower interpolation (or extrapolation) bracket value of the assembly characteristic, assy.
- Post-assy represents the upper interpolation (or extrapolation) bracket value of the assembly characteristic, assy.

The equation above, when performed for the seven interpolations, represents a three-dimensional power log interpolation. This same equation was used in the Spent Nuclear Fuel Decay Heat Function code and was validated in the software qualification report as appropriate for use for interpolating source term values (CRWMS M&O 1996, pp. 9-11). It should be noted that this equation will also perform extrapolations. In this calculation, the only time these equations are used for extrapolation is when calculating thermal heat generation values at 1,000,000 years after the time of waste receipt and for a few assemblies that fall outside the burnup/enrichment combinations provided in the source term files. To extrapolate, as the pre-assy and post-assy values cannot bracket the values, they are assigned to the first two or last two values of burnup, enrichment, or time depending on whether the extrapolation needs to be performed below or above the existing values. For this calculation, as the extrapolations are very minor, there will be no effect on the results. See Section 5.1.3 for detailed information concerning the source term files.

2. Determine the WP design type that an assembly can be loaded into, based on $k_{effective}$ criticality loading curves (see Section 5.1.1). $k_{effective}$ is defined as the effective neutron multiplication factor for an assembly and the calculation of $k_{effective}$ is dependant upon the geometry of the packaging of assemblies inside a WP design. Using a simple counter, the routine keeps track of the number of assemblies allocated to each WP design.

3. Create average assembly heat generation rate curves for each WP design type. These curves are based on normalizing the heat generation curves for each assembly to the time of arrival. This is calculated by using the following four steps: (1) determining which WP design an assembly will be loaded into based on criticality loading curves, (2) calculating assembly heat output, (3) summing the calculated heat output for all assemblies that will be loaded into a specific WP design at each time step, and (4) dividing the sums at each time step by the number of assemblies loaded into that WP design to determine the average heat output at each time step.

   The heat generation rates for the various time-steps evaluated are output in two formats, as a simple array and in a format that can be used directly by the software ANSYS.

4. Determine assembly averages for age, burnup, enrichment, and metric tons of uranium (MTU) for each WP design. Each of these items is determined by adding together the values for each assembly in a given WP design and then dividing by the number of assemblies.

BIN.EXE uses 23 input files:

- **binInfo.source**–a file which provides WP design information (including design ranges for heat output, criticality coefficients, and assembly capacity for each WP design type). This input is discussed in Section 5.1.1.

- **WS.source**–A file containing commercial SNF assembly data (including number of assemblies, burnup, enrichment, MTU, and age). This input is discussed below in Section 5.1.2.

- **timeSteps.source**–A file containing the time steps used in the source term input files.

- 20 source term files containing radionuclide activities, gamma and neutron radiation sources, cobalt-60 activities, and heat generation rates. See Table 9 for a complete file listing, with file descriptions, for these 20 source term input files.

BIN.EXE creates the following files:

1. **AnsysBin[Bin #].dat**–A file which provides a thermal decay curve that represents the average assembly to be loaded into a specific WP bin in a format that can be directly incorporated into an ANSYS thermal evaluation. These curves, which are in watts, begin at the time of assembly receipt at the repository and continue for 1 million years after receipt. The creation of these average curves was discussed previously in this Section. As an example, AnsysBin1.dat will provide the thermal decay curve that represents the average assembly to be placed into WP Bin 1. See Table 3 for the five bins used for this calculation.

2. **thermal.dat**–This file contains the same thermal decay curves as contained in the AnsysBin[Bin #].dat suite of files. The values are presented in a fashion that can easily be read into Microsoft Excel.

3. **average_nuclides.dat**–A file that contains the average assembly curie value for 61 radionuclides. These average values for assemblies are presented for each WP bin (see Table 3) and several time steps (time of repository receipt, time of last receipt at the repository, then 100, 5000, 10000, 20000, and 1 million years after repository receipt). Table 9 provides a listing of the 61 radionuclides.

4. **nuclide.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age at time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

5. **nuclide_mgr_end.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age based on the time of last repository receipt. For the waste streams in this document, the year last receipt is 2033 for the 63,000 MTU arrival cases and 2040 for the 83,800 MTU arrival cases. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input

waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

6. **nuclide_100_years.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age 100 years after the time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

7. **nuclide_5000_years.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age 5,000 years after the time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

8. **nuclide_10000_years.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age 10,000 years after the time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

9. **nuclide_20000_years.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age 20,000 years after the time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

10. **nuclide_1mil_years.dat**–A file that contains the curie value for 61 radionuclides for each assembly forecast to be received at the repository. The curie values are based on the assembly age 1 million years after the time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

11. **bin.dat**–A file that contains the bin number, the heat generation rate, and the cobalt-60 values for each assembly forecast to be received at the repository. The cobalt-60 values are presented for four assembly regions: top end-fitting, bottom end-fitting, plenum, and fuel. The values are based on the assembly age at the time of repository receipt. For each assembly, this file also reprints the assembly characteristics and batch identification number

that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

12. **gamma.dat**–A file that contains the photons per second value for each assembly forecast to be received at the repository. The values are based on the assembly age at the time of repository receipt and are presented for 18 energy bands. For each energy band, the values are presented for four assembly regions: top end-fitting, bottom end-fitting, plenum, and fuel. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

13. **neutron.dat–**A file that contains the neutrons per second value for each assembly forecast to be received at the repository. The values are based on the assembly age at the time of repository receipt and are presented for 18 energy bands. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

14. **preblend.dat**–A file that contains the bin number and the heat generation rate for each assembly forecast to be received at the repository. This file was especially setup to print only one assembly per file line to allow the file to be easily incorporated as input to another software routine which performs a scoping analysis for thermal blending of assemblies. For each assembly, this file also reprints the assembly characteristics and batch identification number that were read into BIN.EXE from input waste stream file. Additionally, the WP bin that each assembly is designated to is output to this file.

15. **summary.dat–**This file contains a summary of the WP bins and assembly arrivals. This summary presents the yearly number of assemblies to arrive for each WP bin and the number of WPs that would result from the loading of those assemblies. This file also contains other summary information for each WP bin, including the number of assemblies, average assembly age, average assembly heat generation rate at time of repository receipt, average assembly burnup, average assembly enrichment, average assembly initial MTU, and total MTU.

Output files 2 through 15 contain header lines to label the information contained in the file. Table 1 lists all the heading descriptions used in the output files and their meaning.

Table 1. Output File Heading Descriptions

Heading	Description	Units
.20E+02to.64E+01 .64E+01to.30E+01 .30E+01to.19E+01 .19E+01to.14E+01 .14E+01to.90E+00 .90E+00to.40E+00 .40E+00to.10E+00 .10E+00to.17E-01 .17E-01to.30E-02 .30E-02to.55E-03 .55E-03to.10E-03 .10E-03to.30E-04 .30E-04to.10E-04 .10E-04to.31E-05 .31E-05to.18E-05 .18E-05to.13E-05 .13E-05to.11E-05 .11E-05to.10E-05 .10E-05to.80E-06 .80E-06to.40E-06 .40E-06to.33E-06 .33E-06to.22E-06 .22E-06to.10E-06 .10E-06to.50E-07 .50E-07to.30E-07 .30E-07to.10E-07 .10E-07to.10E-10	These headings pertain to the 27 neutron energy bands and represent the MeV range for each energy band	Information under these headings are in neutrons per second
.50E-01to.10E-01 .10E+00to.50E-01 .20E+00to.10E+00 .30E+00to.20E+00 .40E+00to.30E+00 .60E+00to.40E+00 .80E+00to.60E+00 .10E+01to.80E+00 .13E+01to.10E+01 .17E+01to.13E+01 .20E+01to.17E+01 .25E+01to.20E+01 .30E+01to.25E+01 .40E+01to.30E+01 .50E+01to.40E+01 .65E+01to.50E+01 .80E+01to.65E+01 .10E+02to.80E+01	These headings pertain to the 18 gamma energy bands and represent the MeV range for each energy band	Information under these headings are in photons per second
age	Assembly age	years
assy_#	This represents a distinct assembly number assigned by BIN.EXE to each assembly in the preblend.dat file	N/A
assy_count	Number of assemblies per output file line	N/A
assy_Mtu	Assembly initial metric tons uranium	metric tons
Avg. Age	Average assembly age	years

Heading	Description	Units
Avg. Assy Watts	Average assembly heat generation rate	watts
Avg. Burnup	Average assembly burnup	GWd/MTU
Avg. Enrich.	Average assembly initial enrichment	%
Avg. MTU/Assy	Average metric tons uranium per assembly	metric tons
batch-ID	Batch identification provided in waste stream input files	N/A
Bin	WP bin that assembly will be loaded into	N/A
bottom	Bottom end-fitting region	N/A
burnup	Assembly burnup	GWd/MTU
cask_#	Arriving cask number provided by waste stream input files	N/A
Co60(bottom)	Cobalt-60 value for the assembly bottom end-fitting region	curies
Co60(fuel)	Cobalt-60 value for the assembly fuel region	curies
Co60(plenum)	Cobalt-60 value for the assembly plenum region	curies
Co60(top)	Cobalt-60 value for the assembly top end-fitting region	curies
csk_type	Cask type	R = rail cask, T = truck cask, D = rail cask containing a non-disposable dual-purpose canister
D_Yr	Assembly discharge year	year
enrich	Assembly initial enrichment	%
fuel	Assembly fuel region	N/A
MTU or Mtu	Metric tons of uranium	metric tons
Number of Assy	Number of assemblies	N/A
Number of WPs	Number of WPs	N/A
plenum	Assembly plenum region	N/A
R_Yr	Assembly receipt year at the repository	year
reactor name	Reactor name	N/A
SS	Indicates whether the assembly has stainless steel cladding	0 = zircaloy cladding, 1 = stainless-steel cladding
top	Assembly top end-fitting region	N/A
Total MTU	Total metric tons of uranium	metric tons
type	Assembly type	BWR or PWR
watts	Assembly heat generation rate	watts
WP	WP bin number	N/A
Years after loading	This description is used in the thermal.dat output file and for this calculation signifies the time since repository receipt. For thermal evaluations, the assembly thermal outputs are assumed to be based on time since WP loading, which is what is reflected in this heading.	years

This software routine was checked to ensure that it provided the correct results for its intended use in this calculation. Check of BIN.EXE by the use of a simple spreadsheet calculation is provided in Attachment III.

4.2.2 SURFACESORT.EXE

Software Routine Name: SURFACESORT.EXE
Software Routine Version: 00
Software Routine Developed Using: C89, Version HP92453-01, C programming language compiler on a Hewlett-Packard HP-UX operating system, Release 10.20

In addition to the BIN.EXE software routine, a second routine entitled SURFACESORT.EXE was developed to translate the output from BIN.EXE into a format that can be directly input into the WITNESS software code. The WITNESS software code is used to simulate the operations of the repository surface facilities.

SURFACESORT.EXE uses the preblend.dat output file from BIN.EXE and translates it into a form that can be directly input into WITNESS. For each commercial waste stream arrival case, there are three files generated by SURFACESORT.EXE. These files are truck.dat, rail.dat, and DPC.dat. Truck.dat contains cask information for casks arriving by truck. Rail.dat contains cask information for rail casks transporting uncanistered assemblies. DPC.dat contains cask information for rail casks containing dual-purpose canisters.

The output files from SURFACESORT.EXE are all in the same comma delimited format:

Cask Line:	Cask Type, Cask Quantity, Cask Arrival Time , , , Cask Number, Cask Arrival Year
Assembly Line:	Assembly Loading, Assembly Quantity, Assembly Arrival Time, "HEAT=" Assembly Heat Output

The number of assembly lines is equal to the number of assemblies in the cask. This sequence of cask line followed by multiple assembly lines repeats until all arrivals are complete.

The items for the output lines are described below:

- **Cask Type**–R = rail, T = truck, C = dual-purpose canister shipped via rail. The output files from SURFACESORT.EXE have been separated by cask type and will not contain varying cask types.

- **Cask Quantity**–Always set as 1, required for WITNESS.

- **Cask Arrival Time**–This is determined by dividing the number of repository operating minutes (set at 504,000 minutes) by the number of casks arriving in a given year. All casks are then spaced to arrive evenly throughout the year. This is required for WITNESS. Arrival time does not start at zero for each year but continues from the previous year.

NOTE: The sequencing specified within a year by a design basis waste stream is just a reflection of the CALVIN software code and was not intended as an actual arrival sequence. SURFACESORT.EXE provides the within-year sequencing as output by CALVIN. This sequence will provide one variation of a potential receipt scenario.

- **Cask Number**–This is a unique cask identifier and is directly extracted from the preblend.dat file, which recorded it from the design basis waste stream files (CRWMS M&O 1999d).

- **Cask Arrival Year**–This is the year the cask is forecast to arrive at the repository and is directly extracted from the preblend.dat file, which recorded it from the design basis waste stream files (CRWMS M&O 1999d).

- **Assembly Loading**–This defines the WP design type that can accommodate the assembly. The WP design type is directly extracted from the preblend.dat file and then translated as shown in Table 2.

  NOTE: There are five commercial WP designs, so one design type was neglected due to current WITNESS constraints. The neglected design is the 12 PWR Absorber Plate-Long (Bin 3 in Table 3).

Table 2. SURFACESORT.EXE Waste Package Translation

WP Design	WP Bin as Identified in BIN.EXE preblend.dat file	WP as identified in SURFACESORT.EXE output files
21 PWR Absorber Plate	1	PWR1
21 PWR Control Rod	2	PWR2
44 BWR Absorber Plate	4	BWR1
24 BWR Thick Absorber Plate	5	BWR2

- **Assembly Quantity**–Always set as 1, required for WITNESS.

- **Assembly Arrival Time**–This value is equal to the cask arrival time for the cask that the assembly will arrive in (see description for “Cask Arrival Time” above).

- **Assembly Heat Output**–This value is in watts and denotes the heat generation rate of the assembly at the time of repository receipt. This value is recorded as presented in the preblend.dat file.

The SURFACESORT.EXE output is readily checked by visual inspection.

4.3 MODELS

None used.

5. CALCULATION

5.1 CALCULATION INPUTS

5.1.1 Assembly Constraints

This calculation uses the WP designs and constraints from Tables 3 and 4 to determine which assemblies can be placed into a specific WP design. While BIN.EXE has the capability to exclude an assembly from being placed into a WP design based on heat generation rate at time of arrival, for this calculation the heat generation rate limits are set such that no assembly will be disqualified from loading (see Assumption 3.6). Therefore, criticality level and assembly class determine which WP design an assembly will be placed into.

This calculation evaluates criticality based on $k_{effective}$. The $k_{effective}$ equation used is:

$$k_{effective} + 2\sigma = c_0 + c_1B + c_2E + c_3B^2 + c_4E^2 + c_5B^3 + c_6E^3$$

where,

- c_0, c_1, c_2, c_3, c_4, c_5, and c_6 are criticality coefficients as shown in Table 3.
- B is the assembly burnup, in gigawatts-days per MTU, provided by CRWMS M&O (1999d) (see Section 5.1.2).
- E is the assembly initial U-235 enrichment, in weight percent, provided by CRWMS M&O (1999d) (see Section 5.1.2).

Criticality coefficients have only been developed for two of the five WP designs (see Table 3), the 21 PWR Absorber Plate WP, and the 44 BWR Absorber Plate WP. These coefficients were developed in the *Disposal Criticality Analysis Methodology Topical Report* (YMP 1998, Table C-12 and Eq. C-7, p. C-43). The criticality equation above applies to scenarios where the fuel has degraded and is lumped at the bottom of the WP. This represents the most reactive geometric configuration. For the degraded configuration, the maximum acceptable $k_{effective} + 2\sigma$ limit was set at 0.98. The coefficients that were used for this calculation are provided in Table 3.

The criticality coefficients for WP Bins 2, 3, and 5 in Table 3 have been set to zero. When all coefficients are set to zero, $k_{effective}$ will always be calculated as zero. Therefore, if a PWR assembly (excluding South Texas assemblies) cannot be placed in Bin 1, then it will always be placed in Bin 2. All South Texas assemblies will be placed into Bin 3. If a BWR assembly cannot be placed into Bin 4, then it will always be placed in Bin 5. As criticality coefficients are generated for the remaining WP designs, it may be determined that some assemblies exceed acceptable criticality levels and will require special handling.

Table 3. Waste Package Criticality Coefficients

	Waste Package Designs				
	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5
Criticality Coefficients	**21 PWR Absorber Plate**	**21 PWR Control Rod**	**12 PWR Absorber Plate-Long**	**44 BWR Absorber Plate**	**24 BWR Thick Absorber Plate**
c_0	0.640653	0	0	0.850736	0
c_1	-0.0102912	0	0	-0.007751	0
c_2	0.300169	0	0	0.087294	0
c_3	-2.54581E-05	0	0	0	0
c_4	-0.0490929	0	0	0	0
c_5	9.92035E-07	0	0	0	0
c_6	0.00364521	0	0	0	0

The WPs listed in Tables 3 and 4 are slightly modified from those presented in the *License Application Design Selection Feature Report: Aging and Blending* (CRWMS M&O 1999e, p. 10). The WP designs in CRWMS M&O (1999e) with no absorber plates for criticality control were removed from the design list to ensure defense-in-depth and reduce the chance of criticality misload.

Table 4. Commercial Waste Package Designs

Bin #	WP Design	Assembly Capacity	Allowable Assembly Heat Generation Range, watts	
			min	max
1	21 PWR Absorber Plate	21	0	2100
2	21 PWR Control Rod	21	0	2100
3	12 PWR Absorber Plate-Long	12	0	2100
4	44 BWR Absorber Plate	44	0	750
5	24 BWR Thick Absorber Plate	24	0	750

The *Waste Container Cavity Size Determination* document (CRWMS M&O 1997, pp. 25-26) determined which assembly classes could be placed in a standard WP basket cell. All classes of PWR assemblies evaluated in Section 4 of CRWMS M&O (1997) can be placed into WP Bins 1 and 2 in Table 4 with the exception of the longer South Texas assemblies. South Texas assemblies will be placed into WP Bin 3. Additionally, WP Bin 3 could hold other assembly classes but not enough definition is available to determine the number of assemblies that would need to be placed into it (see Assumptions 3.3 and 3.4). The cavity size for WP Bins 4 and 5 can hold all of the BWR assembly classes identified in Section 4 of CRWMS M&O (1997).

5.1.2 Commercial Waste Streams

Information for assembly type, burnup, initial U-235 enrichment, MTU per assembly, discharge year, repository receipt year, and other shipment information is provided in CRWMS M&O (1999d). This information was developed for the *1999 Design Basis Waste Stream Input Report for Commercial Spent Nuclear Fuel* (CRWMS M&O 1999a). Since it is unknown which assemblies the utilities will send at a given time, six arrival forecasts were developed based on three different arrival "case" methodologies to account for the most likely scenarios.

The six arrival forecasts are as follows:

1. Case A–63,000 MTU, fuel selection begins with 10-year-old spent fuel
2. Case A–83,800 MTU, fuel selection begins with 10-year-old spent fuel
3. Case B–63,000 MTU, fuel selection begins with 10-year-old spent fuel in strict order of age
4. Case B–83,800 MTU, fuel selection begins with 10-year-old spent fuel in strict order of age
5. Case C–63,000 MTU, fuel selection begins with oldest fuel first
6. Case C–83,800 MTU, fuel selection begins with oldest fuel first.

More description of these cases can be found on pages A-3 through A-5 in CRWMS M&O (1999a). It should be noted that two additional cases, D and E, were evaluated in CRWMS M&O (1999a), but were deemed inappropriate for design (CRWMS M&O 1999a, p. A-5) and are not evaluated herein.

Table 5 provides general waste stream arrival case characteristics, which were calculated using Microsoft Excel 97. It should be noted that occasionally the 83,800 MTU forecasts are referred to as 84k MTU cases for convenience.

When deciding which WP designs can accommodate assemblies from the detailed waste streams, Big Rock Point and South Texas assemblies must be identified (see Assumptions 3.3 and 3.5). As assembly classes are not listed in the waste stream source files (CRWMS M&O 1999d), these assembly classes will be determined solely on the identification of the Big Rock Point and South Texas reactor sites. Some assemblies could potentially be held at other locations, but as the number of unidentified should not be significant, it will not have any appreciable effect on the results of this calculation.

Table 5. Arrival Case Characteristics

Arrival Case	Assembly Type	Number of Assemblies	Average Assembly Age (years)	Median Assembly Age (years)	Average Assembly Burnup (MWd/MTU)	Average Assembly Initial U-235 Enrichment (wt.%)	Average Assembly Initial MTU
Case A - 63,000 MTU	BWR	126984	22.7	18	33626	3.03	0.177
	PWR	93770	23.1	19	41214	3.75	0.432
Case A - 83,800 MTU	BWR	166942	25.3	21	33592	3.02	0.177
	PWR	124761	25.3	21	41697	3.75	0.434
Case B - 63,000 MTU	BWR	127212	22.1	17	34803	3.09	0.177
	PWR	93770	21.9	16	42615	3.82	0.432
Case B - 83,800 MTU	BWR	166942	25.3	19	33592	3.02	0.177
	PWR	124761	25.3	19	41697	3.75	0.434
Case C - 63,000 MTU	BWR	126316	24.6	23	31969	2.94	0.178
	PWR	93870	24.6	23	40132	3.67	0.432
Case C - 83,800 MTU	BWR	166942	25.4	24	33592	3.02	0.177
	PWR	124761	25.3	24	41697	3.75	0.434

5.1.3 Source Terms

Source terms for BWR and PWR assemblies were taken from CRWMS M&O (1999b and 1999c, respectively). In these documents, a representative assembly was developed to determine source terms. In these calculations, the representative assemblies are assumed (see Assumptions 3.1 and 3.2) to be applicable to assemblies of different classes and MTU loadings. The representative assembly characteristics are presented in Table 6.

Table 6. Representative Assembly Characteristics

	PWR Assembly	BWR Assembly
Initial Mass of Uranium per Assembly	0.475 MTU	0.200 MTU
Assembly Class	Babcock & Wilcox Mark B 15x15	General Electric 2/3 8x8

The assemblies in Table 6 were evaluated for both zircaloy cladding and stainless-steel cladding using various burnup and enrichment combinations. Table 7 reflects the burnup/enrichment combinations used in this calculation for zircaloy-clad assemblies and Table 8 reflects those used for stainless-steel-clad assemblies. These burnup and enrichment combinations were evaluated for 180 time steps, ranging from 1 year after reactor discharge to 1 million years after reactor discharge.

Table 7. Zircaloy-Clad Assembly Burnup/Enrichment Combinations

Enrichment (% initial U-235 enrichment)	Burnups Evaluated for Each Enrichment (GWd/MTU)
PWR and BWR Assemblies	
0.711	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
1.00	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
1.50	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
2.00	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
2.50	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
3.00	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
3.50	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
4.00	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
4.50	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
5.00	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75
5.50	0.001, 0.01, 0.1, 1, 10, 20, 30, 40, 50, 60, 70, 75

Table 8. Stainless-Steel-Clad Assembly Burnup/Enrichment Combinations

Enrichment (% initial U-235 enrichment)	Burnups Evaluated for Each Enrichment (GWd/MTU)
PWR Assemblies	
1.00	1, 10, 20, 30, 40
1.50	1, 10, 20, 30, 40
2.00	1, 10, 20, 30, 40
2.50	1, 10, 20, 30, 40
3.00	1, 10, 20, 30, 40
3.50	1, 10, 20, 30, 40
4.00	1, 10, 20, 30, 40
4.50	1, 10, 20, 30, 40
5.00	1, 10, 20, 30, 40
5.50	1, 10, 20, 30, 40
BWR Assemblies	
3.50	1, 10, 20, 30, 40
4.00	1, 10, 20, 30, 40

Table 9 provides an overview of the source files used in this calculation that were developed in CRWMS M&O (1999b, 1999c) and provided as electronic attachments to those references (Attachments IV and VII, respectively). These source files are based on calculations for the representative assemblies shown in Table 6 and reflect the burnup and enrichment combinations shown in Tables 7 and 8.

It should be noted that the source term files provide the average source terms for an assembly or assembly regions, as appropriate. For some calculations, it may be appropriate to add an axial peaking factor to the results of this calculation.

Table 9. Source Term Files Used as Input

File Names	Description
PWR.thermal.source BWR.thermal.source	Provides six components of heat generation rates, in watts, for a zircaloy-clad PWR and BWR assembly, respectively: light elements in the fuel region, fission products in the fuel region, actinides in the fuel region, light elements in the bottom end-fitting, light elements in the plenum region, and light elements in the top end-fitting region.
PWRSS.thermal.source BWRSS.thermal.source	Provides six components of heat generation rates, in watts, for a stainless-steel-clad PWR and BWR assembly, respectively. These components are the same as listed above for zircaloy-clad assemblies.
PWR.nuclide.source BWR.nuclide.source	Provides 61 nuclides, in curies per assembly, for a zircaloy-clad PWR and BWR assembly, respectively: ac-227 am-241 am-242m am-243 ba-137m c-14 cd-113m cl-36 cm-242 cm-243 cm-244 cm-245 cm-246 cm-247 co-60 cs-134 cs-135 cs-137 eu-154 eu-155 fe-55 fr-221 h-3 I-129 kr-85 nb-93m nb-94 ni-59 ni-63 np-237 pa-231 pb-210 pd-107 pm-147 po-218 pu-238 pu-239 pu-240 pu-241 pu-242 ra-226 ra-228 ru-106 sb-125 se-79 sm-147 sm-151 sn-126 sr-90 tc-99 th-229 th-230 th-232 u-232 u-233 u-234 u-235 u-236 u-238 y-90 zr-93
PWRSS.nuclide.source BWRSS.nuclide.source	Provides 61 nuclides, in curies per assembly, for a stainless-steel-clad PWR and BWR assembly, respectively. These nuclides are the same as those listed above for zircaloy-clad assemblies.
PWR.gamma.source BWR.gamma.source	Provides values for 18 gamma energy bands, in photons per second, for the fuel, bottom end-fitting, plenum, and top end-fitting regions of a zircaloy-clad PWR and BWR assembly, respectively: Energy Bands, MeV Energy, high Energy, low 5.00E-02 1.00E-02 1.00E-01 5.00E-02 2.00E-01 1.00E-01 3.00E-01 2.00E-01 4.00E-01 3.00E-01 6.00E-01 4.00E-01 8.00E-01 6.00E-01 1.00E+00 8.00E-01 1.33E+00 1.00E+00 1.66E+00 1.33E+00 2.00E+00 1.66E+00 2.50E+00 2.00E+00 3.00E+00 2.50E+00 4.00E+00 3.00E+00 5.00E+00 4.00E+00 6.50E+00 5.00E+00 8.00E+00 6.50E+00 1.00E+01 8.00E+00
PWRSS.gamma.source BWRSS.gamma.source	Provides values for 18 gamma energy bands, in photons per second, for the fuel region of a stainless-steel-clad PWR and BWR assembly, respectively. The energy bands are the same as those listed above for zircaloy-clad assemblies.

<table>
<tr><th>File Names</th><th>Description</th></tr>
<tr><td>PWR.neutron.source
BWR.neutron.source</td><td>Provides values for 27 neutron energy bands, in neutrons per second, for the fuel region of a zircaloy-clad PWR and BWR assembly, respectively:

Energy Bands, MeV
<table>
<tr><th>Energy, high</th><th>Energy, low</th></tr>
<tr><td>2.00E+01</td><td>6.43E+00</td></tr>
<tr><td>6.43E+00</td><td>3.00E+00</td></tr>
<tr><td>3.00E+00</td><td>1.85E+00</td></tr>
<tr><td>1.85E+00</td><td>1.40E+00</td></tr>
<tr><td>1.40E+00</td><td>9.00E-01</td></tr>
<tr><td>9.00E-01</td><td>4.00E-01</td></tr>
<tr><td>4.00E-01</td><td>1.00E-01</td></tr>
<tr><td>1.00E-01</td><td>1.70E-02</td></tr>
<tr><td>1.70E-02</td><td>3.00E-03</td></tr>
<tr><td>3.00E-03</td><td>5.50E-04</td></tr>
<tr><td>5.50E-04</td><td>1.00E-04</td></tr>
<tr><td>1.00E-04</td><td>3.00E-05</td></tr>
<tr><td>3.00E-05</td><td>1.00E-05</td></tr>
<tr><td>1.00E-05</td><td>3.05E-06</td></tr>
<tr><td>3.05E-06</td><td>1.77E-06</td></tr>
<tr><td>1.77E-06</td><td>1.30E-06</td></tr>
<tr><td>1.30E-06</td><td>1.13E-06</td></tr>
<tr><td>1.13E-06</td><td>1.00E-06</td></tr>
<tr><td>1.00E-06</td><td>8.00E-07</td></tr>
<tr><td>8.00E-07</td><td>4.00E-07</td></tr>
<tr><td>4.00E-07</td><td>3.25E-07</td></tr>
<tr><td>3.25E-07</td><td>2.25E-07</td></tr>
<tr><td>2.25E-07</td><td>1.00E-07</td></tr>
<tr><td>1.00E-07</td><td>5.00E-08</td></tr>
<tr><td>5.00E-08</td><td>3.00E-08</td></tr>
<tr><td>3.00E-08</td><td>1.00E-08</td></tr>
<tr><td>1.00E-08</td><td>1.00E-11</td></tr>
</table></td></tr>
<tr><td>PWRSS.neutron.source
BWRSS.neutron.source</td><td>Provides values for 27 neutron energy bands, in neutrons per second, for the fuel region of a stainless-steel clad PWR and BWR assembly, respectively. The energy bands are the same as those listed above for zircaloy-clad assemblies.</td></tr>
<tr><td>PWR.cobalt.source
BWR.cobalt.source</td><td>Provides cobalt-60 source terms, in curies, for the fuel, bottom end-fitting, plenum, and top end-fitting regions of a zircaloy-clad PWR and BWR assembly, respectively.</td></tr>
<tr><td>PWRSS.cobalt.source
BWRSS.cobalt.source</td><td>Provides cobalt-60 source terms, in curies, for the fuel, bottom end-fitting, plenum, and top end-fitting regions of a stainless-steel-clad PWR and BWR assembly, respectively.</td></tr>
</table>

It should be noted that the detailed waste stream information from CRWMS M&O 1999d contains projected commercial mixed-oxide (MOX) assemblies. As the current MOX source terms are not in the proper format to be included as source files to the BIN.EXE software routine, the MOX assemblies are approximated as standard uranium-oxide assemblies when calculating source terms. MOX assemblies compromise a small percentage, 0.6% (1800 assemblies), of the total assemblies projected to be discharged from reactors. Because of this, treating MOX assemblies as uranium-oxide assemblies will have little impact on average values determined by this calculation. For evaluations that are performed on a per assembly basis, MOX source terms from other references should be considered.

5.2 PROCEDURE

The software routine BIN.EXE was run for the set of WP designs identified in Section 5.1.1 for each waste stream identified in Section 5.1.2. The source terms identified in Section 5.1.3 were used for all runs. After the BIN.EXE runs were complete, the SURFACESORT.EXE software routine was run for each waste arrival case using the BIN.EXE preblend.dat output file.

6. RESULTS

The output files for the software routines BIN.EXE and SURFACESORT.EXE are contained as an electronic media attachment to this calculation. Tables 17 through 19 detail the file listings for the electronic media.

Summaries of the number of WPs and average thermal properties are presented in Tables 10 through 15 and are based on information from the BIN.EXE summary.dat output files. The number of WPs presented is based on WPs that have been loaded to full assembly capacity, with the exception of the final WPs loaded. The average WP heat generation rates provided are based on the average assembly heat generation rate for each WP design multiplied by the assembly capacity for that design.

The source term results from this calculation are not based on the use of an axial peaking factor. For analysis that will be based on the results of this calculation, it may be appropriate to apply an axial peaking factor. Additionally, it should again be noted that the MOX assemblies in this report are treated as uranium-oxide assemblies. For evaluations that are performed on a per assembly basis, MOX source terms from other references should be considered.

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

Table 10. Case A - 63,000 MTU Waste Package Characteristics[a]

WP Design	Average WP Heat Generation Rate Based on Assembly Heat at Repository Arrival (kW)[b]	Number of Assemblies	Number of WPs	Average Initial Burnup (GWd / MTU)	Average Initial U-235 Enrichment	Average MTU / Assembly	Average Assembly Age (years)	Total MTU
21 PWR Absorber Plate	11.53	90262	4299	41.485	3.74	0.430	23.00	38818.86
21 PWR Control Rod	3.11	1992	95	19.624	3.57	0.368	36.14	733.28
12 PWR Absorber Plate-Long	9.55	1955	163	46.326	4.01	0.540	18.04	1055.71
44 BWR Absorber Plate	7.38	124532	2831	34.080	3.04	0.177	22.41	22050.28
24 BWR Thick Absorber Plate	0.52	2013	84	8.065	2.63	0.167	40.32	335.55
Totals		220754	7472					62993.68

NOTES:

[a] Information in table based on summary.dat file for waste arrival Case A, 63,000 MTU.

[b] Average WP Heat Generation Rate, kW: 9.68
Average PWR WP Heat Generation Rate, kW: 11.28
Average BWR WP Heat Generation Rate, kW: 7.18

Table 11. Case A - 83,800 MTU Waste Package Characteristics[a]

WP Design	Average WP Heat Generation Rate Based on Assembly Heat at Repository Arrival (kW)[b]	Number of Assemblies	Number of WPs	Average Initial Burnup (GWd / MTU)	Average Initial U-235 Enrichment	Average MTU / Assembly	Average Assembly Age (years)	Total MTU
21 PWR Absorber Plate	11.33	119480	5690	41.976	3.75	0.431	25.20	51529.19
21 PWR Control Rod	3.26	2207	106	19.862	3.61	0.376	35.83	829.07
12 PWR Absorber Plate-Long	8.97	3513	293	43.337	3.77	0.540	21.59	1897.56
44 BWR Absorber Plate	7.00	164165	3732	33.981	3.02	0.178	25.08	29140.39
24 BWR Thick Absorber Plate	0.54	2338	98	8.480	2.68	0.169	41.82	395.28
Totals		291703	9919					83791.49

NOTES:

[a] Information in table based on summary.dat file for waste arrival Case A, 83,800 MTU.

[b] Average WP Heat Generation Rate, kW: 9.43
Average PWR WP Heat Generation Rate, kW: 11.07
Average BWR WP Heat Generation Rate, kW: 6.83

Table 12. Case B - 63,000 MTU Waste Package Characteristics[a]

WP Design	Average WP Heat Generation Rate Based on Assembly Heat at Repository Arrival (kW)[b]	Number of Assemblies	Number of WPs	Average Initial Burnup (GWd / MTU)	Average Initial U-235 Enrichment	Average MTU / Assembly	Average Assembly Age (years)	Total MTU
21 PWR Absorber Plate	12.51	90310	4301	42.887	3.81	0.43	21.8	38827.55
21 PWR Control Rod	3.06	1944	93	19.544	3.56	0.366	36.31	711.68
12 PWR Absorber Plate-Long	10.92	1955	163	48.302	4.1	0.54	14.9	1055.70
44 BWR Absorber Plate	7.79	124769	2836	35.279	3.1	0.177	21.81	22069.04
24 BWR Thick Absorber Plate	0.52	2004	84	8.042	2.63	0.167	40.39	333.95
Totals		220982	7477					62997.92

NOTES:

[a] Information in table based on summary.dat file for waste arrival Case B, 63,000 MTU.

[b] Average WP Heat Generation Rate, kW: 10.43
Average PWR WP Heat Generation Rate, kW: 12.26
Average BWR WP Heat Generation Rate, kW: 7.58

Table 13. Case B - 83,800 MTU Waste Package Characteristics[a]

WP Design	Average WP Heat Generation Rate Based on Assembly Heat at Repository Arrival (kW)[b]	Number of Assemblies	Number of WPs	Average Initial Burnup (GWd / MTU)	Average Initial U-235 Enrichment	Average MTU / Assembly	Average Assembly Age (years)	Total MTU
21 PWR Absorber Plate	11.64	119480	5690	41.976	3.75	0.431	25.2	51529.19
21 PWR Control Rod	3.23	2207	106	19.862	3.61	0.376	36.19	829.07
12 PWR Absorber Plate-Long	9.25	3513	293	43.337	3.77	0.54	21.59	1897.56
44 BWR Absorber Plate	7.10	164165	3732	33.981	3.02	0.178	25.06	29140.39
24 BWR Thick Absorber Plate	0.54	2338	98	8.48	2.68	0.169	41.88	395.28
Totals		291703	9919					83791.49

NOTES:

[a] Information in table based on summary.dat file for waste arrival Case B, 83,800 MTU.

[b] Average WP Heat Generation Rate, kW: 9.66
Average PWR WP Heat Generation Rate, kW: 11.37
Average BWR WP Heat Generation Rate, kW: 6.93

Table 14. Case C - 63,000 MTU Waste Package Characteristics[a]

WP Design	Average WP Heat Generation Rate Based on Assembly Heat at Repository Arrival (kW)[b]	Number of Assemblies	Number of WPs	Average Initial Burnup (GWd / MTU)	Average Initial U-235 Enrichment	Average MTU / Assembly	Average Assembly Age (years)	Total MTU
21 PWR Absorber Plate	10.69	90238	4298	40.536	3.68	0.43	24.34	38786.87
21 PWR Control Rod	3.52	2116	101	19.547	3.59	0.373	34.3	790.19
12 PWR Absorber Plate-Long	6.62	1955	163	39.67	3.54	0.54	25.71	1056.24
44 BWR Absorber Plate	6.49	123552	2808	32.448	2.94	0.178	24.36	21970.61
24 BWR Thick Absorber Plate	0.59	2325	97	8.466	2.68	0.169	37.34	392.89
Totals		220186	7467					62996.8

NOTES:

[a] Information in table based on summary.dat file for waste arrival Case C, 63,000 MTU.

[b] Average WP Heat Generation Rate, kW: 8.79
Average PWR WP Heat Generation Rate, kW: 10.39
Average BWR WP Heat Generation Rate, kW: 6.29

Table 15. Case C - 83,800 MTU Waste Package Characteristics[a]

WP Design	Average WP Heat Generation Rate Based on Assembly Heat at Repository Arrival (kW)[b]	Number of Assemblies	Number of WPs	Average Initial Burnup (GWd / MTU)	Average Initial U-235 Enrichment	Average MTU / Assembly	Average Assembly Age (years)	Total MTU
21 PWR Absorber Plate	10.97	119480	5690	41.976	3.75	0.431	25.22	51529.19
21 PWR Control Rod	3.55	2207	106	19.862	3.61	0.376	34.74	829.07
12 PWR Absorber Plate-Long	8.32	3513	293	43.337	3.77	0.54	21.6	1897.56
44 BWR Absorber Plate	6.63	164165	3732	33.981	3.02	0.178	25.25	29140.39
24 BWR - Thick Absorber Plate	0.59	2338	98	8.48	2.68	0.169	37.39	395.28
Totals		291703	9919					83791.49

NOTES:

[a] Information in table based on summary.dat file for waste arrival Case C, 83,800 MTU.

[b] Average WP Heat Generation Rate, kW: 9.07
Average PWR WP Heat Generation Rate, kW: 10.71
Average BWR WP Heat Generation Rate, kW: 6.48

7. ATTACHMENTS

Hardcopy attachments to this calculation are summarized below in Table 16. In addition to the attachments listed in Table 16, Attachment III is comprised of three compact discs (CDs) that support this calculation. The file listings for the discs are presented in Tables 17 through 19.

Table 16. List of Attachments

Attachment Number	Title / Description	Number of Pages
I	Document Input Reference System Report	2
II	Spreadsheet Check of BIN.EXE Software Routine[a]	28

NOTES:

[a] The electronic spreadsheet file is contained in Attachment III, disc 3 file routine_check.xls

Table 17. Disc 1 File Listing

File Name	Date Transferred	Time of Transfer	File Size (bytes)
Directory: BIN.EXE_FILES\OUTPUT_FILES\CASE_A_63K			
AnsysBin1.dat	12/09/99	12:06p	4,548
AnsysBin2.dat	12/09/99	12:06p	4,548
AnsysBin3.dat	12/09/99	12:06p	4,548
AnsysBin4.dat	12/09/99	12:06p	4,548
AnsysBin5.dat	12/09/99	12:06p	4,548
average_nuclides.dat	12/09/99	12:06p	31,125
bin.dat	12/09/99	12:06p	3,555,474
gamma.dat	12/09/99	12:05p	26,697,850
neutron.dat	12/09/99	11:56a	11,154,032
nuclide.dat	12/09/99	11:53a	15,461,236
nuclide_10000_years.dat	12/09/99	11:43a	15,461,236
nuclide_100_years.dat	12/09/99	11:48a	15,461,236
nuclide_1mil_years.dat	12/09/99	11:38a	15,501,870
nuclide_20000_years.dat	12/09/99	11:33a	15,461,236
nuclide_5000_years.dat	12/09/99	11:28a	15,461,236
nuclide_mgr_end.dat	12/09/99	11:25a	15,461,236
preblend.dat	12/09/99	11:20a	24,283,049
summary.dat	12/09/99	11:12a	10,782
thermal.dat	12/09/99	11:12a	10,546
Directory: BIN.EXE_FILES\OUTPUT_FILES\CASE_A_84K			
AnsysBin1.dat	12/09/99	1:21p	4,548
AnsysBin2.dat	12/09/99	1:21p	4,548
AnsysBin3.dat	12/09/99	1:21p	4,548
AnsysBin4.dat	12/09/99	1:21p	4,548
AnsysBin5.dat	12/09/99	1:21p	4,548
average_nuclides.dat	12/09/99	1:21p	31,125
bin.dat	12/09/99	1:21p	4,582,024
gamma.dat	12/09/99	1:20p	34,405,774
neutron.dat	12/09/99	1:12p	14,374,466
nuclide.dat	12/09/99	1:08p	19,925,262
nuclide_10000_years.dat	12/09/99	12:55p	19,925,262

File Name	Date Transferred	Time of Transfer	File Size (bytes)
nuclide_100_years.dat	12/09/99	1:02p	19,925,262
nuclide_1mil_years.dat	12/09/99	12:48p	19,977,628
nuclide_20000_years.dat	12/09/99	12:42p	19,925,262
nuclide_5000_years.dat	12/09/99	12:35p	19,925,262
nuclide_mgr_end.dat	12/09/99	12:29p	19,925,262
preblend.dat	12/09/99	12:22p	32,087,439
summary.dat	12/09/99	12:11p	13,512
thermal.dat	12/09/99	12:11p	10,546
Directory: BIN.EXE_FILES\OUTPUT_FILES\CASE_B_63K			
AnsysBin1.dat	12/09/99	2:35p	4,548
AnsysBin2.dat	12/09/99	2:35p	4,548
AnsysBin3.dat	12/09/99	2:35p	4,548
AnsysBin4.dat	12/09/99	2:35p	4,548
AnsysBin5.dat	12/09/99	2:35p	4,548
average_nuclides.dat	12/09/99	2:35p	31,125
bin.dat	12/09/99	2:35p	3,823,749
gamma.dat	12/09/99	2:34p	28,712,212
neutron.dat	12/09/99	2:27p	11,995,649
nuclide.dat	12/09/99	2:23p	16,627,849
nuclide_10000_years.dat	12/09/99	2:16p	16,627,849
nuclide_100_years.dat	12/09/99	2:20p	16,627,849
nuclide_1mil_years.dat	12/09/99	2:10p	16,671,549
nuclide_20000_years.dat	12/09/99	2:05p	16,627,849
nuclide_5000_years.dat	12/09/99	2:01p	16,627,849
nuclide_mgr_end.dat	12/09/99	1:55p	16,627,849
preblend.dat	12/09/99	1:50p	24,308,129
summary.dat	12/09/99	1:41p	10,782
thermal.dat	12/09/99	1:41p	10,546

Table 18. Disc 2 File Listing

File Name	Date Transferred	Time of Transfer	File Size (bytes)
Directory: BIN.EXE_FILES\OUTPUT_FILES\CASE_B_84K			
AnsysBin1.dat	12/09/99	4:11p	4,548
AnsysBin2.dat	12/09/99	4:11p	4,548
AnsysBin3.dat	12/09/99	4:11p	4,548
AnsysBin4.dat	12/09/99	4:11p	4,548
AnsysBin5.dat	12/09/99	4:11p	4,548
average_nuclides.dat	12/09/99	4:11p	31,125
bin.dat	12/09/99	4:11p	4,807,949
gamma.dat	12/09/99	4:09p	36,102,148
neutron.dat	12/09/99	3:57p	15,083,225
nuclide.dat	12/09/99	3:53p	20,907,713
nuclide_10000_years.dat	12/09/99	3:39p	20,907,713
nuclide_100_years.dat	12/09/99	3:46p	20,907,713
nuclide_1mil_years.dat	12/09/99	3:32p	20,962,661
nuclide_20000_years.dat	12/09/99	3:25p	20,907,713
nuclide_5000_years.dat	12/09/99	3:05p	20,907,713
nuclide_mgr_end.dat	12/09/99	2:59p	20,907,713
preblend.dat	12/09/99	2:52p	32,087,439
summary.dat	12/09/99	2:44p	13,512
thermal.dat	12/09/99	2:44p	10,546

File Name	Date Transferred	Time of Transfer	File Size (bytes)
Directory: BIN.EXE_FILES\OUTPUT_FILES\CASE_C_63K			
AnsysBin1.dat	12/09/99	5:06p	4,548
AnsysBin2.dat	12/09/99	5:06p	4,548
AnsysBin3.dat	12/09/99	5:06p	4,548
AnsysBin4.dat	12/09/99	5:06p	4,548
AnsysBin5.dat	12/09/99	5:06p	4,548
average_nuclides.dat	12/09/99	5:06p	31,125
bin.dat	12/09/99	2:42p	3,594,149
gamma.dat	12/09/99	5:06p	26,988,244
neutron.dat	12/09/99	4:57p	11,275,361
nuclide.dat	12/09/99	4:53p	15,629,417
nuclide_10000_years.dat	12/09/99	4:43p	15,629,417
nuclide_100_years.dat	12/09/99	4:48p	15,629,417
nuclide_1mil_years.dat	12/09/99	4:39p	15,670,493
nuclide_20000_years.dat	12/09/99	4:34p	15,629,417
nuclide_5000_years.dat	12/09/99	4:29p	15,629,417
nuclide_mgr_end.dat	12/09/99	4:25p	15,629,417
preblend.dat	12/09/99	4:20p	24,220,569
summary.dat	12/09/99	4:13p	10,782
thermal.dat	12/09/99	4:13p	10,546
Directory: BIN.EXE_FILES\OUTPUT_FILES\CASE_C_84K			
AnsysBin1.dat	12/09/99	7:18p	4,548
AnsysBin2.dat	12/09/99	7:18p	4,548
AnsysBin3.dat	12/09/99	7:18p	4,548
AnsysBin4.dat	12/09/99	7:18p	4,548
AnsysBin5.dat	12/09/99	7:18p	4,548
average_nuclides.dat	12/09/99	7:18p	31,125
bin.dat	12/09/99	7:18p	4,595,149
gamma.dat	12/09/99	7:16p	34,504,324
neutron.dat	12/09/99	7:08p	14,415,641
nuclide.dat	12/09/99	7:04p	19,982,337
nuclide_10000_years.dat	12/09/99	6:51p	19,982,337
nuclide_100_years.dat	12/09/99	6:57p	19,982,337
nuclide_1mil_years.dat	12/09/99	6:44p	20,034,853
nuclide_20000_years.dat	12/09/99	6:37p	19,982,337
nuclide_5000_years.dat	12/09/99	6:31p	19,982,337
nuclide_mgr_end.dat	12/09/99	6:24p	19,982,337
preblend.dat	12/09/99	6:17p	32,087,439
summary.dat	12/09/99	6:07p	13,512
thermal.dat	12/09/99	6:07p	10,546

Table 19. Disc 3 File Listing

File Name	Date Transferred	Time of Transfer	File Size (bytes)
Directory: SURFACESORT.EXE_FILES\OUTPUT_FILES\CASE_A_63K			
DPC.dat	12/15/99	2:23p	2,797,099
rail.dat	12/15/99	2:24p	5,435,464
truck.dat	12/15/99	2:24p	239,924
Directory: SURFACESORT.EXE_FILES \OUTPUT_FILES\CASE_A_84K			
DPC.dat	12/15/99	2:20p	5,121,886
rail.dat	12/15/99	2:22p	5,772,904
truck.dat	12/15/99	2:22p	239,924

File Name	Date Transferred	Time of Transfer	File Size (bytes)
Directory: SURFACESORT.EXE_FILES \OUTPUT_FILES\CASE_B_63K			
DPC.dat	12/15/99	2:16p	2,793,705
rail.dat	12/15/99	2:18p	5,490,224
truck.dat	12/15/99	2:18p	260,750
Directory: SURFACESORT.EXE_FILES \OUTPUT_FILES\CASE_B_84K			
DPC.dat	12/15/99	2:14p	5,108,272
rail.dat	12/15/99	2:15p	5,828,206
truck.dat	12/15/99	2:16p	260,750
Directory: SURFACESORT.EXE_FILES \OUTPUT_FILES\CASE_C_63K			
DPC.dat	12/15/99	2:11p	2,801,742
rail.dat	12/15/99	2:12p	5,416,536
truck.dat	12/15/99	2:12p	236,689
Directory: SURFACESORT.EXE_FILES \OUTPUT_FILES\CASE_C_84K			
DPC.dat	12/15/99	2:08p	5,146,996
rail.dat	12/15/99	2:10p	5,753,697
truck.dat	12/15/99	2:10p	236,689
Directory: SURFACESORT.EXE_FILES \SOURCE_CODE			
Numberconverter.h	12/15/99	2:05p	432
SurfaceSort.c	12/15/99	2:05p	9,321
Directory: BIN.EXE_FILES \SOURCE_CODE			
bin.c	12/09/99	11:11a	142,765
bracketValue.h	12/09/99	11:11a	1,159
interpolate.h	12/09/99	11:11a	922
Numberconverter.h	12/09/99	11:11a	432
Directory: BIN.EXE_FILES \INPUT_FILES			
binInfo.source	01/26/00	3:54p	577
BWR.cobalt.source	01/26/00	3:54p	1,179,265
BWR.gamma.source	01/26/00	3:54p	33,331,668
BWR.neutron.source	01/26/00	3:44p	28,009,428
BWR.nuclide.source	01/26/00	3:36p	14,794,537
BWR.thermal.source	01/26/00	3:31p	1,654,333
BWRSS.cobalt.source	01/26/00	3:30p	89,328
BWRSS.gamma.source	01/26/00	3:30p	2,523,280
BWRSS.neutron.source	01/26/00	3:30p	2,120,080
BWRSS.nuclide.source	01/26/00	3:29p	1,120,788
BWRSS.thermal.source	01/26/00	3:29p	125,318
PWR.cobalt.source	01/26/00	3:29p	1,179,289
PWR.gamma.source	01/26/00	3:28p	33,335,988
PWR.neutron.source	01/26/00	3:18p	28,013,748
PWR.nuclide.source	01/21/00	4:43p	14,794,561
PWR.thermal.source	01/21/00	4:39p	1,654,357
PWRSS.cobalt.source	01/21/00	4:38p	446,640
PWRSS.gamma.source	01/21/00	4:38p	12,616,400
PWRSS.neutron.source	01/21/00	4:34p	10,600,400
PWRSS.nuclide.source	01/21/00	4:31p	5,603,940
PWRSS.thermal.source	01/21/00	4:29p	626,590
timeSteps.source	01/26/00	3:19p	879
Directory: BIN.EXE_FILES \INPUT_FILES\CONDITIONED_WASTESTREAM_FILES			
Case_A_63	01/26/00	5:01p	3,047,550
Case_A_84	01/26/00	5:00p	3,927,450
Case_B_63	01/26/00	4:59p	3,277,500
Case_B_84	01/26/00	4:58p	4,121,100
Case_C_63	01/26/00	4:57p	3,080,700
Case_C_84	01/26/00	4:56p	3,938,700

File Name	Date Transferred	Time of Transfer	File Size (bytes)
Directory: SPREADSHEET_FILES			
Case_A63_Characteristics.xls	02/07/00	4:02p	7,847,424
Case_A84_Characteristics.xls	02/07/00	4:07p	10,109,440
Case_B63_Characteristics.xls	02/07/00	4:06p	8,197,632
Case_B84_Characteristics.xls	02/07/00	3:34p	10,794,496
Case_C63_Characteristics.xls	02/07/00	3:39p	7,662,080
Case_C84_Characteristics.xls	02/07/00	3:59p	10,336,256
routine_check.xls	02/14/00	5:12p	20,419,072

8. REFERENCES

CRWMS M&O (Civilian Radioactive Waste Management System Management & Operating Contractor) 1996. *Software Qualification Report for the Spent Nuclear Fuel Decay Heat Function (SNFDHF).* 20026-2003, Rev. 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOV.19970212.0231.

CRWMS M&O 1997. *Waste Container Cavity Size Determination.* BBAA00000-01717-0200-00026 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980106.0061.

CRWMS M&O 1999a. *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel.* B00000000-01717-5700-00041 REV 00. Washington, D.C.: CRWMS M&O. ACC: MOV.19991006.0003.

CRWMS M&O 1999b. *BWR Source Term Generation and Evaluation.* BBAC00000-01717-0210-00006 REV 01. Las Vegas, NV: CRWMS M&O. ACC: MOL.20000113.0334.

CRWMS M&O 1999c. *PWR Source Term Generation and Evaluation.* BBAC00000-01717-0210-00010 REV 01. Las Vegas, NV: CRWMS. ACC: MOL.20000113.0333.

CRWMS M&O 1999d. *Transmittal of Site Recommendation Waste Streams.* Input Transmittal WP-SEV-99233.Ta. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990824.0138.

CRWMS M&O 1999e. *License Application Design Selection Feature Report: Aging and Blending.* B00000000-01717-2200-00217 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990407.0039.

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

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SYSTEM

1. Document Identifier No./Rev.: CAL-MGR-MD-000001 REV 00	Change: N/A	Title: Waste Packages and Source Terms for the Commercial 1999 Design Basis Waste Streams

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBVDue To		
2a.	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-Confirmed
1	CRWMS M&O 1997. *Waste Container Cavity Size Determination.* BBAA00000-01717-0200-00026 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980106.0061.	7	N/A - Not Critical	3,5	Waste package assembly basket requirements	N/A	N/A	N/A	N/A
5	YMP (Yucca Mountain Project) 1998. *Disposal Criticality Analysis Methodology Topical Report.* YMP/TR-004Q, Rev. 0. Las Vegas, Nevada: Yucca Mountain Site Characterization Office. ACC: MOL.19990210.0236.	5	N/A - Qualified/ Confirmed /Controlled	5	keffective loading curves for waste package designs	N/A	N/A	N/A	N/A
6	CRWMS M&O 1999. *Transmittal of Site Recommendation Waste Streams.* Input Transmittal WP-SEV-99233.Ta. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990824.0138.	Entire	N/A - Reference Only	Entire	Transmittal of detailed assembly characteristics and arrival years	N/A	N/A	N/A	N/A
7	CRWMS M&O 1999. *License Application Design Selection Feature Report: Aging and Blending.* B00000000-01717-2200-00217 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990407.0039.	3	N/A - Reference Only	5	General description of commercial waste package design types used for LADS Blending	N/A	N/A	N/A	N/A
8	CRWMS M&O 1996. *Software Qualification Report for the Spent Nuclear Fuel Decay Heat Function (SNFDHF).* 20026-2003, Rev. 0. Las Vegas, Nevada: CRWMS M&O. ACC: MOV.19970212.0231.	5.3.1	N/A - Reference Only	4.2.1	Validation of Power Log Equations	N/A	N/A	N/A	N/A

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
DOCUMENT INPUT REFERENCE SYSTEM

1. Document Identifier No./Rev.: CAL-MGR-MD-000001 REV 00	Change: N/A	Title: Waste Packages and Source Terms for the Commercial 1999 Design Basis Waste Streams

Input Document			4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBVDue To		
2a.	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-Confirmed
9	CRWMS M&O 1999. *1999 Design Basis Waste Input Report for Commercial Spent Nuclear Fuel*. B00000000-01717-5700-00041 REV 00. Washington, D.C.: CRWMS M&O. ACC: MOV.19991006.0003.	Appendix A	N/A - Reference Only	5	Description of waste arrival cases		N/A	N/A	N/A
		Appendix C	N/A - Reference Only	3	Canistered fuel characteristics		N/A	N/A	N/A
10	CRWMS M&O 1999. *BWR Source Term Generation and Evaluation*. BBAC00000-01717-0210-00006 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000113.0334.	5	N/A - Reference Only	3, 4, 5	Development of representative BWR assembly		N/A	N/A	N/A
		Attachment VII	TBV-4110	4, 5	BWR assembly thermal, cobalt, gamma, neutron, and nuclide source term files	2	X	N/A	N/A
		3	TBV-4108	3	Assumption 3.1 which states that representative assembly in the calculation can approximate other various BWR types	2	X	N/A	N/A
11	CRWMS M&O 1999. *PWR Source Term Generation and Evaluation*. BBAC00000-01717-0210-00010 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000113.0333.	5	N/A - Reference Only	3,4,5	Development of Representative PWR Assembly		N/A	N/A	N/A
		Attachment IV	TBV-4111	4,5	PWR assembly thermal, cobalt, gamma, neutron, and nuclide source term files	2	X	N/A	N/A
		3	TBV-4109	3	Assumption that representative assembly in the calculation can approximate other various PWR types	2	X	N/A	N/A

Spreadsheet Check of BIN.EXE Software Routine

Section 4.2.1 lists the following functions of BIN.EXE:

FUNCTION 1. For each assembly in the design basis waste stream, BIN.EXE looks up and interpolates or extrapolates, if necessary, source term values from source term input files extracted from CRWMS M&O (1999b, 1999c).

FUNCTION 2. Determine the WP design type that an assembly can be loaded into, based on coefficients for $k_{effective}$ criticality loading curves input into the software routine (see Section 5.1.1). Using a simple counter, the routine keeps track of the number of assemblies allocated to each WP design.

FUNCTION 3. Create average assembly heat generation curves for each WP design type. These curves are based on normalizing the heat generation curves for each assembly to the time of arrival. This is calculated by using the following four steps: (1) determining which WP design a group of assemblies will be loaded into, (2) calculating assembly heat output by summing the contributions from 4 assembly regions, (3) summing the calculated heat output for all assemblies that will be loaded into a specific WP design at each time step, and (4) dividing the sums at each time step by the number of assemblies in that WP design to determine the average heat output at each time step.

FUNCTION 4. Determine assembly averages for age, burnup, enrichment, and MTU for each WP design. Each of these items is determined by adding together the values for each assembly in a given WP design and then dividing by the number of assemblies.

Function Check

The checks for Functions 1 and 2, as listed above, were performed for 8 assemblies based on specific assemblies selected from the Case A, 84k MTU, waste stream. These assemblies have low, middle and high initial enrichments for zircaloy clad assemblies. For the stainless steel assemblies, as there are a limited amount, the assemblies chosen represent the middle values for initial enrichment. The assemblies chosen for this check are shown in Table II-1.

Table II-1. Assemblies for Check of Functions 1 and 2

Assembly Number	Type	Cladding Type	Initial Enrichment (% U-235)	Initial MTU	Burnup (GWd/MTU)	Age (time since reactor discharge) at Repository Arrival (years)	CALVIN Batch ID Number	Cask Load Number	Reactor Name
1	BWR	Zircaloy	0.70	0.185	4.000	42	4393	6894	LASALLE 2
2	BWR	Zircaloy	3.00	0.173	27.000	21	6668	1634	QUAD CITIES 1
3	BWR	Zircaloy	4.28	0.173	57.000	10	16362	9521	LIMERICK 2
4	PWR	Zircaloy	0.71	0.374	39.149	44	3740	6861	GINNA
5	PWR	Zircaloy	3.75	0.456	37.399	35	7315	7151	CATAWBA 2
6	PWR	Zircaloy	5.00	0.460	60.000	26	13242	10226	SEABROOK 1
7	BWR	Stainless Steel	3.71	0.110	5.000	23	4540	30	LACROSSE
8	PWR	Stainless Steel	4.00	0.411	26.000	25	5195	937	HADDAM NECK

For each assembly there are over 100 source terms that are looked up and interpolated or extrapolated. Assembly 1 requires an extrapolation for the enrichment plane, while all calculations for Assemblies 2 through 8 will be interpolations. For this check, selective points were chosen to check the 20 input source term files. These files are grouped into five areas: nuclides, heat generation, gamma, neutron, and cobalt-60. To ensure that each source file is read into the software routine correctly, assemblies with low, average, and high enrichments are evaluated. This checks that source terms, which are grouped in various burnup/enrichment combinations, are being properly read into the BIN.EXE routine. It should be noted that Section 4.2 explains the eight points, seven interpolations or extrapolations, and MTU ratio necessary to achieve the final source term value. The eight points represent:

Point 1: pre-time, pre-enrichment, pre-burnup
Point 2: pre-time, pre-enrichment, post-burnup
Point 3: pre-time, post-enrichment, pre-burnup
Point 4: pre-time, post-enrichment, post-burnup
Point 5: post-time, pre-enrichment, pre-burnup
Point 6: post-time, pre-enrichment, post-burnup
Point 7: post-time, post-enrichment, pre-burnup
Point 8: post-time, post-enrichment, post-burnup

Interpolations are performed between Points 1 and 2, then Points 3 and 4, then Points 5 and 6, and then Points 7 and 8. The resulting values can be considered a, b, c, and d, respectively. The second set of interpolations are interpolating between values a and b, then values c and d. The resulting values can be considered ab and cd, respectively. The final interpolation is between ab and cd, which results in the value at the MTU of the assembly used to generate the source terms. This value must then be adjusted, by simple MTU ratio, to achieve the final value for the assembly from the waste stream (see Assumptions 3.1 and 3.2).

Check of Function 1

Table II-2. Pre- and Post-Values

Assembly Number	Pre-Time	Post-Time	Pre-Enrichment	Post-Enrichment	Pre-Burnup	Post-Burnup
1	42	42	0.711	1.000	1.00	10.00
2	21	21	3.000	3.000	20.00	30.00
3	10	10	4.000	4.500	50.00	60.00
4	44	44	0.711	1.000	30.00	40.00
5	35	35	3.500	4.000	30.00	40.00
6	26	26	5.000	5.000	60.00	60.00
7	23	23	3.500	4.000	1.00	10.00
8	25	25	4.000	4.000	20.00	30.00

The pre- and post-values in Table II-2 represent actual burnup, enrichments and times that directly correlate with values presented in the source term files. The pre- and post-times reflect the age of the assemblies at the time of repository arrival. As the source term files contain the exact age of interest for times less than 100 years, it is not necessary to interpolate for time. The pre- and post-values in the table above are used to extract the source term values for Tables II-3, II-5, II-7, II-9 through II-14, II-22 through II-25, II-30, II-32 through II-35, and II-41.

Nuclide Check for Function 1

Table II-3. Values for Ac-227 at the Eight Points (curies)

Assembly Number	Ac-227 Value at Point 1	Ac-227 Value at Point 2	Ac-227 Value at Point 3	Ac-227 Value at Point 4	Ac-227 Value at Point 5	Ac-227 Value at Point 6	Ac-227 Value at Point 7	Ac-227 Value at Point 8	Source File
1	0	0	0	0	0	0	0	0	BWR.nuclide.source
2	0	0	0	0	0	0	0	0	BWR.nuclide.source
3	0	0	0	0	0	0	0	0	BWR.nuclide.source
4	0	0	0	0	0	0	0	0	PWR.nuclide.source
5	1.28E-05	1.51E-05	1.53E-05	1.82E-05	1.28E-05	1.51E-05	1.53E-05	1.82E-05	PWR.nuclide.source
6	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	PWR.nuclide.source
7	0	0	0	0	0	0	0	0	BWRSS.nuclide.source
8	0	1.19E-05	0	1.19E-05	0	1.19E-05	0	1.19E-05	PWRSS.nuclide.source

Table II-4. Values for Ac-227 for the Seven Interpolations (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	Final Ac-227 Value After MTU Ratio	Ac-227 Value from BIN.EXE[a]
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	1.45E-05	1.75E-05	1.45E-05	1.75E-05	1.60E-05	1.60E-05	1.60E-05	1.53E-05	1.53E-05
6	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.55E-05	2.47E-05	2.47E-05
7	0	0	0	0	0	0	0	0	0
8	5.95E-06	5.95E-06	5.95E-06	5.95E-06	5.95E-06	5.95E-06	5.95E-06	5.15E-06	5.15E-06

[a] The BIN.EXE values are extracted from the output file nuclide.dat for the Case A, 84k MTU waste stream.

Table II-5. Values for Ni-63 at the Eight Points (curies)

Assembly Number	Ni-63 Value at Point 1	Ni-63 Value at Point 2	Ni-63 Value at Point 3	Ni-63 Value at Point 4	Ni-63 Value at Point 5	Ni-63 Value at Point 6	Ni-63 Value at Point 7	Ni-63 Value at Point 8	Source File
1	3.87E+00	3.23E+01	3.05E+00	2.75E+01	3.87E+00	3.23E+01	3.05E+00	2.75E+01	BWR.nuclide.source
2	3.01E+01	4.84E+01	3.01E+01	4.84E+01	3.01E+01	4.84E+01	3.01E+01	4.84E+01	BWR.nuclide.source
3	7.75E+01	1.00E+02	6.89E+01	8.93E+01	7.75E+01	1.00E+02	6.89E+01	8.93E+01	BWR.nuclide.source
4	3.16E+02	3.90E+02	2.90E+02	3.65E+02	3.16E+02	3.90E+02	2.90E+02	3.65E+02	PWR.nuclide.source
5	1.53E+02	2.11E+02	1.37E+02	1.90E+02	1.53E+02	2.11E+02	1.37E+02	1.90E+02	PWR.nuclide.source
6	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	PWR.nuclide.source
7	1.17E+01	1.16E+02	1.04E+01	1.04E+02	1.17E+01	1.16E+02	1.04E+01	1.04E+02	BWRSS.nuclide.source
8	4.70E+02	7.19E+02	4.70E+02	7.19E+02	4.70E+02	7.19E+02	4.70E+02	7.19E+02	PWRSS.nuclide.source

Table II-6. Values for Ni-63 for the Seven Interpolations (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd - Final Ni-63 Value	Final Ni-63 Value After MTU Ratio	Ni-63 Value from BIN.EXE[a]
1	1.39E+01	1.15E+01	1.39E+01	1.15E+01	1.40E+01	1.40E+01	1.40E+01	1.30E+01	1.30E+01
2	4.28E+01	4.28E+01	4.28E+01	4.28E+01	4.28E+01	4.28E+01	4.28E+01	3.70E+01	3.70E+01
3	9.31E+01	8.30E+01	9.31E+01	8.30E+01	8.72E+01	8.72E+01	8.72E+01	7.53E+01	7.53E+01
4	3.84E+02	3.59E+02	3.84E+02	3.59E+02	3.84E+02	3.84E+02	3.84E+02	3.03E+02	3.03E+02
5	1.96E+02	1.76E+02	1.96E+02	1.76E+02	1.85E+02	1.85E+02	1.85E+02	1.78E+02	1.78E+02
6	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.71E+02	2.62E+02	2.62E+02
7	5.82E+01	5.20E+01	5.82E+01	5.20E+01	5.54E+01	5.54E+01	5.54E+01	3.05E+01	3.05E+01
8	6.19E+02	6.19E+02	6.19E+02	6.19E+02	6.19E+02	6.19E+02	6.19E+02	5.35E+02	5.35E+02

[a] The BIN.EXE values are extracted from the output file nuclide.dat for the Case A, 84k MTU waste stream.

Table II-7. Values for Zr-93 at The Eight Points (curies)

Assembly Number	Zr-93 Value at Point 1	Zr-93 Value at Point 2	Zr-93 Value at Point 3	Zr-93 Value at Point 4	Zr-93 Value at Point 5	Zr-93 Value at Point 6	Zr-93 Value at Point 7	Zr-93 Value at Point 8	Source File
1	1.07E-02	9.01E-02	1.05E-02	9.09E-02	1.07E-02	9.01E-02	1.05E-02	9.09E-02	BWR.nuclide.source
2	1.79E-01	2.59E-01	1.79E-01	2.59E-01	1.79E-01	2.59E-01	1.79E-01	2.59E-01	BWR.nuclide.source
3	4.16E-01	4.88E-01	4.20E-01	4.93E-01	4.16E-01	4.88E-01	4.20E-01	4.93E-01	BWR.nuclide.source
4	5.07E-01	6.47E-01	5.18E-01	6.61E-01	5.07E-01	6.47E-01	5.18E-01	6.61E-01	PWR.nuclide.source
5	5.85E-01	7.51E-01	5.92E-01	7.63E-01	5.85E-01	7.51E-01	5.92E-01	7.63E-01	PWR.nuclide.source
6	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	PWR.nuclide.source
7	8.37E-03	7.96E-02	8.42E-03	8.06E-02	8.37E-03	7.96E-02	8.42E-03	8.06E-02	BWRSS.nuclide.source
8	3.69E-01	5.30E-01	3.69E-01	5.30E-01	3.69E-01	5.30E-01	3.69E-01	5.30E-01	PWRSS.nuclide.source

Table II-8. Values for Zr-93 for the Seven Interpolations (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd - Final Zr-93 Value	Final Zr-93 Value After MTU Ratio	Zr-93 Value from BIN.EXE[a]
1	3.86E-02	3.85E-02	3.86E-02	3.85E-02	3.86E-02	3.86E-02	3.86E-02	3.57E-02	3.57E-02
2	2.35E-01	2.35E-01	2.35E-01	2.35E-01	2.35E-01	2.35E-01	2.35E-01	2.04E-01	2.04E-01
3	4.67E-01	4.71E-01	4.67E-01	4.71E-01	4.69E-01	4.69E-01	4.69E-01	4.05E-01	4.05E-01
4	6.35E-01	6.49E-01	6.35E-01	6.49E-01	6.35E-01	6.35E-01	6.35E-01	5.01E-01	5.01E-01
5	7.08E-01	7.19E-01	7.08E-01	7.19E-01	7.14E-01	7.14E-01	7.14E-01	6.85E-01	6.85E-01
6	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.11E+00	1.07E+00	1.07E+00
7	4.04E-02	4.08E-02	4.04E-02	4.08E-02	4.06E-02	4.06E-02	4.06E-02	2.23E-02	2.23E-02
8	4.66E-01	4.66E-01	4.66E-01	4.66E-01	4.66E-01	4.66E-01	4.66E-01	4.04E-01	4.04E-01

[a] The BIN.EXE values are extracted from the output file nuclide.dat for the Case A, 84k MTU waste stream.

Heat Generation Rate Check for Function 1

Table II-9. Values for Heat Generation Rates at the Eight Points - FUEL REGION - LIGHT ELEMENTS (watts)

Assembly Number	Heat Generation Rate Value at Point 1	Heat Generation Rate Value at Point 2	Heat Generation Rate Value at Point 3	Heat Generation Rate Value at Point 4	Heat Generation Rate Value at Point 5	Heat Generation Rate Value at Point 6	Heat Generation Rate Value at Point 7	Heat Generation Rate Value at Point 8	Source File
1	2.48E-03	1.89E-02	1.99E-03	1.65E-02	2.48E-03	1.89E-02	1.99E-03	1.65E-02	BWR.thermal.source
2	2.33E-01	3.40E-01	2.33E-01	3.40E-01	2.33E-01	3.40E-01	2.33E-01	3.40E-01	BWR.thermal.source
3	1.91E+00	2.26E+00	1.75E+00	2.08E+00	1.91E+00	2.26E+00	1.75E+00	2.08E+00	BWR.thermal.source
4	4.45E-01	5.26E-01	4.16E-01	5.00E-01	4.45E-01	5.26E-01	4.16E-01	5.00E-01	PWR.thermal.source
5	7.40E-01	9.65E-01	6.80E-01	8.89E-01	7.40E-01	9.65E-01	6.80E-01	8.89E-01	PWR.thermal.source
6	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00	PWR.thermal.source
7	3.06E-01	2.71E+00	2.78E-01	2.49E+00	3.06E-01	2.71E+00	2.78E-01	2.49E+00	BWRSS.thermal.source
8	6.81E+00	9.86E+00	6.81E+00	9.86E+00	6.81E+00	9.86E+00	6.81E+00	9.86E+00	PWRSS.thermal.source

In the software routine, there are six separate heat generation rates that are looked up and interpolated between, then are added together for the final heat calculation. In this check, the numbers presented at each point are the sum of the six heat generation rates which will be used for the calculation in this check.

Table II-10. Values for Heat Generation Rates at the Eight Points - FUEL REGION - ACTINIDES (watts)

Assembly Number	Heat Generation Rate Value at Point 1	Heat Generation Rate Value at Point 2	Heat Generation Rate Value at Point 3	Heat Generation Rate Value at Point 4	Heat Generation Rate Value at Point 5	Heat Generation Rate Value at Point 6	Heat Generation Rate Value at Point 7	Heat Generation Rate Value at Point 8	Source File
1	7.22E-01	1.42E+01	5.62E-01	1.26E+01	7.22E-01	1.42E+01	5.62E-01	1.26E+01	BWR.thermal.source
2	1.73E+01	3.40E+01	1.73E+01	3.40E+01	1.73E+01	3.40E+01	1.73E+01	3.40E+01	BWR.thermal.source
3	8.53E+01	1.38E+02	7.69E+01	1.23E+02	8.53E+01	1.38E+02	7.69E+01	1.23E+02	BWR.thermal.source
4	1.35E+02	1.95E+02	1.30E+02	1.89E+02	1.35E+02	1.95E+02	1.30E+02	1.89E+02	PWR.thermal.source
5	9.51E+01	1.50E+02	8.98E+01	1.43E+02	9.51E+01	1.50E+02	8.98E+01	1.43E+02	PWR.thermal.source
6	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02	PWR.thermal.source
7	2.56E-01	5.96E+00	2.38E-01	5.39E+00	2.56E-01	5.96E+00	2.38E-01	5.39E+00	BWRSS.thermal.source
8	4.85E+01	9.63E+01	4.85E+01	9.63E+01	4.85E+01	9.63E+01	4.85E+01	9.63E+01	PWRSS.thermal.source

Table II-11. Values for Heat Generation Rates at the Eight Points - FUEL REGION - FISSION PRODUCTS (watts)

Assembly Number	Heat Generation Rate Value at Point 1	Heat Generation Rate Value at Point 2	Heat Generation Rate Value at Point 3	Heat Generation Rate Value at Point 4	Heat Generation Rate Value at Point 5	Heat Generation Rate Value at Point 6	Heat Generation Rate Value at Point 7	Heat Generation Rate Value at Point 8	Source File
1	2.36E+00	2.10E+01	2.47E+00	2.21E+01	2.36E+00	2.10E+01	2.47E+00	2.21E+01	BWR.thermal.source
2	7.98E+01	1.14E+02	7.98E+01	1.14E+02	7.98E+01	1.14E+02	7.98E+01	1.14E+02	BWR.thermal.source
3	2.52E+02	2.90E+02	2.56E+02	2.95E+02	2.52E+02	2.90E+02	2.56E+02	2.95E+02	BWR.thermal.source
4	1.30E+02	1.66E+02	1.35E+02	1.72E+02	1.30E+02	1.66E+02	1.35E+02	1.72E+02	PWR.thermal.source
5	2.00E+02	2.55E+02	2.04E+02	2.60E+02	2.00E+02	2.55E+02	2.04E+02	2.60E+02	PWR.thermal.source
6	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02	PWR.thermal.source
7	4.23E+00	4.00E+01	4.25E+00	4.04E+01	4.23E+00	4.00E+01	4.25E+00	4.04E+01	BWRSS.thermal.source
8	1.78E+02	2.57E+02	1.78E+02	2.57E+02	1.78E+02	2.57E+02	1.78E+02	2.57E+02	PWRSS.thermal.source

Table II-12. Values for Heat Generation Rates at the Eight Points - BOTTOM END-FITTING REGION - LIGHT ELEMENTS (watts)

Assembly Number	Heat Generation Rate Value at Point 1	Heat Generation Rate Value at Point 2	Heat Generation Rate Value at Point 3	Heat Generation Rate Value at Point 4	Heat Generation Rate Value at Point 5	Heat Generation Rate Value at Point 6	Heat Generation Rate Value at Point 7	Heat Generation Rate Value at Point 8	Source File
1	6.31E-04	5.58E-03	5.06E-04	4.86E-03	6.31E-04	5.58E-03	5.06E-04	4.86E-03	BWR.thermal.source
2	6.55E-02	9.74E-02	6.55E-02	9.74E-02	6.55E-02	9.74E-02	6.55E-02	9.74E-02	BWR.thermal.source
3	5.07E-01	5.97E-01	4.67E-01	5.51E-01	5.07E-01	5.97E-01	4.67E-01	5.51E-01	BWR.thermal.source
4	5.49E-02	6.52E-02	5.12E-02	6.19E-02	5.49E-02	6.52E-02	5.12E-02	6.19E-02	PWR.thermal.source
5	8.94E-02	1.17E-01	8.21E-02	1.08E-01	8.94E-02	1.17E-01	8.21E-02	1.08E-01	PWR.thermal.source
6	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	PWR.thermal.source
7	2.28E-03	2.26E-02	2.07E-03	2.07E-02	2.28E-03	2.26E-02	2.07E-03	2.07E-02	BWRSS.thermal.source
8	2.04E-01	3.00E-01	2.04E-01	3.00E-01	2.04E-01	3.00E-01	2.04E-01	3.00E-01	PWRSS.thermal.source

Table II-13. Values for Heat Generation Rates at the Eight Points - PLENUM REGION - LIGHT ELEMENTS (watts)

Assembly Number	Heat Generation Rate Value at Point 1	Heat Generation Rate Value at Point 2	Heat Generation Rate Value at Point 3	Heat Generation Rate Value at Point 4	Heat Generation Rate Value at Point 5	Heat Generation Rate Value at Point 6	Heat Generation Rate Value at Point 7	Heat Generation Rate Value at Point 8	Source File
1	3.68E-03	2.77E-02	2.95E-03	2.40E-02	3.68E-03	2.77E-02	2.95E-03	2.40E-02	BWR.thermal.source
2	3.43E-01	5.02E-01	3.43E-01	5.02E-01	3.43E-01	5.02E-01	3.43E-01	5.02E-01	BWR.thermal.source
3	2.75E+00	3.27E+00	2.50E+00	2.99E+00	2.75E+00	3.27E+00	2.50E+00	2.99E+00	BWR.thermal.source
4	2.79E-02	3.30E-02	2.61E-02	3.14E-02	2.79E-02	3.30E-02	2.61E-02	3.14E-02	PWR.thermal.source
5	4.64E-02	6.05E-02	4.26E-02	5.57E-02	4.64E-02	6.05E-02	4.26E-02	5.57E-02	PWR.thermal.source
6	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	PWR.thermal.source
7	2.12E-02	1.90E-01	1.92E-02	1.74E-01	2.12E-02	1.90E-01	1.92E-02	1.74E-01	BWRSS.thermal.source
8	2.52E-01	3.65E-01	2.52E-01	3.65E-01	2.52E-01	3.65E-01	2.52E-01	3.65E-01	PWRSS.thermal.source

Table II-14. Values for Heat Generation Rates at the Eight Points - TOP END-FITTING REGION - LIGHT ELEMENTS (watts)

Assembly Number	Heat Generation Rate Value at Point 1	Heat Generation Rate Value at Point 2	Heat Generation Rate Value at Point 3	Heat Generation Rate Value at Point 4	Heat Generation Rate Value at Point 5	Heat Generation Rate Value at Point 6	Heat Generation Rate Value at Point 7	Heat Generation Rate Value at Point 8	Source File
1	7.82E-04	6.64E-03	6.27E-04	5.78E-03	7.82E-04	6.64E-03	6.27E-04	5.78E-03	BWR.thermal.source
2	8.02E-02	1.19E-01	8.02E-02	1.19E-01	8.02E-02	1.19E-01	8.02E-02	1.19E-01	BWR.thermal.source
3	6.22E-01	7.32E-01	5.73E-01	6.75E-01	6.22E-01	7.32E-01	5.73E-01	6.75E-01	BWR.thermal.source
4	3.52E-02	4.18E-02	3.28E-02	3.97E-02	3.52E-02	4.18E-02	3.28E-02	3.97E-02	PWR.thermal.source
5	5.75E-02	7.51E-02	5.28E-02	6.91E-02	5.75E-02	7.51E-02	5.28E-02	6.91E-02	PWR.thermal.source
6	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	PWR.thermal.source
7	2.90E-03	2.81E-02	2.63E-03	2.57E-02	2.90E-03	2.81E-02	2.63E-03	2.57E-02	BWRSS.thermal.source
8	1.31E-01	1.93E-01	1.31E-01	1.93E-01	1.31E-01	1.93E-01	1.31E-01	1.93E-01	PWRSS.thermal.source

Table II-15. Heat Generation Rates for the Seven Interpolations - FUEL REGION - LIGHT ELEMENTS (watts)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd
1	8.42E-03	7.11E-03	8.42E-03	7.11E-03	8.49E-03	8.49E-03	8.49E-03
2	3.08E-01	3.08E-01	3.08E-01	3.08E-01	3.08E-01	3.08E-01	3.08E-01
3	2.16E+00	1.98E+00	2.16E+00	1.98E+00	2.05E+00	2.05E+00	2.05E+00
4	5.19E-01	4.93E-01	5.19E-01	4.93E-01	5.20E-01	5.20E-01	5.20E-01
5	9.07E-01	8.35E-01	9.07E-01	8.35E-01	8.69E-01	8.69E-01	8.69E-01
6	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00	3.61E+00
7	1.41E+00	1.29E+00	1.41E+00	1.29E+00	1.35E+00	1.35E+00	1.35E+00
8	8.65E+00	8.65E+00	8.65E+00	8.65E+00	8.65E+00	8.65E+00	8.65E+00

Table II-16. Heat Generation Rates for the Seven Interpolations - FUEL REGION - ACTINIDES (watts)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd
1	4.34E+00	3.66E+00	4.34E+00	3.66E+00	4.37E+00	4.37E+00	4.37E+00
2	2.85E+01	2.85E+01	2.85E+01	2.85E+01	2.85E+01	2.85E+01	2.85E+01
3	1.21E+02	1.08E+02	1.21E+02	1.08E+02	1.13E+02	1.13E+02	1.13E+02
4	1.90E+02	1.84E+02	1.90E+02	1.84E+02	1.90E+02	1.90E+02	1.90E+02
5	1.35E+02	1.28E+02	1.35E+02	1.28E+02	1.31E+02	1.31E+02	1.31E+02
6	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02	2.85E+02
7	2.31E+00	2.11E+00	2.31E+00	2.11E+00	2.22E+00	2.22E+00	2.22E+00
8	7.56E+01	7.56E+01	7.56E+01	7.56E+01	7.56E+01	7.56E+01	7.56E+01

Table II-17. Heat Generation Rates for the Seven Interpolations - FUEL REGION - FISSION PRODUCTS (watts)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd
1	8.80E+00	9.24E+00	8.80E+00	9.24E+00	8.78E+00	8.78E+00	8.78E+00
2	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02	1.04E+02
3	2.79E+02	2.83E+02	2.79E+02	2.83E+02	2.81E+02	2.81E+02	2.81E+02
4	1.63E+02	1.69E+02	1.63E+02	1.69E+02	1.63E+02	1.63E+02	1.63E+02
5	2.41E+02	2.46E+02	2.41E+02	2.46E+02	2.43E+02	2.43E+02	2.43E+02
6	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02	4.69E+02
7	2.03E+01	2.05E+01	2.03E+01	2.05E+01	2.04E+01	2.04E+01	2.04E+01
8	2.26E+02	2.26E+02	2.26E+02	2.26E+02	2.26E+02	2.26E+02	2.26E+02

Table II-18. Heat Generation Rates for the Seven Interpolations - BOTTOM END-FITTING REGION - LIGHT ELEMENTS (watts)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd
1	2.34E-03	1.98E-03	2.34E-03	1.98E-03	2.36E-03	2.36E-03	2.36E-03
2	8.79E-02	8.79E-02	8.79E-02	8.79E-02	8.79E-02	8.79E-02	8.79E-02
3	5.70E-01	5.26E-01	5.70E-01	5.26E-01	5.44E-01	5.44E-01	5.44E-01
4	6.44E-02	6.10E-02	6.44E-02	6.10E-02	6.44E-02	6.44E-02	6.44E-02
5	1.10E-01	1.01E-01	1.10E-01	1.01E-01	1.05E-01	1.05E-01	1.05E-01
6	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01	4.37E-01
7	1.13E-02	1.04E-02	1.13E-02	1.04E-02	1.09E-02	1.09E-02	1.09E-02
8	2.62E-01	2.62E-01	2.62E-01	2.62E-01	2.62E-01	2.62E-01	2.62E-01

Table II-19. Heat Generation Rates for the Seven Interpolations - PLENUM REGION - LIGHT ELEMENTS (watts)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd
1	1.24E-02	1.04E-02	1.24E-02	1.04E-02	1.25E-02	1.25E-02	1.25E-02
2	4.55E-01	4.55E-01	4.55E-01	4.55E-01	4.55E-01	4.55E-01	4.55E-01
3	3.11E+00	2.84E+00	3.11E+00	2.84E+00	2.96E+00	2.96E+00	2.96E+00
4	3.26E-02	3.10E-02	3.26E-02	3.10E-02	3.26E-02	3.26E-02	3.26E-02
5	5.69E-02	5.23E-02	5.69E-02	5.23E-02	5.45E-02	5.45E-02	5.45E-02
6	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01	2.26E-01
7	9.82E-02	8.96E-02	9.82E-02	8.96E-02	9.43E-02	9.43E-02	9.43E-02
8	3.20E-01	3.20E-01	3.20E-01	3.20E-01	3.20E-01	3.20E-01	3.20E-01

Table II-20. Heat Generation Rates for the Seven Interpolations - TOP END-FITTING REGION - LIGHT ELEMENTS (watts)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd
1	2.83E-03	2.39E-03	2.83E-03	2.39E-03	2.86E-03	2.86E-03	2.86E-03
2	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01	1.07E-01
3	6.99E-01	6.45E-01	6.99E-01	6.45E-01	6.67E-01	6.67E-01	6.67E-01
4	4.13E-02	3.91E-02	4.13E-02	3.91E-02	4.13E-02	4.13E-02	4.13E-02
5	7.06E-02	6.49E-02	7.06E-02	6.49E-02	6.76E-02	6.76E-02	6.76E-02
6	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01	2.81E-01
7	1.42E-02	1.29E-02	1.42E-02	1.29E-02	1.36E-02	1.36E-02	1.36E-02
8	1.68E-01	1.68E-01	1.68E-01	1.68E-01	1.68E-01	1.68E-01	1.68E-01

Table II-21. Heat Generation Rate Final Values (watts)

Assembly Number	Heat from Fuel Region Light Elements	Heat from Fuel Region Actinides	Heat from Fuel Region Fission Products	Heat from Bottom End-Fitting Region Light Elements	Heat from Plenum Region Light Elements	Heat from Top End-Fitting Region Light Elements	Total Heat	Heat After MTU Ratio - FINAL Heat Value	BIN.EXE Heat Value[a]
1	0.01	4.37	8.78	0.00	0.01	0.00	13.18	12.19	12.19
2	0.31	28.53	103.91	0.09	0.45	0.11	133.39	115.38	115.38
3	2.05	113.03	281.45	0.54	2.96	0.67	400.70	346.16	346.16
4	0.52	189.74	162.97	0.06	0.03	0.04	353.37	278.42	278.42
5	0.87	131.40	243.37	0.11	0.05	0.07	375.87	360.72	360.72
6	3.61	285.00	469.00	0.44	0.23	0.28	758.55	734.00	734.00
7	1.35	2.22	20.41	0.01	0.09	0.01	24.10	13.26	13.26
8	8.65	75.60	225.75	0.26	0.32	0.17	310.75	268.88	268.88

[a] The BIN.EXE values are extracted from the output file bin.dat for the Case A, 84k MTU waste stream.

Gamma Check for Function 1

BIN.EXE calculates 18 energy bands for gamma radiation. For each energy band, the software routine interpolates values for four assembly regions and outputs values for each region. One mid-level energy band, 0.8 to 1.0 MeV, will be evaluated for each of the eight assemblies for each of the four assembly regions.

Table II-22. Values for 0.8 to 1.0 MeV Energy Band at the Eight Points - FUEL REGION (photons/s)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	2.36E+10	2.46E+11	2.49E+10	2.56E+11	2.36E+10	2.46E+11	2.49E+10	2.56E+11	BWR.gamma.source
2	1.70E+12	2.98E+12	1.70E+12	2.98E+12	1.70E+12	2.98E+12	1.70E+12	2.98E+12	BWR.gamma.source
3	3.07E+13	3.92E+13	2.95E+13	3.80E+13	3.07E+13	3.92E+13	2.95E+13	3.80E+13	BWR.gamma.source
4	1.91E+12	2.58E+12	1.97E+12	2.68E+12	1.91E+12	2.58E+12	1.97E+12	2.68E+12	PWR.gamma.source
5	3.36E+12	4.74E+12	3.35E+12	4.76E+12	3.36E+12	4.74E+12	3.35E+12	4.76E+12	PWR.gamma.source
6	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	PWR.gamma.source
7	4.62E+10	6.05E+11	4.63E+10	5.99E+11	4.62E+10	6.05E+11	4.63E+10	5.99E+11	BWRSS.gamma.source
8	3.40E+12	6.11E+12	3.40E+12	6.11E+12	3.40E+12	6.11E+12	3.40E+12	6.11E+12	PWRSS.gamma.source

Table II-23. Values for 0.8 to 1.0 MeV Energy Band at the Eight Points - BOTTOM REGION (photons/s)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	7.28E+06	1.16E+09	5.26E+06	1.05E+09	7.28E+06	1.16E+09	5.26E+06	1.05E+09	BWR.gamma.source
2	1.22E+10	1.97E+10	1.22E+10	1.97E+10	1.22E+10	1.97E+10	1.22E+10	1.97E+10	BWR.gamma.source
3	6.56E+10	6.49E+10	6.81E+10	6.81E+10	6.56E+10	6.49E+10	6.81E+10	6.81E+10	BWR.gamma.source
4	1.96E+09	2.52E+09	1.86E+09	2.42E+09	1.96E+09	2.52E+09	1.86E+09	2.42E+09	PWR.gamma.source
5	1.27E+09	1.74E+09	1.21E+09	1.65E+09	1.27E+09	1.74E+09	1.21E+09	1.65E+09	PWR.gamma.source
6	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	PWR.gamma.source
7	6.89E+06	2.70E+09	6.06E+06	2.50E+09	6.89E+06	2.70E+09	6.06E+06	2.50E+09	BWRSS.gamma.source
8	8.06E+08	1.24E+09	8.06E+08	1.24E+09	8.06E+08	1.24E+09	8.06E+08	1.24E+09	PWRSS.gamma.source

Table II-24. Values for 0.8 to 1.0 MeV Energy Band at the Eight Points - PLENUM REGION (photons/s)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	3.00E+07	1.33E+09	2.42E+07	1.20E+09	3.00E+07	1.33E+09	2.42E+07	1.20E+09	BWR.gamma.source
2	1.24E+10	2.01E+10	1.24E+10	2.01E+10	1.24E+10	2.01E+10	1.24E+10	2.01E+10	BWR.gamma.source
3	6.61E+10	6.55E+10	6.84E+10	6.86E+10	6.61E+10	6.55E+10	6.84E+10	6.86E+10	BWR.gamma.source
4	1.57E+09	2.01E+09	1.49E+09	1.93E+09	1.57E+09	2.01E+11	1.49E+09	1.93E+09	PWR.gamma.source
5	1.01E+09	1.38E+09	9.60E+08	1.31E+09	1.01E+09	1.38E+09	9.60E+08	1.31E+09	PWR.gamma.source
6	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	PWR.gamma.source
7	4.66E+07	3.44E+09	4.30E+07	3.18E+09	4.66E+07	3.44E+09	4.30E+07	3.18E+09	BWRSS.gamma.source
8	7.04E+08	1.08E+09	7.04E+08	1.08E+09	7.04E+08	1.08E+09	7.04E+08	1.08E+09	PWRSS.gamma.source

Table II-25. Values for 0.8 to 1.0 MeV Energy Band at the Eight Points - TOP REGION (photons/s)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	1.12E+07	1.19E+09	8.56E+06	1.08E+09	1.12E+07	1.19E+09	8.56E+06	1.08E+09	BWR.gamma.source
2	1.22E+10	1.98E+10	1.22E+10	1.98E+10	1.22E+10	1.98E+10	1.22E+10	1.98E+10	BWR.gamma.source
3	6.54E+10	6.47E+10	6.78E+10	6.78E+10	6.54E+10	6.47E+10	6.78E+10	6.78E+10	BWR.gamma.source
4	1.36E+09	1.74E+09	1.29E+09	1.67E+09	1.36E+09	1.74E+09	1.29E+09	1.67E+09	PWR.gamma.source
5	8.80E+08	1.20E+09	8.35E+08	1.14E+09	8.80E+08	1.20E+09	8.35E+08	1.14E+09	PWR.gamma.source
6	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	PWR.gamma.source
7	8.65E+06	2.71E+09	7.70E+06	2.52E+09	8.65E+06	2.71E+09	7.70E+06	2.52E+09	BWRSS.gamma.source
8	5.57E+08	8.59E+08	5.57E+08	8.59E+08	5.57E+08	8.59E+08	5.57E+08	8.59E+08	PWRSS.gamma.source

Table II-26. Values for 0.8 to 1.0 MeV Energy Band for the Seven Interpolations - FUEL REGION (photons/s)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	9.68E+10	1.01E+11	9.68E+10	1.01E+11	9.66E+10	9.66E+10	9.66E+10	8.93E+10	8.93E+10
2	2.58E+12	2.58E+12	2.58E+12	2.58E+12	2.58E+12	2.58E+12	2.58E+12	2.23E+12	2.23E+12
3	3.66E+13	3.54E+13	3.66E+13	3.54E+13	3.59E+13	3.59E+13	3.59E+13	3.10E+13	3.10E+13
4	2.52E+12	2.62E+12	2.52E+12	2.62E+12	2.52E+12	2.52E+12	2.52E+12	1.99E+12	1.99E+12
5	4.37E+12	4.38E+12	4.37E+12	4.38E+12	4.38E+12	4.38E+12	4.38E+12	4.20E+12	4.20E+12
6	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.33E+13	1.29E+13	1.29E+13
7	2.79E+11	2.77E+11	2.79E+11	2.77E+11	2.78E+11	2.78E+11	2.78E+11	1.53E+11	1.53E+11
8	4.97E+12	4.97E+12	4.97E+12	4.97E+12	4.97E+12	4.97E+12	4.97E+12	4.30E+12	4.30E+12

[a] The BIN.EXE values are extracted from the output file gamma.dat for the Case A, 84k MTU waste stream.

Table II-27. Values for 0.8 to 1.0 MeV Energy Band for the Seven Interpolations - BOTTOM REGION (photons/s)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	1.54E+08	1.28E+08	1.54E+08	1.28E+08	1.56E+08	1.56E+08	1.56E+08	1.44E+08	1.44E+08
2	1.74E+10	1.74E+10	1.74E+10	1.74E+10	1.74E+10	1.74E+10	1.74E+10	1.50E+10	1.50E+10
3	6.51E+10	6.81E+10	6.51E+10	6.81E+10	6.68E+10	6.68E+10	6.68E+10	5.77E+10	5.77E+10
4	2.47E+09	2.37E+09	2.47E+09	2.37E+09	2.47E+09	2.47E+09	2.47E+09	1.95E+09	1.95E+09
5	1.62E+09	1.53E+09	1.62E+09	1.53E+09	1.57E+09	1.57E+09	1.57E+09	1.51E+09	1.51E+09
6	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.43E+09	2.35E+09	2.35E+09
7	4.47E+08	4.08E+08	4.47E+08	4.08E+08	4.30E+08	4.30E+08	4.30E+08	2.36E+08	2.36E+08
8	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09	1.07E+09	9.22E+08	9.22E+08

[a] The BIN.EXE values are extracted from the output file gamma.dat for the Case A, 84k MTU waste stream.

Table II-28. Values for 0.8 to 1.0 MeV Energy Band for the Seven Interpolations - PLENUM REGION (photons/s)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	2.94E+08	2.54E+08	2.94E+08	2.54E+08	2.96E+08	2.96E+08	2.96E+08	2.74E+08	2.74E+08
2	1.77E+10	1.77E+10	1.77E+10	1.77E+10	1.77E+10	1.77E+10	1.77E+10	1.53E+10	1.53E+10
3	6.57E+10	6.85E+10	6.57E+10	6.85E+10	6.73E+10	6.73E+10	6.73E+10	5.81E+10	5.81E+10
4	1.97E+09	1.89E+09	1.97E+09	1.89E+09	1.97E+09	1.97E+09	1.97E+09	1.55E+09	1.55E+09
5	1.28E+09	1.22E+09	1.28E+09	1.22E+09	1.25E+09	1.25E+09	1.25E+09	1.20E+09	1.20E+09
6	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.92E+09	1.86E+09	1.86E+09
7	9.42E+08	8.71E+08	9.42E+08	8.71E+08	9.10E+08	9.10E+08	9.10E+08	5.01E+08	5.01E+08
8	9.29E+08	9.29E+08	9.29E+08	9.29E+08	9.29E+08	9.29E+08	9.29E+08	8.03E+08	8.03E+08

[a] The BIN.EXE values are extracted from the output file gamma.dat for the Case A, 84k MTU waste stream.

Table II-29. Values for 0.8 to 1.0 MeV Energy Band for the Seven Interpolations - TOP REGION (photons/s)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	1.86E+08	1.58E+08	1.86E+08	1.58E+08	1.87E+08	1.87E+08	1.87E+08	1.73E+08	1.73E+08
2	1.75E+10	1.75E+10	1.75E+10	1.75E+10	1.75E+10	1.75E+10	1.75E+10	1.51E+10	1.51E+10
3	6.49E+10	6.78E+10	6.49E+10	6.78E+10	6.65E+10	6.65E+10	6.65E+10	5.75E+10	5.75E+10
4	1.71E+09	1.64E+09	1.71E+09	1.64E+09	1.71E+09	1.71E+09	1.71E+09	1.35E+09	1.35E+09
5	1.12E+09	1.06E+09	1.12E+09	1.06E+09	1.09E+09	1.09E+09	1.09E+09	1.04E+09	1.04E+09
6	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.68E+09	1.63E+09	1.63E+09
7	4.80E+08	4.41E+08	4.80E+08	4.41E+08	4.63E+08	4.63E+08	4.63E+08	2.55E+08	2.55E+08
8	7.37E+08	7.37E+08	7.37E+08	7.37E+08	7.37E+08	7.37E+08	7.37E+08	6.38E+08	6.38E+08

[a] The BIN.EXE values are extracted from the output file gamma.dat for the Case A, 84k MTU waste stream.

Neutron Check for Function 1

BIN.EXE calculates 27 energy bands for neutron radiation. One mid-level energy band, 0.1 to 0.4 MeV, will be evaluated for each of the eight assemblies. It should be noted that all values for energy bands below 0.1 are zero in the BIN.EXE output files. These zero values were checked by visual examination of the neutron source term files.

Table II-30. Values for 0.1 to 0.4 MeV Energy Band at the Eight Points (neutrons/s)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	7.22E+02	4.27E+04	5.35E+02	2.89E+04	7.22E+02	4.27E+04	5.35E+02	2.89E+04	BWR.neutron.source
2	1.00E+05	6.24E+05	1.00E+05	6.24E+05	1.00E+05	6.24E+05	1.00E+05	6.24E+05	BWR.neutron.source
3	5.00E+06	1.09E+07	3.85E+06	8.64E+06	5.00E+06	1.09E+07	3.85E+06	8.64E+06	BWR.neutron.source
4	4.80E+06	1.09E+07	3.87E+06	9.34E+06	4.80E+06	1.09E+07	3.87E+06	9.34E+06	PWR.neutron.source
5	9.01E+05	3.07E+06	6.77E+05	2.36E+06	9.01E+05	3.07E+06	6.77E+05	2.36E+06	PWR.neutron.source
6	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	PWR.neutron.source
7	2.06E+02	7.34E+03	1.90E+02	6.08E+03	2.06E+02	7.34E+03	1.90E+02	6.08E+03	BWRSS.neutron.source
8	1.81E+05	1.10E+06	1.81E+05	1.10E+06	1.81E+05	1.10E+06	1.81E+05	1.10E+06	PWRSS.neutron.source

Table II-31. Values for 0.1 to 0.4 MeV Energy Band for the Seven Interpolations (neutrons/s)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	8.42E+03	5.91E+03	8.42E+03	5.91E+03	8.56E+03	8.56E+03	8.56E+03	7.92E+03	7.92E+03
2	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.88E+05	3.35E+05	3.35E+05
3	8.75E+06	6.88E+06	8.75E+06	6.88E+06	7.62E+06	7.62E+06	7.62E+06	6.59E+06	6.59E+06
4	1.03E+07	8.74E+06	1.03E+07	8.74E+06	1.03E+07	1.03E+07	1.03E+07	8.08E+06	8.08E+06
5	2.31E+06	1.76E+06	2.31E+06	1.76E+06	2.01E+06	2.01E+06	2.01E+06	1.93E+06	1.93E+06
6	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.16E+07	1.12E+07	1.12E+07
7	2.50E+03	2.14E+03	2.50E+03	2.14E+03	2.34E+03	2.34E+03	2.34E+03	1.29E+03	1.29E+03
8	5.82E+05	5.82E+05	5.82E+05	5.82E+05	5.82E+05	5.82E+05	5.82E+05	5.03E+05	5.03E+05

[a] The BIN.EXE values are extracted from the output file neutron.dat for the Case A, 84k MTU waste stream.

Cobalt-60 Check for Function 1

BIN.EXE calculates the cobalt-60 activity for four assembly regions.

Table II-32. Cobalt-60 Values at the Eight Points - FUEL REGION (curies)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	1.48E-01	1.07E+00	1.19E-01	9.30E-01	1.48E-01	1.07E+00	1.19E-01	9.30E-01	BWR.cobalt.source
2	1.41E+01	2.05E+01	1.41E+01	2.05E+01	1.41E+01	2.05E+01	1.41E+01	2.05E+01	BWR.cobalt.source
3	1.14E+02	1.37E+02	1.04E+02	1.25E+02	1.14E+02	1.37E+02	1.04E+02	1.25E+02	BWR.cobalt.source
4	2.68E+01	3.15E+01	2.50E+01	3.00E+01	2.68E+01	3.15E+01	2.50E+01	3.00E+01	PWR.cobalt.source
5	4.68E+01	6.10E+01	4.30E+01	5.62E+01	4.68E+01	6.10E+01	4.30E+01	5.62E+01	PWR.cobalt.source
6	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	PWR.cobalt.source
7	1.98E+01	1.75E+02	1.79E+01	1.60E+02	1.98E+01	1.75E+02	1.79E+01	1.60E+02	BWRSS.cobalt.source
8	4.38E+02	6.34E+02	4.38E+02	6.34E+02	4.38E+02	6.34E+02	4.38E+02	6.34E+02	PWRSS.cobalt.source

Table II-33. Cobalt-60 Values at the Eight Points -BOTTOM REGION (curies)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	3.71E-02	2.70E-01	2.98E-02	2.34E-01	3.71E-02	2.70E-01	2.98E-02	2.34E-01	BWR.cobalt.source
2	3.55E+00	5.19E+00	3.55E+00	5.19E+00	3.55E+00	5.19E+00	3.55E+00	5.19E+00	BWR.cobalt.source
3	2.91E+01	3.50E+01	2.64E+01	3.18E+01	2.91E+01	3.50E+01	2.64E+01	3.18E+01	BWR.cobalt.source
4	3.23E+00	3.82E+00	3.02E+00	3.63E+00	3.23E+00	3.82E+00	3.02E+00	3.63E+00	PWR.cobalt.source
5	5.63E+00	7.35E+00	5.17E+00	6.77E+00	5.63E+00	7.35E+00	5.17E+00	6.77E+00	PWR.cobalt.source
6	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	PWR.cobalt.source
7	1.46E-01	1.30E+00	1.33E-01	1.19E+00	1.46E-01	1.30E+00	1.33E-01	1.19E+00	BWRSS.cobalt.source
8	1.31E+01	1.93E+01	1.31E+01	1.93E+01	1.31E+01	1.93E+01	1.31E+01	1.93E+01	PWRSS.cobalt.source

Table II-34. Cobalt-60 Values at the Eight Points -PLENUM REGION (curies)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	2.26E-01	1.64E+00	1.82E-01	1.42E+00	2.26E-01	1.64E+00	1.82E-01	1.42E+00	BWR.cobalt.source
2	2.15E+01	3.13E+01	2.15E+01	3.13E+01	2.15E+01	3.13E+01	2.15E+01	3.13E+01	BWR.cobalt.source
3	1.74E+02	2.08E+02	1.58E+02	1.90E+02	1.74E+02	2.08E+02	1.58E+02	1.90E+02	BWR.cobalt.source
4	1.68E+00	1.98E+00	1.57E+00	1.88E+00	1.68E+00	1.98E+00	1.57E+00	1.88E+00	PWR.cobalt.source
5	2.94E+00	3.83E+00	2.70E+00	3.52E+00	2.94E+00	3.83E+00	2.70E+00	3.52E+00	PWR.cobalt.source
6	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	PWR.cobalt.source
7	1.37E+00	1.21E+01	1.24E+00	1.11E+01	1.37E+00	1.21E+01	1.24E+00	1.11E+01	BWRSS.cobalt.source
8	1.63E+01	2.35E+01	1.63E+01	2.35E+01	1.63E+01	2.35E+01	1.63E+01	2.35E+01	PWRSS.cobalt.source

Table II-35. Cobalt-60 Values at the Eight Points -TOP REGION (curies)

Assembly Number	Value at Point 1	Value at Point 2	Value at Point 3	Value at Point 4	Value at Point 5	Value at Point 6	Value at Point 7	Value at Point 8	Source File
1	4.74E-02	3.43E-01	3.81E-02	2.97E-01	4.74E-02	3.43E-01	3.81E-02	2.97E-01	BWR.cobalt.source
2	4.51E+00	6.57E+00	4.51E+00	6.57E+00	4.51E+00	6.57E+00	4.51E+00	6.57E+00	BWR.cobalt.source
3	3.67E+01	4.38E+01	3.33E+01	4.00E+01	3.67E+01	4.38E+01	3.33E+01	4.00E+01	BWR.cobalt.source
4	2.08E+00	2.46E+00	1.94E+00	2.33E+00	2.08E+00	2.46E+00	1.94E+00	2.33E+00	PWR.cobalt.source
5	3.62E+00	4.73E+00	3.33E+00	4.35E+00	3.62E+00	4.73E+00	3.33E+00	4.35E+00	PWR.cobalt.source
6	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	PWR.cobalt.source
7	1.87E-01	1.66E+00	1.70E-01	1.52E+00	1.87E-01	1.66E+00	1.70E-01	1.52E+00	BWRSS.cobalt.source
8	8.46E+00	1.24E+01	8.46E+00	1.24E+01	8.46E+00	1.24E+01	8.46E+00	1.24E+01	PWRSS.cobalt.source

Table II-36. Cobalt-60 Values for the Seven Interpolations - FUEL REGION (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	4.87E-01	4.10E-01	4.87E-01	4.10E-01	4.91E-01	4.91E-01	4.91E-01	4.54E-01	4.54E-01
2	1.86E+01	1.86E+01	1.86E+01	1.86E+01	1.86E+01	1.86E+01	1.86E+01	1.61E+01	1.61E+01
3	1.30E+02	1.19E+02	1.30E+02	1.19E+02	1.23E+02	1.23E+02	1.23E+02	1.07E+02	1.07E+02
4	3.11E+01	2.96E+01	3.11E+01	2.96E+01	3.11E+01	3.11E+01	3.11E+01	2.45E+01	2.45E+01
5	5.73E+01	5.28E+01	5.73E+01	5.28E+01	5.49E+01	5.49E+01	5.49E+01	5.27E+01	5.27E+01
6	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.31E+02	2.24E+02	2.24E+02
7	9.08E+01	8.27E+01	9.08E+01	8.27E+01	8.72E+01	8.72E+01	8.72E+01	4.80E+01	4.80E+01
8	5.56E+02	5.56E+02	5.56E+02	5.56E+02	5.56E+02	5.56E+02	5.56E+02	4.81E+02	4.81E+02

[a] The BIN.EXE values are extracted from the output file cobalt.dat for the Case A, 84k MTU waste stream.

Table II-37. Cobalt-60 Values for the Seven Interpolations - BOTTOM REGION (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	1.23E-01	1.03E-01	1.23E-01	1.03E-01	1.24E-01	1.24E-01	1.24E-01	1.14E-01	1.14E-01
2	4.70E+00	4.70E+00	4.70E+00	4.70E+00	4.70E+00	4.70E+00	4.70E+00	4.07E+00	4.07E+00
3	3.32E+01	3.02E+01	3.32E+01	3.02E+01	3.14E+01	3.14E+01	3.14E+01	2.72E+01	2.72E+01
4	3.77E+00	3.58E+00	3.77E+00	3.58E+00	3.77E+00	3.77E+00	3.77E+00	2.97E+00	2.97E+00
5	6.91E+00	6.36E+00	6.91E+00	6.36E+00	6.62E+00	6.62E+00	6.62E+00	6.35E+00	6.35E+00
6	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.80E+01	2.71E+01	2.71E+01
7	6.73E-01	6.15E-01	6.73E-01	6.15E-01	6.47E-01	6.47E-01	6.47E-01	3.56E-01	3.56E-01
8	1.68E+01	1.68E+01	1.68E+01	1.68E+01	1.68E+01	1.68E+01	1.68E+01	1.46E+01	1.46E+01

[a] The BIN.EXE values are extracted from the output file cobalt.dat for the Case A, 84k MTU waste stream.

Table II-38. Cobalt-60 Values for the Seven Interpolations - PLENUM REGION (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	7.45E-01	6.27E-01	7.45E-01	6.27E-01	7.51E-01	7.51E-01	7.51E-01	6.95E-01	6.95E-01
2	2.84E+01	2.84E+01	2.84E+01	2.84E+01	2.84E+01	2.84E+01	2.84E+01	2.46E+01	2.46E+01
3	1.98E+02	1.80E+02	1.98E+02	1.80E+02	1.88E+02	1.88E+02	1.88E+02	1.62E+02	1.62E+02
4	1.96E+00	1.85E+00	1.96E+00	1.85E+00	1.96E+00	1.96E+00	1.96E+00	1.54E+00	1.54E+00
5	3.60E+00	3.31E+00	3.60E+00	3.31E+00	3.45E+00	3.45E+00	3.45E+00	3.31E+00	3.31E+00
6	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.45E+01	1.40E+01	1.40E+01
7	6.28E+00	5.74E+00	6.28E+00	5.74E+00	6.04E+00	6.04E+00	6.04E+00	3.32E+00	3.32E+00
8	2.07E+01	2.07E+01	2.07E+01	2.07E+01	2.07E+01	2.07E+01	2.07E+01	1.79E+01	1.79E+01

[a] The BIN.EXE values are extracted from the output file cobalt.dat for the Case A, 84k MTU waste stream.

Table II-39. Cobalt-60 Values for the Seven Interpolations - TOP REGION (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd	After MTU Ratio - FINAL Value	BIN.EXE Value[a]
1	1.56E-01	1.31E-01	1.56E-01	1.31E-01	1.57E-01	1.57E-01	1.57E-01	1.45E-01	1.45E-01
2	5.96E+00	5.96E+00	5.96E+00	5.96E+00	5.96E+00	5.96E+00	5.96E+00	5.15E+00	5.15E+00
3	4.17E+01	3.80E+01	4.17E+01	3.80E+01	3.95E+01	3.95E+01	3.95E+01	3.41E+01	3.41E+01
4	2.43E+00	2.30E+00	2.43E+00	2.30E+00	2.43E+00	2.43E+00	2.43E+00	1.91E+00	1.91E+00
5	4.44E+00	4.09E+00	4.44E+00	4.09E+00	4.26E+00	4.26E+00	4.26E+00	4.08E+00	4.08E+00
6	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.80E+01	1.74E+01	1.74E+01
7	8.60E-01	7.86E-01	8.60E-01	7.86E-01	8.27E-01	8.27E-01	8.27E-01	4.55E-01	4.55E-01
8	1.08E+01	1.08E+01	1.08E+01	1.08E+01	1.08E+01	1.08E+01	1.08E+01	9.37E+00	9.37E+00

[a] The BIN.EXE values are extracted from the output file cobalt.dat for the Case A, 84k MTU waste stream.

Time Plane Interpolation Check for Function 1

In the above checks of Function 1, the pre- and post-times are the same and no interpolation is required in the time plane. Therefore, to check that the interpolation equations are working properly for all three planes (burnup, enrichment, and time), a nuclide calculation for Ac-227 will be checked at 10,000 years after the end of waste receipt for the same 8 assemblies shown in Table II-1.

Table II-40. Pre- and Post-Values

Assembly Number	Discharge Year	Age at 10,000 Years After the End of Waste Receipt	Pre-Time	Post-Time	Pre-Enrichment	Post-Enrichment	Pre-Burnup	Post-Burnup
1	1987	10053	10000	15000	0.711	1.000	1.00	10.00
2	1994	10046	10000	15000	3.000	3.000	20.00	30.00
3	2027	10013	10000	15000	4.000	4.500	50.00	60.00
4	1985	10055	10000	15000	0.711	1.000	30.00	40.00
5	1995	10045	10000	15000	3.500	4.000	30.00	40.00
6	2013	10027	10000	15000	5.000	5.000	60.00	60.00
7	1987	10053	10000	15000	3.500	4.000	1.00	10.00
8	1989	10051	10000	15000	4.000	4.000	20.00	30.00

The pre- and post-values in Table II-40 represent burnup, enrichments, and times that directly correlate with values presented in the source term files and reflect the age of the assemblies at the time of repository arrival. The pre- and post-values are used to determine the source term values to extract for the check below.

Table II-41. Values for Ac-227 at the Eight Points (curies)

Assembly Number	Ac-227 Value at Point 1	Ac-227 Value at Point 2	Ac-227 Value at Point 3	Ac-227 Value at Point 4	Ac-227 Value at Point 5	Ac-227 Value at Point 6	Ac-227 Value at Point 7	Ac-227 Value at Point 8	Source File
1	5.31E-04	2.37E-04	7.60E-04	3.69E-04	7.65E-04	3.61E-04	1.09E-03	5.49E-04	BWR.nuclide.source
2	1.11E-03	6.69E-04	1.11E-03	6.69E-04	1.61E-03	9.81E-04	1.61E-03	9.81E-04	BWR.nuclide.source
3	4.65E-04	2.69E-04	6.50E-04	3.88E-04	6.87E-04	4.06E-04	9.51E-04	5.76E-04	BWR.nuclide.source
4	2.33E-04	1.90E-04	3.17E-04	2.34E-04	4.15E-04	3.59E-04	5.33E-04	4.21E-04	PWR.nuclide.source
5	2.42E-03	1.64E-03	3.10E-03	2.16E-03	3.55E-03	2.42E-03	4.51E-03	3.18E-03	PWR.nuclide.source
6	1.73E-03	1.73E-03	1.73E-03	1.73E-03	2.56E-03	2.56E-03	2.56E-03	2.56E-03	PWR.nuclide.source
7	2.80E-03	2.11E-03	3.21E-03	2.49E-03	4.00E-03	3.02E-03	4.58E-03	3.57E-03	BWRSS.nuclide.source
8	4.42E-03	3.25E-03	4.42E-03	3.25E-03	6.40E-03	4.73E-03	6.40E-03	4.73E-03	PWRSS.nuclide.source

Table II-42. Values for Ac-227 for the Seven Interpolations (curies)

Assembly Number	Interpolation Between Points 1 and 2 (a)	Interpolation Between Points 3 and 4 (b)	Interpolation Between Points 5 and 6 (c)	Interpolation Between Points 7 and 8 (d)	Interpolation Between Points a and b (ab)	Interpolation Between Points c and d (cd)	Interpolation Between Points ab and cd - Final Ac-227 Value	Final Ac-227 Value After MTU Ratio	Ac-227 Value from BIN.EXE[a]
1	3.27E-04	4.92E-04	4.87E-04	7.21E-04	3.21E-04	4.78E-04	3.22E-04	2.98E-04	2.98E-04
2	7.63E-04	7.63E-04	1.12E-03	1.12E-03	7.63E-04	1.12E-03	7.66E-04	6.63E-04	6.63E-04
3	3.14E-04	4.49E-04	4.71E-04	6.63E-04	3.85E-04	5.73E-04	3.86E-04	3.33E-04	3.33E-04
4	1.93E-04	2.39E-04	3.63E-04	4.28E-04	1.93E-04	3.63E-04	1.94E-04	1.53E-04	1.53E-04
5	1.80E-03	2.35E-03	2.65E-03	3.45E-03	2.06E-03	3.04E-03	2.07E-03	1.99E-03	1.99E-03
6	1.73E-03	1.73E-03	2.56E-03	2.56E-03	1.73E-03	2.56E-03	1.73E-03	1.68E-03	1.68E-03
7	2.30E-03	2.69E-03	3.29E-03	3.85E-03	2.46E-03	3.52E-03	2.47E-03	1.36E-03	1.36E-03
8	3.62E-03	3.62E-03	5.26E-03	5.26E-03	3.62E-03	5.26E-03	3.64E-03	3.15E-03	3.15E-03

[a] The BIN.EXE values are extracted from the output file nuclide_10000_years.dat for the Case A, 84k MTU waste stream.

Check of Function 2

Function 2 determines the waste package design that an assembly will be loaded into based on a $k_{effective}$ criticality level. For this check the same 8 assemblies in Table II-1 are used. It should be additionally noted that Big Rock assemblies are automatically placed in the first PWR waste package design (see Assumption 3.6) as specified in the waste package design input file (binInfo.dat). The Big Rock assumption was checked by visual observation of the output files. Additionally, a visual check was performed to ensure that the South Texas assemblies were loaded into waste package Bin 3 (12 PWR Absorber Plate-Long).

Table II-43. Assembly Criticality Level Determination

Assembly Number	Type	Initial Enrichment (% U-235)	Burnup (GWd/MTU)	$k_{effective}$ for WP Bin 1 (21 PWR Absorber Plate)	$k_{effective}$ for WP Bin 2 (21 PWR Control Rod)	$k_{effective}$ for WP Bin 3 (12 PWR Absorber Plate-Long)	$k_{effective}$ for WP Bin 4 (44 BWR Absorber Plate)	$k_{effective}$ for WP Bin 5 (24 BWR Thick Absorber Plate)	WP Bin that Assembly Should be Loaded Into [a]
1	BWR	0.70	4.000	N/A	N/A	N/A	0.881	0	4
2	BWR	3.00	27.000	N/A	N/A	N/A	0.903	0	4
3	BWR	4.28	57.000	N/A	N/A	N/A	0.783	0	4
4	PWR	0.71	39.149	0.448	0	0	N/A	N/A	1
5	PWR	3.75	37.399	0.900	0	0	N/A	N/A	1
6	PWR	5.00	60.000	0.875	0	0	N/A	N/A	1
7	BWR	3.71	5.000	N/A	N/A	N/A	1.136	0	5
8	PWR	4.00	26.000	1.022	0	0	N/A	N/A	2

[a] The first bin of appropriate type (BWR or PWR) which provides a calculated $k_{effective}$ of 0.98 or less is bin that the assembly should be placed into.

Table II-44. Criticality Level Check

Assembly Number	Waste Package Bin That Assembly Should be Loaded Into	BIN.EXE Waste Package Bin[a]
1	4	4
2	4	4
3	4	4
4	1	1
5	1	1
6	1	1
7	5	5
8	2	2

[a] The BIN.EXE WP bin numbers is extracted from the output file bin.dat for the Case A, 84k MTU waste stream.

The other portion of Function 2 is the counting of assemblies that are placed into a specific waste package bin. This was checked in Table II-45 using arrival Case A, 84k MTU. Additionally checked is that the number of assemblies are translated into the correct number of waste packages. The number of waste packages for the check was simply calculated by dividing the number of assemblies for a given waste package design by the number of assemblies loaded into it, then rounding up the result.

Table II-45. Assembly and Waste Package Numbers Check

Waste Package Bin	Number of Assemblies	BIN.EXE number of assemblies[a]	Number of Waste Packages	BIN.EXE Number of Waste Packages[a]
1	119480	119480	5690	5690
2	2207	2207	106	106
3	3513	3513	293	293
4	164165	164165	3732	3732
5	2338	2338	98	98

[a] The BIN.EXE values are extracted from the output file summary.dat for the Case A, 84k MTU waste stream.

Check of Function 3

Function 3 creates an average heat value at multiple time steps, normalized to the time of assembly arrival, for each waste package design. The check of Function 1 above determined that the interpolations for heat are correct. Therefore, the only check required for Function 3 is that the heat values are being appropriately averaged. For this check, the time step checked to determine that averaging was being applied correctly was based on the time of repository arrival. For the other time steps, the trend for decreasing heat values with the appropriate exponential decay shape was visually checked.

BIN.EXE Case A, 84k MTU output file bin.dat was used for this check.

Table II-46. Average Heat Generation Rate Check (watts)

Waste Package Bin	Number of Assemblies	Total Heat Generation Rate at Time of Repository Receipt from BIN.EXE output file "bin.dat"	Average Heat Generation Rate at Time of Repository Receipt	BIN.EXE Average Heat Generation Rate at Time of Repository Receipt [a,b]
1	119480	64439245.97	539.33	539.33
2	2207	342338.88	155.12	155.11
3	3513	2626510.77	747.65	747.65
4	164165	26105156.08	159.02	159.02
5	2338	52704.46	22.54	22.54

[a] Slight discrepancies in average heat as calculated by manipulating the BIN.EXE output file versus the average calculated by BIN.EXE are expected. This is because BIN.EXE will carry more significant digits than what it outputs to files. Therefore, the fractional difference for Waste Package Bin 2 is

[b] The BIN.EXE values are extracted from the output file summary.dat for the Case A, 84k MTU waste stream.

Check of Function 4

Function 4 creates averages for burnup, enrichment, age, and MTU for each waste package design/bin. Through visual inspection, it was determined that the values for burnup, enrichment, age, and MTU from the input files were being properly recorded into the BIN.EXE output files. This check, shown in Table II-47, uses the "bin.dat" output file for waste stream Case A, 84k MTU. The bin.dat file was opened into Excel so that the averages for burnup, enrichment, age, and MTU could be determined for this check.

Table II-47. Average Characteristic Check for Waste Package Bins

Waste Package Bin	Average Burnup (GWd/MTU)	BIN.EXE Average Burnup[a] (GWd/MTU)	Average Initial Enrichment (% U-235)	BIN.EXE Average Enrichment[a] (% U-235)	Average Age (years)	BIN.EXE Average Age[a] (years)	Average Assembly MTU	BIN.EXE Average Assembly MTU[a]
1	41.98	41.98	3.75	3.75	25.20	25.20	0.431	0.431
2	19.86	19.86	3.61	3.61	35.83	35.83	0.376	0.376
3	43.44	43.44	3.77	3.77	21.59	21.59	0.540	0.540
4	33.98	33.98	3.02	3.02	25.08	25.08	0.178	0.178
5	8.48	8.48	2.68	2.68	41.82	41.82	0.169	0.169

[a] The BIN.EXE values are extracted from the output file summary.dat for the Case A, 84k MTU waste stream.

This check of the software routine determined that the software routine is properly reading the input files and performing the intended calculations correctly for all four functions.