OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
SPECIAL INSTRUCTION SHEET

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1. PURPOSE

The purpose of this calculation is to perform partially and fully degraded mode criticality evaluations of plutonium disposed of in a ceramic waste form and emplaced in a Monitored Geologic Repository (MGR). The partially degraded mode is represented by the immobilized plutonium ceramic discs piled in the bottom of the waste package (WP) while neutron absorbers begin to leach out of the discs. The fully degraded mode, which is the final stage of degradation, is represented by a mixture of degradation products and non-degraded materials that have settled in the bottom of the WP producing a uniform "sludge." The criticality evaluations calculate the values of k_{eff}, the effective neutron multiplication factor, for partial and fully degraded internal WP configurations with various amounts of water added to and various amounts of neutron absorbing materials removed from the sludge. The fully degraded cases were done for different times in life after the breach of the WP, which was assumed to occur 10,000 years after emplacement.

This document has been prepared according to Procedure AP-3.12Q/Rev. 0/ICN 0, *Calculations*, in support of the work outlined in Reference 5.

2. METHOD

The following steps are performed to determine the values of k_{eff} for fully degraded internal configurations of the WP:

1. Calculations are conducted on the results of geochemical calculations that determine the volume and mass of chemical elements or isotopes in the homogenized mixture, along with its density for each case of interest. These results are incorporated in the computational representation developed in Item 2. The geochemical calculations have been performed with the EQ6 software package (Ref. 1, Sections 4.1 and 4.2) and are inputs to this calculation.

2. A computational representation, representing the partially and fully degraded internal configurations of the WP, is developed for MCNP Version 4B2, a computer code appropriate for performing nuclear criticality analysis (Ref. 1, pp. 2 and 3).

3. MCNP4B2 is run for the computational represention developed above to estimate the k_{eff} value and its corresponding standard deviation for each case of interest.

3. ASSUMPTIONS

The assumptions used to perform the WP fully degraded mode criticality investigation are listed below:

3.1 It is assumed that the final stage of degradation after breach of WP at 10,000 years (relevant to Pu decay only) can be represented by a mixture of degradation products and non-degraded materials settled in the bottom of the WP producing a uniform "sludge." This assumption was made to study the impact of a homogenized mixture on the k_{eff} of the system. The basis of this assumption is that it is conservative because the void space in the mixture is ignored and various amounts of water can be added to the sludge mixture to determine the optimum dilution of the sludge. The range of dilution considered (0 to 100% by volume water added) covers the extent of water addition that produces the highest k_{eff} at any given time. This assumption is used throughout Section 5.

3.2 The highest loss of gadolinium is assumed as calculated in EQ6 Case 13 (ID p00_2131) and Case 14 (ID p00_2133) from Reference 1 (Sections 6.4 and 6.5), which represent 78% and 49% gadolinium loss, respectively. The basis of this assumption is that it is conservative because the loss of gadolinium, one of the primary neutron absorbers, will cause the system to have the highest k_{eff}. This assumption is used throughout Section 5.

3.3 It is assumed that the worst-case separation of Pu from gadolinium and hafnium is when the ceramic discs are piled in the bottom of the WP while the gadolinium and hafnium are spread throughout the water filled WP. The basis for this assumption is that it is conservative (resulting in higher values for k_{eff}). This assumption is used throughout Section 5.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE (QA) WORK

The calculation of k_{eff} of degraded internal WP configurations was performed with MCNP Version 4B2 on a Hewlett Packard (HP) workstation (Computer Software Configuration Item [CSCI] 30033 V4B2LV [Ref. 2, pp. 1 and 2]). MCNP is a three-dimensional Monte Carlo particle transport computer code with a generalized geometry capability that allows the development of detailed, accurate models of the systems of interest. MCNP4B2 calculates k_{eff} for a variety of geometric configurations with neutron cross sections for elements and isotopes described in the Evaluated Nuclear Data File Version B-V (ENDF-B/V) and Version B-VI (ENDF-B/VI). MCNP4B2 is appropriate for the fissile isotopes involved in the geometry and materials required for this analysis. The calculations using the MCNP4B2 software were executed on an HP model 9000 workstation. The software qualification of the MCNP4B2 software is summarized in the Software Qualification Report for the Monte Carlo N-Particle Code (Ref. 2, pp. 67 and 68). The MCNP4B2 evaluations performed for this calculation are within the range of MCNP Software Qualification Report and are appropriate for the MCNP physics models. Access to and use of the MCNP4B2 software for this analysis was granted by Software Configuration Management and performed in accordance with the appropriate procedures. The names and other attributes of the MCNP4B2 input and output files are listed in Table 7-2.

4.2 SOFTWARE ROUTINES

None used.

4.3 MODELS

None used.

5. CALCULATION

The degraded mode criticality calculations are performed for a 5-DHLW (5 Defense High-Level Waste) Codisposal WP design that has incorporated the can-in-canister concept for plutonium immobilization (Ref. 4). The initial configuration of each HLW (high-level waste) glass pour canister before degradation contained seven tubes. Each tube contained 4 cans, with 20 ceramic discs (immobilized plutonium) in each. After 10,000 years, water is assumed to breach the WP. The contents are degraded to the extent that the mixture of degradation products and non-degraded materials are settled in the bottom of the WP producing a uniform "sludge."

5.1 INPUT DATA

The dimensions of the intact components of the Viability Assessment (VA) WP design (Ref. 3, p. 10) are provided in Table 5-1.

Table 5-1. The Physical Characteristics of the Main Components of the 5-DHLW Codisposal WP

Component	Number	Material	Density (g/cm^3)	Inner Diam. (cm)	Outer Diam. (cm)	Thickness (cm)	Inner Height (cm)	Outer Height (cm)
Outer Barrier	1	ASTM A 516 GR 55 Carbon Steel	7.832	177	197	10.0	------	331
Outer Barrier Lid	2 (Top and Bottom)	ASTM A 516 GR 70 Carbon Steel	7.832	--------	197	11.0	------	------
Inner Barrier	1	ASTM B 575 (N06022 (Alloy 22)	8.69	173	177	2.0	304	------
Inner Barrier Lid	2 (Top and Bottom)	ASTM B 575 N06022 (Alloy 22)	8.69	--------	177	2.5	------	------
HLW Canister	5	ASTM A312 Type 304L Stainless Steel	7.9	59.055	60.96	0.9525	------	299.72
HLW	--------	High-Level Waste Glass	2.73	--------	--------	--------	------	------
Can	140 (28 per Canister)	Type 316 L Stainless Steel	7.9497	6.9850	7.6200	0.3175	52.705	53.340
Ceramic Disc	2800 (20 per Can)	Ceramic	5.5	--------	6.6675	2.3876	------	2.3876

5.2 PARTIALLY DEGRADED CONFIGURATIONS

The following useful example of a partly degraded configuration is evaluated. The ceramic discs containing immobilized plutonium are retained in their magazine geometry (80 discs stacked) and the 35 magazines are stacked in a close-packed rectangular array as shown in Figure 5-1. As a worst-case representation of relative displacement between the fissile material and the neutron absorber, the latter was assumed to become soluble and uniformly distributed throughout the water in the fully flooded WP, as shown in Figure 5-1. The composition of the discs is conservatively represented with initial weight fraction of Pu listed in Table 5-2, as taken from Table 3.1 of Reference 4. Each ceramic disk has a density of 5.5 g/cm^3, a diameter of 6.6675 cm, and a thickness of 2.3876 cm (Ref. 4). The masses and the abundance values of all the isotopes were taken from Reference 6. Five cases were represented. The first case used the initial compositions of the discs. The other cases had the gadolinium and hafnium spread uniformly throughout the waste package volume, in both the water and the remainder of the ceramic discs. In the second case, all the gadolinium and hafnium remained in the waste package. In the third, fourth, and fifth cases, the percentages of initial gadolinium and hafnium retained were 50, 25, and 0%, respectively.

Neither the HLW glass nor the steel were represented. This is conservative because the water is a more efficient moderator than the silica in the HLW glass, and the steel contains neutron absorbers and displaces water.

Table 5-2. The Overall Input Composition of the Baseline Ceramic, not Including Impurities

Oxide	wt%
CaO	9.95
HfO_2	10.65
UO_2	23.69
PuO_2	11.89
Gd_2O_3	7.95
TiO_2	35.86

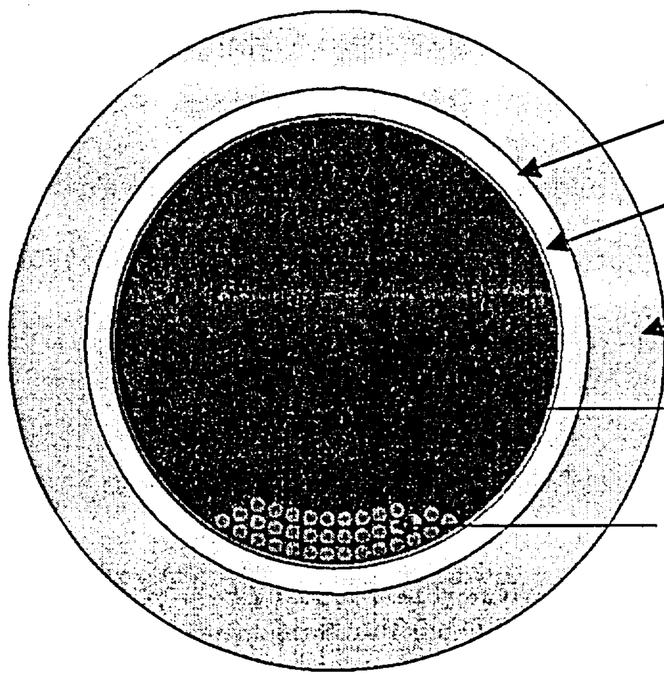

Figure 5-1. A Cross-sectional Front View of a Horizontally Emplaced Waste Package for the Partial Degradation Configuration

5.3 FULLY DEGRADED CONFIGURATION

The fully degraded mode configuration of the WP, where the WP internals have lost their original intact configurations and compositions and settled, is depicted in Figure 5-2. Note that the bottom of the WP contains a settled mixture of degradation products and non-degraded WP internals. Water fills the remaining volume above the sludge. The most abundant elements in the compositions present in the homogenized mixture of the fully degraded sludge at various times in life after WP breach are taken from the geochemical degradation calculation for Case 14 (p00_2133) and Case 13 (p00_2131) (Ref. 1, Table 6-10 and Table 6-8), which represent 49% and 78% gadolinium loss, respectively. These compositions are given in Table 5-3 and Table 5-4, respectively. The compositions at the different times in life are given in moles per liter of waste package void volume (4593.965 total liters) to preserve consistency with the geochemical calculations and mole fraction percent normalized to 100 percent. The quantities of uranium and plutonium are reported by EQ6 at the elemental level. The isotope breakdown of these two elements at time of WP emplacement (Ref. 1, p. 12) is given in Table 5-5. The masses and the abundance values of all the isotopes were taken from Reference 6.

The criticality analysis is performed at times of 10,017, 30,200, and 42,518 years after the initial breach of the WP (10,000 years) for Case 14. The 18.58-year time step for Case 14 was not calculated because full degradation could occur that soon after WP breach. Based upon the results obtained for Case 14, the only time calculated for Case 13 is the 13,175-year time step. To search for the optimum sludge dilution, the criticality evaluations were performed for cases where the homogenized mixture of the degradation products and non-degraded WP internals contained added percentages of water by volume. Cases were also run with total removal of the principal neutron absorbers, gadolinium and hafnium, which is unrealistic. Additional cases were run with partial replacement of the two neutron absorbers for Case 14. The partial replacement cases demonstrated that only small amounts of either absorber are needed to maintain subcriticality.

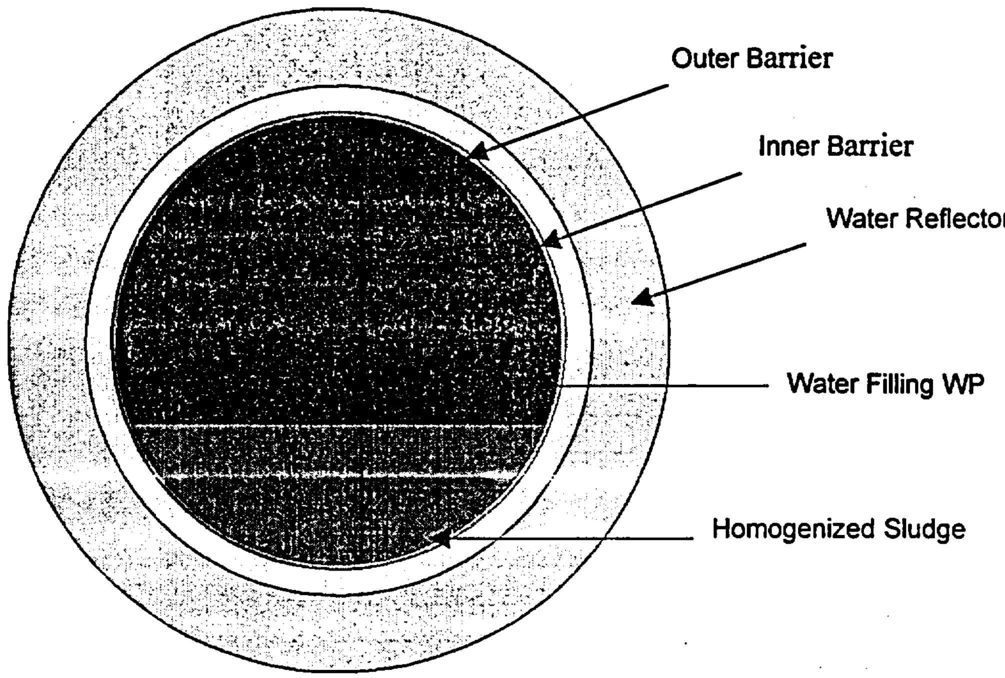

Figure 5-2. A Cross-sectional Front View of a Horizontally Emplaced Waste Package for the Full Degradation Configuration

Table 5-3. The Most Abundant Elements Present in the Sludge for Case 14 (p00_2133)

Vol. of Minerals (cm^3) in 1 liter	43.6200		419.9900		466.0800		492.9900	
Years/ Element	18.58	18.58	10017.00	10017.00	30200.00	30200.00	42518.00	42518.00
	mole/liter	mole%	mole/liter	mole%	mole/liter	mole%	mole/liter	mole%
O	4.3271E+00	6.0151E+01	4.1349E+01	6.0365E+01	4.5249E+01	6.0128E+01	4.7569E+01	6.0056E+01
Al	8.1099E-05	1.1274E-03	4.3685E-02	6.3776E-02	1.3174E-01	1.7506E-01	1.8549E-01	2.3418E-01
B	2.1684E-19	3.0143E-18	0.0000E+00	0.0000E+00	1.0842E-19	1.4407E-19	0.0000E+00	0.0000E+00
Ba	3.8856E-07	5.4013E-06	3.9259E-04	5.7314E-04	1.2289E-03	1.6330E-03	1.7393E-03	2.1959E-03
Ca	9.0206E-04	1.2539E-02	3.0721E-02	4.4850E-02	1.3296E-01	1.7668E-01	1.9151E-01	2.4178E-01
Cl	0.0000E+00	0.0000E+00	1.0842E-19	1.5828E-19	8.1315E-20	1.0805E-19	1.6263E-19	2.0532E-19
Cr	3.8856E-07	5.4013E-06	1.6941E-21	2.4732E-21	0.0000E+00	0.0000E+00	8.3009E-20	1.0480E-19
Cu	0.0000E+00	0.0000E+00	5.6431E-04	8.2384E-04	2.7973E-03	3.7171E-03	4.1602E-03	5.2523E-03
F	1.7458E-04	2.4268E-03	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	4.0658E-19	5.1331E-19
Fe	2.7995E+00	3.8916E+01	2.2376E+01	3.2667E+01	2.2511E+01	2.9913E+01	2.2593E+01	2.8524E+01
Gd	6.4822E-04	9.0109E-03	6.2173E-02	9.0766E-02	6.2130E-02	8.2560E-02	6.2104E-02	7.8407E-02
H	4.4151E-03	6.1374E-02	9.6463E-01	1.4083E+00	2.0023E+00	2.6607E+00	2.5236E+00	3.1861E+00
C	8.4346E-14	1.1725E-12	4.6189E-02	6.7431E-02	4.7534E-02	6.3164E-02	5.8246E-02	7.3536E-02
P	1.1762E-03	1.6350E-02	1.7237E-02	2.5164E-02	1.8530E-02	2.4623E-02	1.9318E-02	2.4389E-02
K	2.1113E-06	2.9349E-05	2.6480E-03	3.8658E-03	7.9852E-03	1.0611E-02	1.2342E-02	1.5582E-02
Li	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	7.5894E-19	9.5817E-19
Mg	9.1119E-06	1.2666E-04	9.5408E-03	1.3929E-02	2.8795E-02	3.8264E-02	4.9227E-02	6.2149E-02
Mn	3.1181E-02	4.3344E-01	4.0301E-01	5.8835E-01	4.3190E-01	5.7392E-01	4.4953E-01	5.6753E-01
Mo	3.5745E-31	4.9689E-30	0.0000E+00	0.0000E+00	1.4791E-31	1.9655E-31	0.0000E+00	0.0000E+00
N	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	2.9816E-19	3.7643E-19
Na	2.4946E-06	3.4677E-05	2.6721E-03	3.9010E-03	8.0578E-03	1.0707E-02	1.2518E-02	1.5804E-02
Ni	0.0000E+00	0.0000E+00	4.6906E-01	6.8478E-01	4.8177E-01	6.4019E-01	4.8953E-01	6.1803E-01
Np	0.0000E+00	0.0000E+00	1.0373E-21	1.5144E-21	0.0000E+00	0.0000E+00	3.7866E-20	4.7806E-20
Pb	2.7535E-07	3.8276E-06	1.4840E-04	2.1665E-04	4.4685E-04	5.9379E-04	6.2898E-04	7.9409E-04
Pu	5.6847E-04	7.9023E-03	1.2134E-01	1.7714E-01	1.2141E-01	1.6133E-01	1.2145E-01	1.5333E-01
S	0.0000E+00	0.0000E+00	7.3184E-19	1.0684E-18	2.7105E-20	3.6018E-20	2.5452E-17	3.2133E-17
Si	1.9244E-02	2.6751E-01	9.4676E-01	1.3822E+00	2.3426E+00	3.1129E+00	3.1793E+00	4.0139E+00
Tc	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	1.7256E-31	2.2930E-31	0.0000E+00	0.0000E+00
Ti	6.6957E-03	9.3076E-02	1.2622E+00	1.8427E+00	1.2749E+00	1.6941E+00	1.2827E+00	1.6194E+00
U	1.3115E-03	1.8231E-02	2.4913E-01	3.6370E-01	2.5666E-01	3.4106E-01	2.6138E-01	3.2999E-01
Zr (Hf)[a]	7.4895E-04	1.0411E-02	1.4073E-01	2.0545E-01	1.4073E-01	1.8701E-01	1.4073E-01	1.7767E-01
Totals	7.1938E+00	1.0000E+02	6.8498E+01	1.0000E+02	7.5254E+01	1.0000E+02	7.9208E+01	1.0000E+02

NOTE: [a]Hf was converted to Zr for geochemistry calculations then converted back to Hf due to insufficient thermodynamic data for Hf in the database.

Table 5-4. The Most Abundant Elements Present in the Sludge for Case 13 (p00_2131)

Vol. of Minerals (cm^3) in 1 liter	417.14	417.14
Element/Years	13175	13175
	mole/liter	mole%
O	4.1045E+01	6.0384E+01
Al	5.7485E-02	8.4569E-02
B	6.9404E-18	1.0210E-17
Ba	5.4664E-04	8.0419E-04
Ca	5.0279E-03	7.3968E-03
Cl	0.0000E+00	0.0000E+00
Cr	7.4233E-04	1.0921E-03
Cu	6.5903E-04	9.6953E-04
F	2.9169E-04	4.2913E-04
Fe	2.2402E+01	3.2957E+01
Gd	2.6982E-02	3.9695E-02
H	7.4638E-01	1.0980E+00
C	8.1400E-03	1.1975E-02
P	1.8859E-02	2.7745E-02
K	6.8435E-03	1.0068E-02
Li	0.0000E+00	0.0000E+00
Mg	3.6234E-03	5.3306E-03
Mn	4.0762E-01	5.9967E-01
Mo	0.0000E+00	0.0000E+00
N	2.1689E-19	3.1908E-19
Na	4.2248E-03	6.2154E-03
Ni	6.8294E-01	1.0047E+00
Np	4.9000E-05	7.2086E-05
Pb	1.9570E-04	2.8791E-04
Pu	1.2161E-01	1.7890E-01
S	4.3378E-19	6.3815E-19
Si	7.7863E-01	1.1455E+00
Tc	0.0000E+00	0.0000E+00
Ti	1.2645E+00	1.8602E+00
U	2.5057E-01	3.6862E-01
Zr (Hf)[a]	1.4076E-01	2.0708E-01
Totals	6.7974E+01	1.0000E+02

NOTE: [a]Hf was converted to Zr for geochemistry calculations then converted back to Hf due to insufficient thermodynamic data for Hf in the database.

Table 5-5. Pu and U Isotopic Compositions

Isotope	Wt%	Atom%
U-235	------	1.91
U-238	------	98.09
Pu-238	0.02	0.020093
Pu-239	90.59	90.62945
Pu-240	8.41	8.37855
Pu-241	0.89	0.88298
Pu-242	0.09	0.08892

6. RESULTS

The results of the k_{eff} evaluations performed for the partially and fully degraded configuration of the WP internals are provided in this section. Input and output files whose attributes are listed in Table 7-2 are contained on a computer compact disc (CD) as Attachment II. The k_{eff} results represent the average combined collision, absorption, and track-length estimator from the MCNP calculations. The standard deviation (σ) represents the standard deviation of k_{eff} about the average combined collision, absorption, and track-length estimate due to the Monte Carlo calculation statistics. The AENCF values are calculated dividing the energy per source particle by the weight per source particle found in Summary Table 1 of the MCNP output file.

The results reported in Section 6 must be verified prior to use in quality affecting activities or for use in analyses affecting procurement, fabrication, or construction, since they were based on unqualified data.

6.1 PARTIALLY DEGRADED CASES

The k_{eff} estimates and their corresponding standard deviations along with the AENCF are listed in Table 6-1 for the partially degraded cases described in Section 5.2.

Table 6-1. k_{eff} for Partially Degraded Cases

Run ID	Gd and Hf Remaining in WP (%)	Gd and Hf Presence	k_{eff}	Standard Deviation	AENCF (MeV)
nominal	100	Ceramic Discs	0.38801	0.00072	0.529689
0loss	100	Throughout WP	0.53098	0.00124	0.409477
50loss	50	Throughout WP	0.57550	0.00129	0.373800
75loss	25	Throughout WP	0.61782	0.00152	0.348299
100loss	0	Throughout WP	0.90653	0.00140	0.217954

6.2 FULLY DEGRADED CASES

6.2.1 Fully Degraded Case 14 (P00_2133)

The k_{eff} estimates, their corresponding standard deviations, and the AENCF values for the fully degraded configuration with various amounts of water added are provided in Table 6-2. Variation of k_{eff} with volume of water is provided in Figure 6-1 for Case 14 (p00_2133). Note that the amount of water added to the sludge and homogenized varies from no water added to the addition of water equal to 50 percent of the final volume. That is, the initial volume of sludge was doubled with the 100% water addition. Three times in the life of the WP after breach were evaluated. These times were 10,017, 30,200, and 42,518 years after WP breach. For the decay of plutonium isotopes, 10,000 years have to be added to the above times to account for the assumed emplacement time before WP breach.

Table 6-2. k_{eff} for Case 14 (p00_2133): Water Added to Sludge

Case ID	Water in Sludge (vol%)	Time after WP Breach (years)[a]	k_{eff}	Standard Deviation	AENCF (MeV)
fdp10k00h	0	10017	0.34030	0.00067	0.143638
fdp10k10h	9	10017	0.36649	0.00073	0.110336
fdp10k20h	17	10017	0.38094	0.00077	0.091260
fdp10k40h	29	10017	0.37626	0.00078	0.069897
fdp10k60h	38	10017	0.35692	0.00072	0.060087
fdp10k80h	44	10017	0.33515	0.00053	0.053405
fdp10k100h	50	10017	0.31578	0.00052	0.049048
fdp30k00h	0	30200	0.33260	0.00070	0.120516
fdp30k10h	9	30200	0.33772	0.00073	0.098150
fdp30k20h	17	30200	0.33348	0.00060	0.081135
fdp30k40h	29	30200	0.30807	0.00061	0.071642
fdp30k60h	38	30200	0.28209	0.00050	0.064405
fdp30k80h	44	30200	0.26048	0.00039	0.057352
fdp30k100h	50	30200	0.24217	0.00037	0.054716
fdp42k00h	0	42518	0.32302	0.00060	0.113224
fdp42k10h	9	42518	0.31698	0.00052	0.095775
fdp42k20h	17	42518	0.30509	0.00068	0.086280
fdp42k40h	29	42518	0.27522	0.00053	0.073057
fdp42k60h	38	42518	0.24808	0.00037	0.065728
fdp42k80h	44	42518	0.22735	0.00032	0.060338
fdp42k100h	50	42518	0.20971	0.00033	0.058842

NOTE: [a]Assumed 10,000 years after discharge from reactor

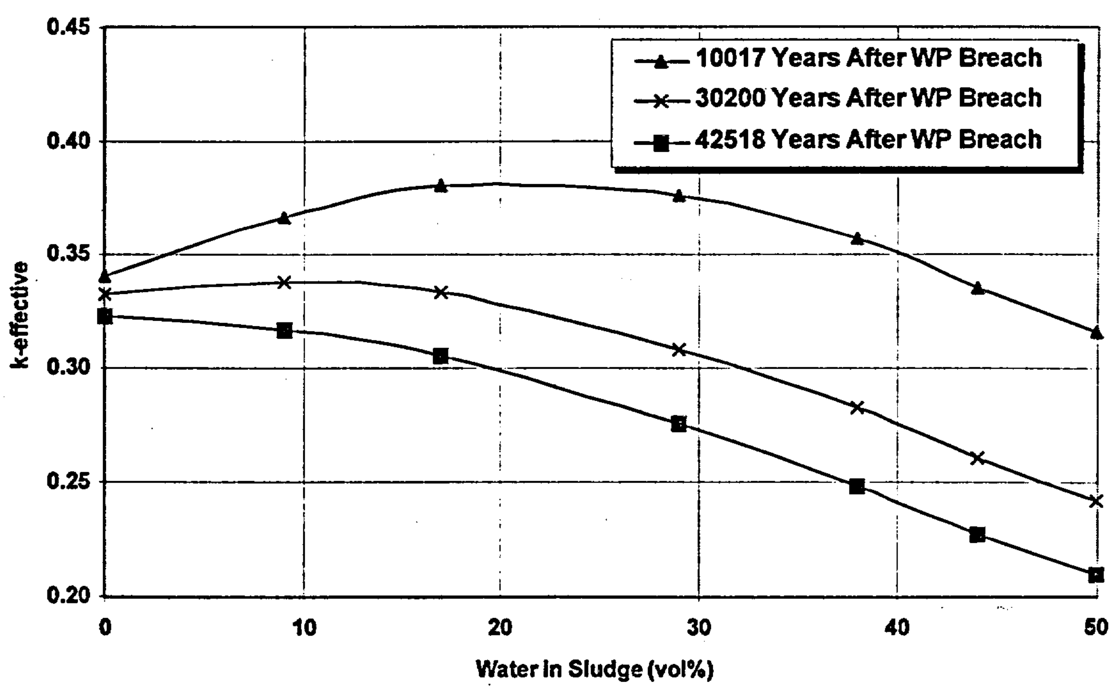

Figure 6-1. k_{eff} for Case 14 (p00_2133) with Water Addition

The k_{eff} is seen to be low for any amount of water added to the sludge. To see if the degraded material could stay subcritical with a total loss of both of the primary neutron poisons, cases were run with all the gadolinium and hafnium removed (Table 6-3, Figure 6-2). From the results it can be seen that the system cannot have all the gadolinium and hafnium removed and stay subcritical. Additional cases were run with small quantities of the poison material in the WP. For the 10,017-year time step, which gave the highest k_{eff}, the WP in these additional cases contained (a) 1% of the original gadolinium and 50% of hafnium, (b) 1% of the original gadolinium and no hafnium, and (c) no gadolinium and 50% of hafnium. Table 6-4 and Figure 6-3 present the results of these partial-poison-replacement cases.

Table 6-5 and Figure 6-4 show the minimum required hafnium to maintain subcriticality as a function of time since discharge. What follows is an explanation of this behavior:

- The reactivity in the WP decreases as the Pu-239 decays to the less reactive U-235.

- There is no peak in reactivity as a function of time (as there is between 15,000 and 25,000 years following discharge for highly burned SNF) because the waste form contains very little Pu-240. This isotope is a strong neutron absorber and, if there is enough of it, its relatively rapid decay (6,560-year half-life) will cause a temporary increase in reactivity, which will ultimately be reduced by the slower decay of Pu-239.

- Beyond 42,000 years so much Pu has decayed to U that the configuration can no longer go critical.

Table 6-3. k_{eff} for Case 14 (p00_2133): All Gd and Hf Removed

Run ID	Water in Sludge (vol%)	Time after WP Breach (years)[a]	k_{eff}	Standard Deviation	AENCF (MeV)
fdp10k00hngh	0	10017	0.56296	0.00100	0.084303
fdp10k20hngh	17	10017	0.88653	0.00127	0.038062
fdp10k40hngh	29	10017	0.97697	0.00149	0.026650
fdp10k60hngh	38	10017	1.01533	0.00098	0.021546
fdp10k80hngh	44	10017	1.02247	0.00125	0.017961
fdp10k100hngh	50	10017	1.02553	0.00107	0.014790
fdp30k00hngh	0	30200	0.61185	0.00105	0.064730
fdp30k20hngh	17	30200	0.87002	0.00094	0.031996
fdp30k40hngh	29	30200	0.93111	0.00127	0.023039
fdp30k60hngh	38	30200	0.95209	0.00091	0.018471
fdp30k80hngh	44	30200	0.95647	0.00106	0.015497
fdp30k100hngh	50	30200	0.95391	0.00077	0.013768
fdp42k00hngh	0	42518	0.62378	0.00120	0.058954
fdp42k20hngh	17	42518	0.84788	0.00124	0.030238
fdp42k40hngh	29	42518	0.90222	0.00109	0.021903
fdp42k60hngh	38	42518	.91843	0.00097	0.017116
fdp42k80hngh	44	42518	0.91902	0.00076	0.014697
fdp42k100hngh	50	42518	0.91494	0.00093	0.012547

NOTE: [a]Assumed 10,000 years after discharge from reactor

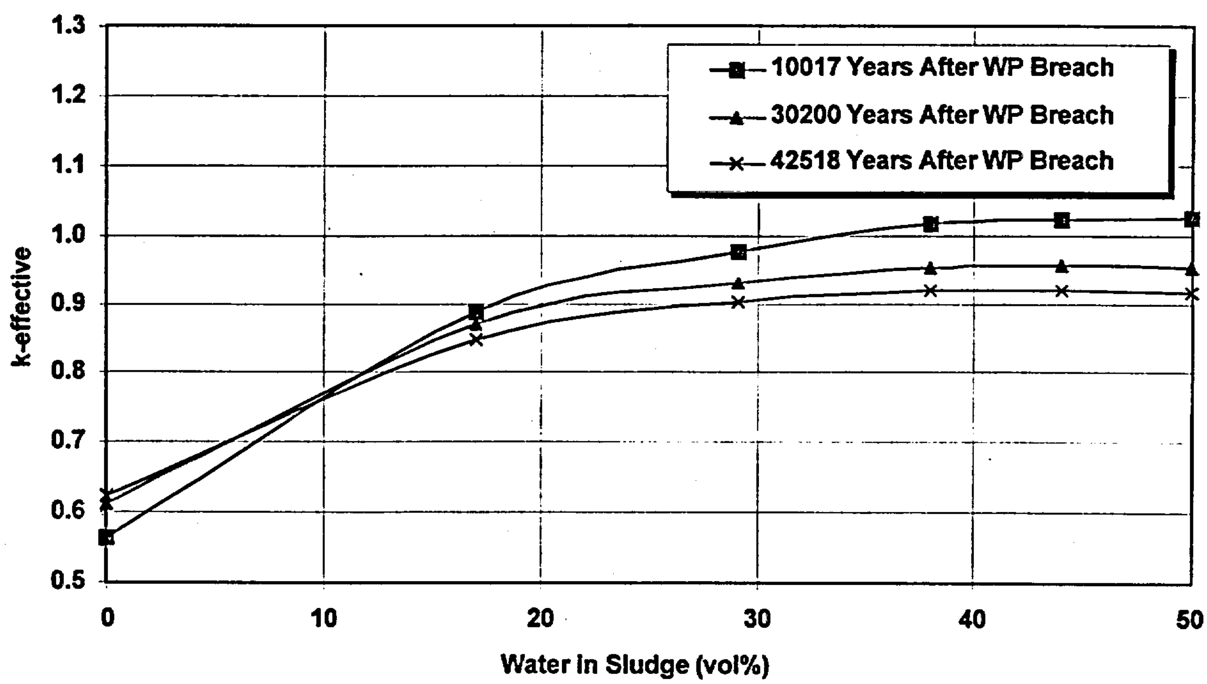

Figure 6-2. k_{eff} for Case 14 (p00_2133) with All Gd and Hf Removed

Table 6-4. k_{eff} for Case 14 (p00_2133): Partial Gd and Hf Replaced (10,017 years)[a]

Run ID	Water in Sludge (vol%)	Initial Gd Present[b] (%)	Initial Hf Present[b] (%)	k_{eff}	Standard Deviation	AENCF (MeV)
fdp10k00h1gd50hf	0	1.0	50.0	0.44258	0.00085	0.105954
fdp10k20h1gd50hf	17	1.0	50.0	0.64007	0.00135	0.052097
fdp10k40h1gd50hf	29	1.0	50.0	0.72283	0.00110	0.035741
fdp10k60h1gd50hf	38	1.0	50.0	0.76336	0.00125	0.027225
fdp10k80h1gd50hf	44	1.0	50.0	0.77973	0.00101	0.023774
fdp10k100h1gd50hf	50	1.0	50.0	0.78554	0.00112	0.020523
fdp10k00h1gd0hf	0	1.0	0.0	0.54861	0.00100	0.087127
fdp10k20h1gd0hf	17	1.0	0.0	0.82848	0.00114	0.040489
fdp10k40h1gd0hf	29	1.0	0.0	0.88532	0.00117	0.029617
fdp10k60h1gd0hf	38	1.0	0.0	0.90073	0.00118	0.023837
fdp10k80h1gd0hf	44	1.0	0.0	0.89404	0.00092	0.020910
fdp10k100h1gd0hf	50	1.0	0.0	0.89099	0.00097	0.017242
fdp10k00h0gd50hf	0	0.0	50.0	0.45296	0.00081	0.098325
fdp10k20h0gd50hf	17	0.0	50.0	0.68111	0.00145	0.048568
fdp10k40h0gd50hf	29	0.0	50.0	0.79447	0.00124	0.032912
fdp10k60h0gd50hf	38	0.0	50.0	0.85417	0.00114	0.024976
fdp10k80h0gd50hf	44	0.0	50.0	0.88277	0.00118	0.020624
fdp10k100h0gd50hf	50	0.0	50.0	0.90218	0.00114	0.017734

NOTES: [a]Assumed 10,000 years after discharge from reactor
[b]Percent of the remaining fraction

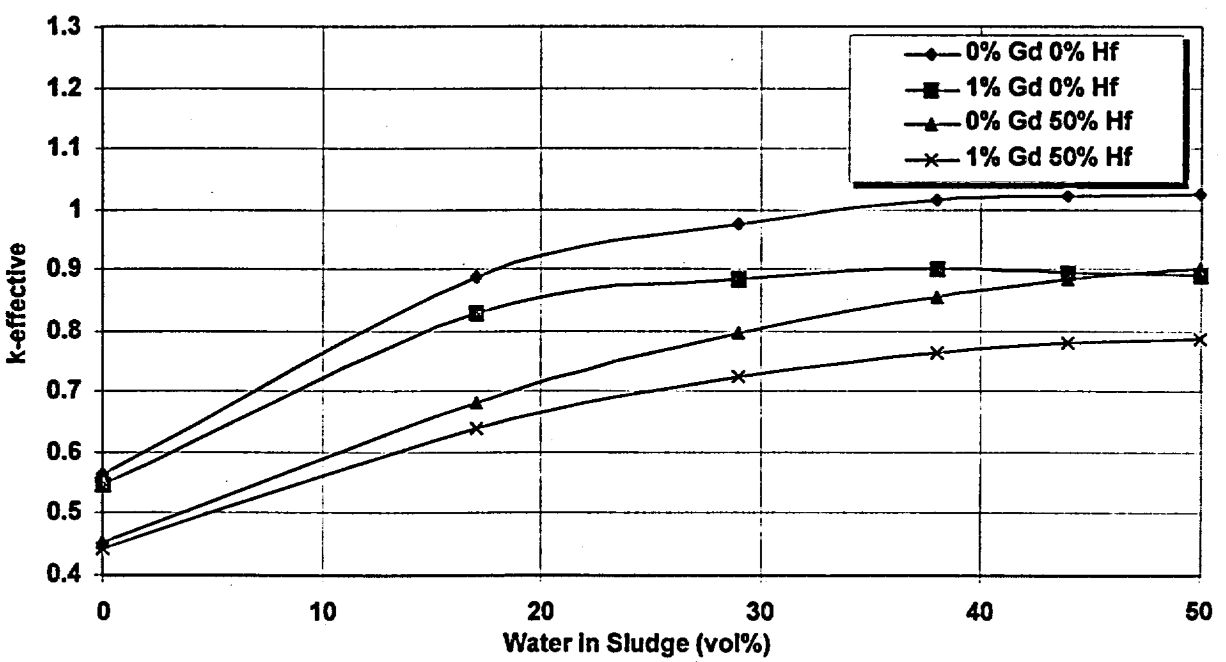

Figure 6-3. k_{eff} for Case 14 (p00_2133) with Partial Gd and Hf Replaced

Table 6-5. Minimum Hf Required to Maintain Subcriticality

Run ID	Time Since WP Breach[a] (y)	Water in Sludge (vol%)	Initial Gd Present (wt%)	Initial Hf Present (wt%)	k_{eff}	Standard Deviation	AENCF (MeV)
fdp10k100h0gd50hf	10017	50	0	50	0.90218	0.00114	0.017734
fdp10k100h0gd40hf	10017	50	0	40	0.92370	0.00098	0.016720
fdp10k100h0gd30hf	10017	50	0	30	0.94466	0.00103	0.017019
fdp20k100h0gd25hf	20000	50	0	25	0.92727	0.00068	0.016267
fdp20k100h0gd20hf	20000	50	0	20	0.93963	0.00062	0.015594
fdp20k100h0gd15hf	20000	50	0	15	0.95226	0.00062	0.015484
fdp30k100h0gd05hf	30200	50	0	5	0.94017	0.00098	0.013720
Fdp30k100hngh	30200	50	0	0	0.95391	0.00077	0.013768
Fdp42k100hngh	42518	50	0	0	0.91494	0.00093	0.012547

NOTE: [a]Assumed 10,000 years after discharge from reactor

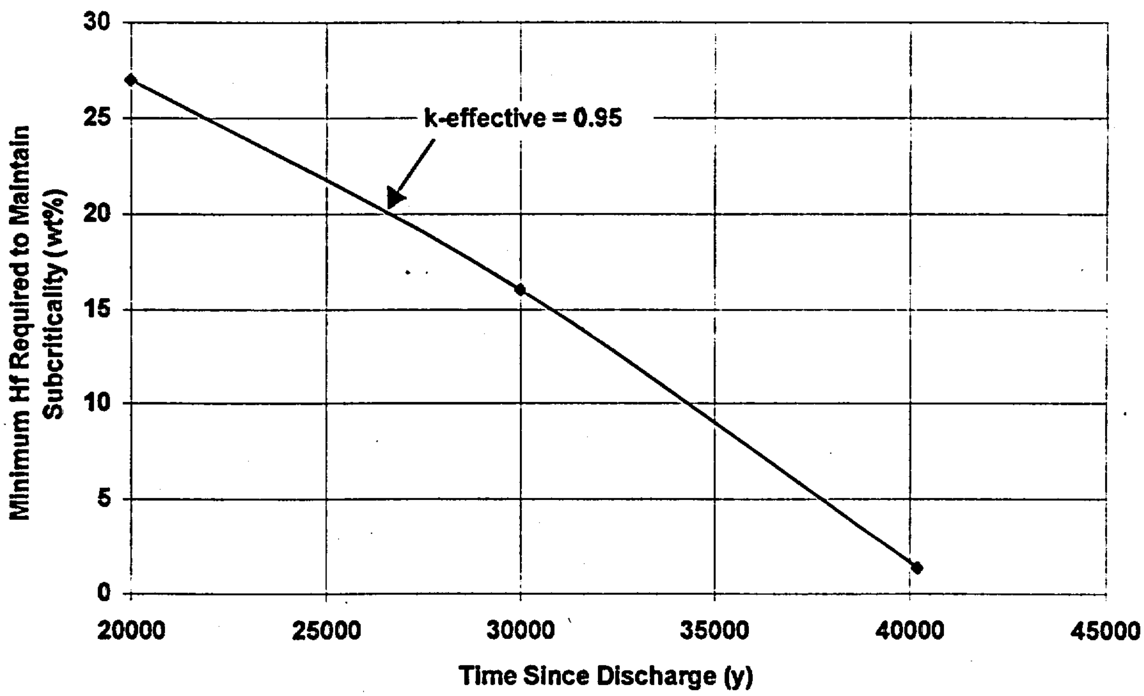

Figure 6-4. Minimum Hf Required to Maintain Subcriticality versus Time Since Discharge

6.2.2 Fully Degraded Case 13 (P00_2131)

A second degradation scenario was evaluated that had approximately 78% of the gadolinium removed from the sludge 13,175 years after breach of the WP. This was Case 13 (p00_2131) from Reference 1 (Section 6.4). Case 14 from Reference 1 (Section 6.5), evaluated earlier, only had about 49% of the gadolinium removed 42,518 years after WP breach. Table 6-6 gives the results for the addition of water to the sludge for Case 13. Figure 6-5 shows a plot of the Case 13 results along with the results for the 10,017 years from Case 14. A comparison of the curves in Figure 6-5 shows the effects of the higher gadolinium loss in Case 13 (p00_2131) relative to Case 14.

Table 6-6. k_{eff} for Case 13 (p00_2131): Water Added to Sludge

Run ID	Water in Sludge (vol%)	Time after WP Breach (years)[a]	k_{eff}	Standard Deviation	AENCF (MeV)
fdp13k00h	0	13175	0.35566	0.00062	0.135576
fdp13k20h	17	13175	0.41528	0.00099	0.079676
fdp13k40h	29	13175	0.41638	0.00075	0.062564
fdp13k60h	38	13175	0.40175	0.00084	0.053375
fdp13k80h	44	13175	0.38227	0.00059	0.046309
fdp13k100h	50	13175	0.36489	0.00064	0.044042

NOTE: [a]Assumed 10,000 years after discharge from reactor

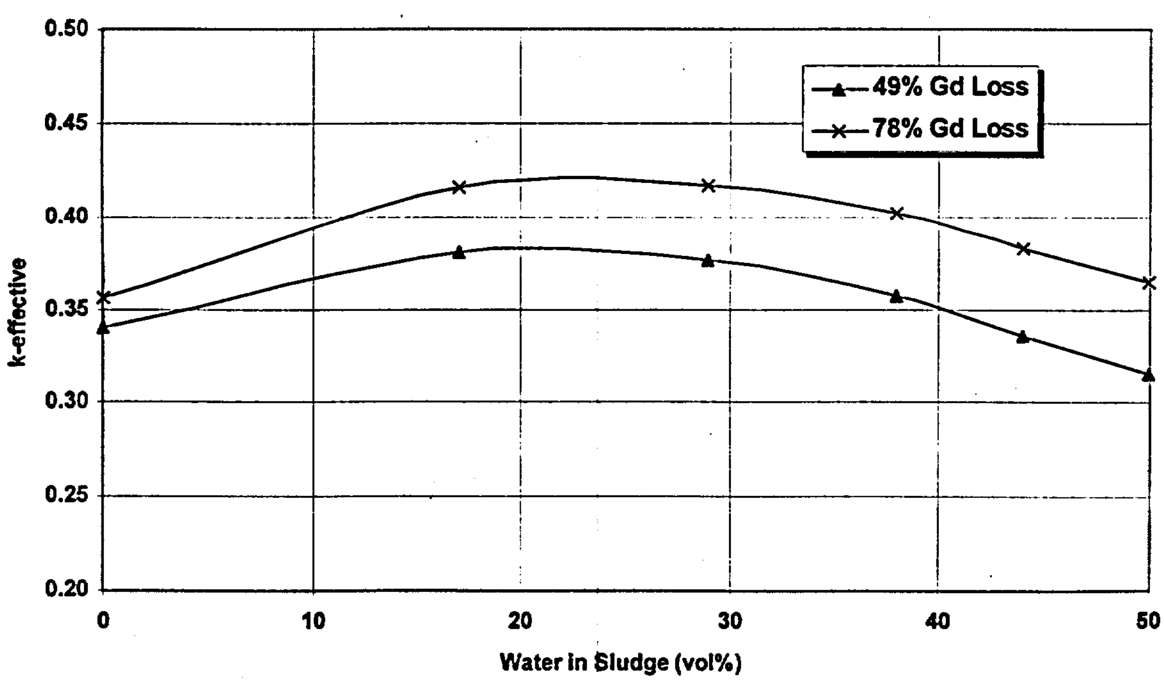

Figure 6-5. Comparison Between Cases 13 and 14

All the gadolinium and hafnium were also removed from Case 13 at 13,175 years to determine if it would go critical with both of the primary neutron poisons removed. Case 13, like Case 14, would go critical if all of the gadolinium and hafnium were removed and the optimum dilution were to occur. Case 13 does have a lower k_{eff} than the previously evaluated Case 14 for all neutron absorber removal; therefore, the partial replacement of neutron absorbers was not done for the Case 14 scenario. Table 6-7 presents the results of removing all the gadolinium and hafnium. Figure 6-6 presents the results of removing all the gadolinium and hafnium (Case 13) along with the results for the 10,017 years calculation for Case 14. Case 13 was evaluated with more water added to demonstrate that k_{eff} decreases with increase in water content of the sludge.

Table 6-7. k_{eff} for Case 13 (p00_2131): All Gd and Hf Removed

Run ID	Volume% Water	Time after WP Breach (years)	k_{eff}	Standard Deviation	AENCF (MeV)
fdp13k00hngh	0	13175	0.54522	0.00096	0.084910
fdp13k20hngh	17	13175	0.87544	0.00148	0.039096
fdp13k40hngh	29	13175	0.96676	0.00117	0.026554
fdp13k60hngh	38	13175	0.99713	0.00090	0.020916
fdp13k80hngh	44	13175	1.00910	0.00089	0.018161
fdp13k100hngh	50	13175	1.01251	0.00107	0.015615
fdp13k150hngh	60	13175	1.00142	0.00086	0.012122
fdp13k200hngh	67	13175	0.97691	0.00073	0.009498

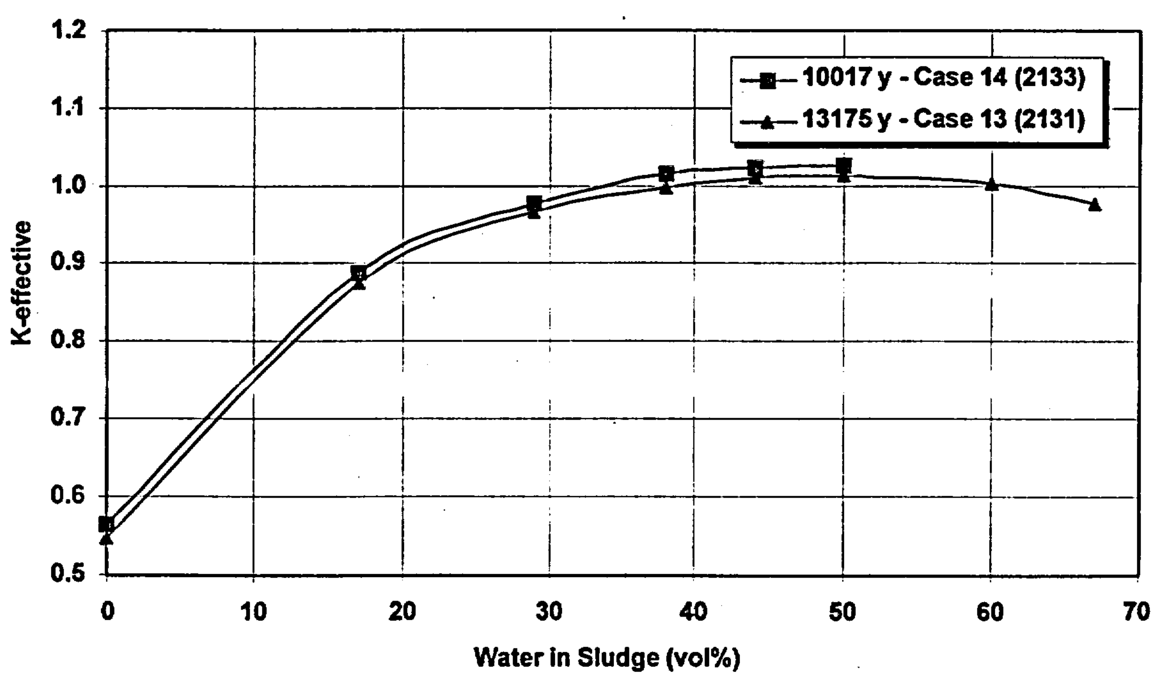

Figure 6-6. k_{eff} for Case 13 (p00_2131) with All Gd and Hf Removed - Comparison with Case 14 Results

7. ATTACHMENTS

Table 7-1 provides the list of attachments.

Table 7-1. List of Attachments

Attachment	Contents
I	Document Input Reference Sheets (DIRS)
II	CD Containing All MCNP Input and Output Files

Table 7-2 lists the contents of Attachment II (CD). The MCNP input and output files were transferred from an HP Series 9000 workstation to a Pentium II PC using a file transfer protocol. The CD was written using a Pentium II PC.

Table 7-2. MCNP Input and Output Files

Name	Date	Time	Size (byte)
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fdp10k00h1gd0hf.out	08/31/1999	3:00p	346,487
fdp10k00h1gd50hf.out	08/31/1999	2:59p	339,243
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fdp10k100h1gd50hf.out	08/31/1999	2:59p	340,750
fdp10k100hngh.out	08/31/1999	2:59p	335,942
fdp10k10h.out	08/31/1999	2:59p	346,818
fdp10k20h.out	08/31/1999	2:59p	339,440
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fdp10k20h1gd0hf.out	08/31/1999	3:00p	344,585
fdp10k20h1gd50hf.out	08/31/1999	2:59p	342,222
fdp10k20hngh.out	08/31/1999	2:59p	347,141
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fdp30k100h.out	08/31/1999	3:01p	337,511
fdp30k100h0gd05hfo	09/14/1999	9:30a	342,138
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fdp30k100hngh	08/31/1999	2:52p	7,424
fdp30k10h	08/31/1999	2:52p	7,427
fdp30k20h	08/31/1999	2:52p	7,427
fdp30k20hngh	08/31/1999	2:52p	7,421
fdp30k40h	08/31/1999	2:52p	7,427
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fdp30k60hngh	08/31/1999	2:52p	7,419
fdp30k80h	08/31/1999	2:52p	7,425
fdp30k80hngh	08/31/1999	2:52p	7,419
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fdp42k00hngh	08/31/1999	2:53p	7,454
fdp42k100h	08/31/1999	2:53p	7,430
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fdp42k20h	08/31/1999	2:53p	7,429
fdp42k20hngh	08/31/1999	2:53p	7,423
fdp42k40h	08/31/1999	2:53p	7,427
fdp42k40hngh	08/31/1999	2:53p	7,421
fdp42k60h	08/31/1999	2:54p	7,425

Name	Date	Time	Size (byte)
fdp42k60hngh	08/31/1999	2:54p	7,419
fdp42k80h	08/31/1999	2:54p	7,425
fdp42k80hngh	08/31/1999	2:54p	7,419
nominal	09/26/1999	7:04p	9,441

8. REFERENCES

1. CRWMS M&O 1999. *EQ6 Calculations for Chemical Degradation of Pu-Ceramic Waste Packages: Effects of Updated Materials, Compositions and Rates.* CAL-EDC-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0235.

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

3. CRWMS M&O 1998. *Criticality Evaluation of Plutonium Disposition Ceramic Waste Form: Degraded Mode.* BBA000000-01717-0210-00014 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980918.0003.

4. LLNL 1999. *Plutonium Immobilization Project, Data for Yucca Mountain Total Systems Performance Assessment, Rev. 1.* PIP Milestone Report. Milestone 2.b.b. PIP 98-012. Livermore, California: LLNL. ACC: MOL.19980818.0349.

5. CRWMS M&O 1999. *FY1999 Plutonium Disposition Waste Package Criticality Tasks (21019074M1).* TDP-DDC-MD-000001. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990729.0059.

6. General Electric Company 1996. *Nuclides and Isotopes, Fifteenth Edition.* San Jose, California: General Electric Company. TIC: 233705.

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DOCUMENT INPUT REFERENCE SHEET

1. Document Identifier No./Rev.:	Change:	Title:
CAL-EBS-NU-000006 REV 00	N/A	Evaluation of Internal Criticality of the Plutonium Disposition Ceramic Waste Form

	Input Document		4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due 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 1999. *EQ6 Calculations for Chemical Degradation of Pu-Ceramic Waste Packages: Effects of Updated Materials, Compositions and Rates.* CAL-EDC-MD-000003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990928.0235.	§ 4.1 & 4.2 § 6.4 & 6.5 Table 6-10, Table 6-8. §5.4.1	TBV-3414	2, 4.1 3 5.2	Description of EQ6. Description of Cases 13 and 14. Composition of corrosion products for Cases 14 and 13. Gd removed from sludge for Cases 13 & 14. Based on unqualified data.	3	Yes	N/A	N/A
2	CRWMS M&O 1998. *Software Qualification Report for MCNP Version 4B2, A General Monte Carlo N-Particle Transport Code.* DI: 30033-2003 Rev. 01; CSCI: 30033 V4B2LV. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980622.0637	pp. 2, 3 pp. 67 & 68	N/A	2 4.1	Description of MCNP4B2. Statement of qualification of MCNP4B2. Reference only.	N/A	N/A	N/A	N/A
3	CRWMS M&O 1998. *Criticality Evaluation of Plutonium Disposition Ceramic Waste Form: Degraded Mode.* BBA000000-01717-0210-00014 REV 01. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980918.003.	p. 10	TBV-3398	5.1	Dimensions and other characteristics of the WP internals.	3	Yes	N/A	N/A
4	LLNL 1999. *Plutonium Immobilization Project, Input for Yucca Mountain Total Systems Performance Assessment.* PIP Milestone Report, Milestone 4.3.a. PIP 99-107. Livermore, California: Lawrence Livermore National Laboratory. TIC: 245437.	p. 15 Table 3.1	TBV-3427	5.3 5.2	Isotopic composition of uranium and plutonium in the plutonium ceramic. Baseline composition of ceramic. Based on unqualified data.	3	Yes	N/A	N/A

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	2. Technical Product Input Source Title and Identifier(s) with Version	3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	Unqual.	From Uncontrolled Source	Un-confirmed
5	CRWMS M&O 1999. *FY1999 Plutonium Disposition Waste Package Criticality Tasks (21019074M1)*. TDP-DDC-MD-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990729.0059.	Entire	N/A	1	Reference to Development Plan.	N/A	N/A	N/A	N/A
6	General Electric Company 1996. *Nuclides and Isotopes, Fifteenth Edition*. San Jose, California: General Electric Company. TIC: 233705.	Entire	N/A	5.2	Isotopic abundance and mass values. This is a handbook.	N/A	N/A	N/A	N/A