ATTACHMENT (6)

CCNPP CALCULATION, "HORIZONTAL STORAGE MODULE DOSE RATES FOR ISFSI 32P BURNUP EXTENSION," DOCUMENT NO. CA06751, REVISION NO. 0

Calvert Cliffs Nuclear Power Plant, Inc.
June 15, 2009

ATTACHMENT 1, CALCULATION COVER SHEET

A. INITIATION

Site ☒ CCNPP ☐ NMP ☐ REG

Calculation No.: CA06751 Revision No.: 0000

Vendor Calculation (Check one): ☐ Yes ☒ No

Responsible Group: Nuclear Fuel Services – Nuclear Analysis Unit

Responsible Engineer: John Massari

B. CALCULATION

ENGINEERING DISCIPLINE: ☐ Civil ☐ Instr & Controls ☒ Nuclear ☐ Electrical ☐ Mechanical ☐ Other _____

Title: HORIZONTAL STORAGE MODULE DOSE RATES FOR ISFSI 32P BURNUP EXTENSION

Unit ☐ 1 ☐ 2 ☒ COMMON

Proprietary or Safeguards Calculation ☐ YES ☒ NO

Comments: ES200600043-000

Vendor Calc No.: N/A REVISION NO.: N/A

Vendor Name: N/A

Safety Class (Check one): ☒ SR ☐ AUGMENTED QUALITY ☐ NSR

There are assumptions that require Verification during walkdown: TRACKING ID: N/A

This calculation **SUPERSEDES**: N/A

C. REVIEW AND APPROVAL:

Responsible Engineer: John Massari — Printed Name and Signature — 9/22/08 Date

Is Design Verification Required? ☒ Yes ☐ No

If yes, Design Verification Form is ☒ Attached ☐ Filed with:

Independent Reviewer: Gerard Gryczkowski — Printed Name and Signature — 9/23/08 Date

Approval: Phil Wengloski — Printed Name and Signature — 9/23/08 Date

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1.0 INTRODUCTION

The purpose of this calculation is to evaluate the Calvert Cliffs NUHOMS-32P horizontal storage module (HSM) dose rates from Reference 6 using the extended burnup neutron and photon sources from Reference 1. In addition, this calculation also determines the impact of forest fire induced spalling on HSM dose rates, which were previously done for the 24P and 32P using shielding reduction factors from Reference 4 on dose rates from References 3 and 6, respectively.

2.0 INPUT

2.1 32P HSM Dose MCNP Input/Output Decks

The only inputs are the base 32P MCNP cases from the CD-ROM associated with Reference 6 (listed in Table 2-1 below). Table 2-1 also provides the output filenames for the revised MCNP runs performed in this calculation.

Table 2-1. MCNP Output Filenames

Target ID[A]	Configuration	USAR Reference	Extended Burnup 32P Filenames		Base 32P Filenames	
			Gamma	Neutron	Gamma	Neutron
H1	Above HSM Roof Surface on fuel axial mid-plane	Table 12.7-1 row 1	pXbg12co	nXbg12do	nubg12co	nubg12do
H2	HSM Air Outlet Grill	Table 12.7-1 row 2				
H3	Center of Door (Door is closed)	Table 12.7-1 row 3				
H4	Center of Doorway (Door is open)	Table 12.7-1 row 4				
H4	Bottom of DSC on axis at 1 ft (Seismic Restraint - door open)	n/a				
H5	Air Inlet Grill	Table 12.7-1 row 5 Section 12.8.2.7.3				
H6	1 meter from HSM Door	Table 12.7-1 row 6				
H7	Below DSC on Axis at 66.7 ft (Seismic Restraint - door open 2')	Section 7.4.2	pXbg09eo	nXbg09ho	nubg9ebo	nubg09ho
H7	Below DSC on Axis at 66.7 ft (Seismic Restraint Activity - door open 2' – 3' end wall modeled)		pXbg9eMo	n/a	n/a	
-	Above HSM Roof Surface on fuel axial mid-plane (forest fire spalling)	Section 12.8.2.10.2	pXb12cfo	nXb12dfo	n/a	
-	HSM Concrete Fluence	Section 12.8.1.1.5	pXbg12Mo	nXbg12Ho	n/a	
-	Site East/West 10ft	Figure 7.4-1	Xewp-0o	Xewn10o	ewp10do	ewn10co
-	Site East/West 30 ft		Xewp-1ao	Xewn21o	ewp01do	ewn21ao
-	Site East/West 60 ft		Xewp-2o	Xewn12o	ewp12ao	ewn12co
-	Site East/West 100 ft		Xewp-3o	Xewn13o	ewp03bo	ewn13bo
-	Site East/West 300 ft		Xewp-4ao	Xewn14o	ewp04ao	ewn14o
-	Site East/West 600 ft		Xewp-5ao	Xewn15o	ewp15o	ewn15ao
-	Site East/West 1000 ft		Xewp-6ao	Xewn16o	ewp16o	ewn16co
-	Site East/West 3000 ft		Xewp-7o	Xnsn57o	ewp17o	nsn57o
-	Site North/Sourth 10 ft	Figure 7.4-2	Xnsp10o	Xnsn10o	nsp10co	nsn10do
-	Site North/Sourth 30 ft		Xnsp11o	Xnsn11o	nsp11co	nsn11o
-	Site North/Sourth 60 ft		Xnsp02o	Xnsn12o	nsp02co	nsn12o
-	Site North/Sourth 100 ft		Xnsp03o	Xnsn13o	nsp03co	nsn13ao
-	Site North/Sourth 300 ft		Xnsp24o	Xnsn14o	nsp24o	nsn14co
-	Site North/Sourth 600 ft		Xnsp15o	Xnsn15o	nsp15o	nsn15o
-	Site North/Sourth 1000 ft		Xnsp16o	Xnsn16o	nsp16o	nsn16do
-	Site North/Sourth 3000 ft		Xnsp17o	Xnsn57o	nsp17o	nsn57o

Notes: A The configuration target ID numbers are based in part on Table 7.3-1 in USAR.

2.2 Extended Burnup Neutron Source Term

The neutron source term is obtained from Reference 1 (Table 6-6) and is summarized in Table 2-2 below. Only the tally multiplier and the energy spectrum (ERG) portion of the neutron source description was changed in the MCNP inputs. Reference 1 (Section 6.4) determined that the burnup profiles used in References 2, 3, and 6 remain applicable, and therefore the axial distribution (EXT) portion of the source used in the original 32P cases remains unchanged. Since the F4 tally result modified by the ANSI/ANS-6.1.1-1977 dose conversion factors is in the form of rem/hr/history, it must be multiplied by 4.175E8 neutrons/second per assembly, 32 assemblies per canister, and a factor of 1.107 to account for axial peaking of the neutron source. An additional factor of 1000 is also applied to convert the final result to mrem/hr, yielding the mulplier of 1.479E13 used on the FM cards for neutrons and capture photons.

2.3 Extended Burnup Photon Source Term

The photon source term is obtained from Reference 1 (Table 6-10) and is summarized in Table 2-3 below. For consistencey with previous 24P and 32P shielding calculations (References 2,3 and 6), the total photon source is conservatively used for the active fuel region source. While the fuel region axial burnup distribution is not being changed, changes in the endfitting and plenum sources require the axial distribution input on the EXT card of the source to be updated. This revised axial distribution is developed and presented below in Table 2-4. Since the F4 tally result modified by the ANSI/ANS-6.1.1-1977 dose conversion factors is in the form of rem/hr/history, it must be multiplied by 471E15 photons/second per assembly and 32 assemblies per canister. An additional factor of 1000 is also applied to convert the final result to mrem/hr, yielding the mulplier of 1.506E20 used on the FM cards for direct photon cases.

Table 2-2. 44-group Extended Burnup Assembly Neutron Source (3.4% enrichment, 52 GWd/MTU, 16y decay)

Group	Emin (MeV)	Emax (MeV)	Neutrons/sec	Group	Emin (MeV)	Emax	Neutrons/sec
1	1.40E+01	2.00E+01	0.000E+00	20	1.66E+00	1.80E+00	1.640E+07
2	1.20E+01	1.40E+01	7.343E+04	21	1.57E+00	1.66E+00	1.091E+07
3	1.00E+01	1.20E+01	4.500E+05	22	1.50E+00	1.57E+00	9.098E+06
4	8.00E+00	1.00E+01	1.525E+06	23	1.44E+00	1.50E+00	7.771E+06
5	7.50E+00	8.00E+00	1.233E+06	24	1.33E+00	1.44E+00	1.556E+07
6	7.00E+00	7.50E+00	1.648E+06	25	1.20E+00	1.33E+00	1.924E+07
7	6.50E+00	7.00E+00	2.438E+06	26	1.00E+00	1.20E+00	2.992E+07
8	6.00E+00	6.50E+00	3.643E+06	27	8.00E-01	1.00E+00	2.910E+07
9	5.50E+00	6.00E+00	5.460E+06	28	7.00E-01	8.00E-01	1.680E+07
10	5.00E+00	5.50E+00	7.343E+06	29	6.00E-01	7.00E-01	1.678E+07
11	4.50E+00	5.00E+00	1.017E+07	30	5.12E-01	6.00E-01	1.443E+07
12	4.00E+00	4.50E+00	1.330E+07	31	5.10E-01	5.12E-01	3.280E+05
13	3.50E+00	4.00E+00	2.145E+07	32	4.50E-01	5.10E-01	9.839E+06
14	3.00E+00	3.50E+00	2.662E+07	33	4.00E-01	4.50E-01	8.198E+06
15	2.50E+00	3.00E+00	3.467E+07	34	3.00E-01	4.00E-01	1.583E+07
16	2.35E+00	2.50E+00	1.310E+07	35	2.00E-01	3.00E-01	3.838E+03
17	2.15E+00	2.35E+00	1.833E+07	36	1.50E-01	2.00E-01	1.919E+03
18	2.00E+00	2.15E+00	1.456E+07	37	1.00E-01	1.50E-01	1.919E+03
19	1.80E+00	2.00E+00	2.124E+07	38 - 44	1.00E-02	1.00E-01	0.000E+00
						Total	4.175E+08

Table 2-3. 18-group Extended Burnup Assembly Photon Source (4.3% enrichment, 40 GWd/MTU, 7y decay)

Group	Emin (MeV)	Emax (MeV)	Top Endfitting		Plenum		Active Fuel		Bottom Endfitting		Total	
			γ/sec	MeV/sec	γ/sec	MeV/sec	γ/sec	MeV/sec	γ/sec	MeV/sec	γ/sec	MeV/sec
1	0.00E+00	2.00E-02	2.76E+11	2.78E+09	1.75E-11	1.76E+09	1.12E+15	1.13E+13	6.89E+11	6.92E+09	1.12E+15	1.13E+13
2	2.00E-02	3.00E-02	2.12E+12	5.29E+10	7.18E-10	1.79E+09	2.41E+14	6.01E+12	2.19E+12	5.47E+10	2.45E+14	6.12E+12
3	3.00E-02	4.50E-02	5.06E+11	1.90E+10	2.97E-10	1.11E+09	3.03E+14	1.13E+13	5.53E+11	2.07E+10	3.04E+14	1.14E+13
4	4.50E-02	7.00E-02	1.77E+10	1.02E+09	1.70E+10	9.75E+08	1.96E+14	1.13E+13	5.84E+10	3.36E+09	1.96E+14	1.13E+13
5	7.00E-02	1.00E-01	9.01E+09	7.66E+08	8.06E+09	6.85E+08	1.31E+14	1.11E+13	2.83E+10	2.41E+09	1.31E+14	1.11E+13
6	1.00E-01	1.50E-01	1.60E+10	1.99E+09	4.10E+09	5.12E+08	1.33E+14	1.67E+13	2.52E+10	3.15E+09	1.33E+14	1.67E+13
7	1.50E-01	3.00E-01	1.74E+11	3.92E+10	4.51E+09	1.01E+09	1.15E+14	2.58E+13	1.77E+11	3.97E+10	1.15E+14	2.59E+13
8	3.00E-01	4.50E-01	1.03E+12	3.87E+11	2.14E+10	8.01E+09	5.71E+13	2.14E+13	1.03E+12	3.88E+11	5.92E+13	2.22E+13
9	4.50E-01	7.00E-01	1.33E+12	7.64E+11	2.72E+10	1.56E+10	2.00E+15	1.15E+15	1.33E+12	7.64E+11	2.00E+15	1.15E+15
10	7.00E-01	1.00E+00	1.93E+09	1.64E+09	1.84E+10	1.56E+10	2.73E+14	2.32E+14	1.31E+10	1.11E+10	2.73E+14	2.32E+14
11	1.00E+00	1.50E+00	1.36E+12	1.70E+12	6.50E+12	8.13E+12	6.43E+13	8.04E+13	1.72E+13	2.16E+13	8.94E+13	1.12E+14
12	1.50E+00	2.00E+00	9.78E-01	1.71E+00	8.09E+01	1.42E+02	1.88E+12	3.28E+12	1.15E+01	2.02E+01	1.88E+12	3.28E+12
13	2.00E+00	2.50E+00	7.19E+06	1.62E+07	3.43E+07	7.72E+07	4.62E+11	1.04E+12	9.10E+07	2.05E+08	4.62E+11	1.04E+12
14	2.50E+00	3.00E+00	1.12E+04	3.07E+04	5.32E+04	1.46E+05	1.71E+10	4.70E+10	1.41E+05	3.88E+05	1.71E+10	4.70E+10
15	3.00E+00	4.00E+00	3.11E-12	1.09E-11	2.05E-13	7.18E-13	2.13E+09	7.46E+09	3.95E-10	1.38E-09	2.13E+09	7.46E+09
16	4.00E+00	6.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.48E+06	2.74E+07	0.00E+00	0.00E+00	5.48E+06	2.74E+07
17	6.00E+00	8.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.31E+05	4.42E+06	0.00E+00	0.00E+00	6.31E+05	4.42E+06
18	8.00E+00	1.10E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.26E+04	6.90E+05	0.00E+00	0.00E+00	7.26E+04	6.90E+05
		Total	6.84E+12	2.97E+12	6.88E+12	8.18E+12	4.63E+15	1.58E+15	2.33E+13	2.28E+13	4.67E+15	1.61E+15

Table 2-4. Extended Burnup Assembly Photon Source Axial Distribution

Source Region	Region γ/sec	Model Elevation (cm)	Region Axial Distribution	Assembly γ/sec	Assembly Axial Distribution
Bottom	2.33E+13	-12.7 - 0.0	1	2.33E+13	0.00496
Active Fuel	4.67E+15	0.0 - 8.9	0.01463	6.83E+13	0.01452
		8.9 - 26.7	0.04201	1.96E+14	0.04168
		26.7 - 49.5	0.06552	3.06E+14	0.06500
		49.5 - 297.8	0.76058	3.55E+15	0.75459
		297.8 - 320.5	0.06400	2.99E+14	0.06350
		320.5 - 338.3	0.03993	1.86E+14	0.03962
		338.3 - 347.2	0.01333	6.22E+13	0.01322
Plenum	6.88E+12	347.2 - 370.9	1	6.88E+12	0.00146
Top	6.84E+12	370.9 - 386.1	1	6.84E+12	0.00145
			Total	4.71E+15	1.00000

2.4 Material Compositions

All material compositions in the model remain the same as those used in Reference 6.

2.5 MCNP Cross Section Libraries

All MCNP5 cross section libraries are contained on Constellation Energy safety related computer PCD4307 in the directory *C:/Program Files/LANL/MCNPDATA*. The gamma shielding calculations were performed with the *mcplib04* photon interaction cross sections, which are based on evaluated data from ENDF/B-VI from 1 keV to 100 MeV. The *xsdir* cross section directory was used for this calculation. These are the default cross-sections selected by MCNP if specific libraries are not specified for each isotope.

2.6 Flux-to-Dose Conversion Factors

For gamma dose rate calculations in MCNP, the ANSI/ANS-6.1.1-1977 (Ref. 14, App. H) photon flux-to-dose conversion factors were utilized (see Table 2-5), in conjunction with the total direct gamma and neutron source strength, to produce tally results in dose equivalent units of rem/hour. ANSI/ANS-6.1.1-1977 neutron flux-to-dose conversion factors were also utilized (see Table 2-6), in conjunction with the total neutron source strength, to produce tally results in dose equivalent units of rem/hour. These flux-to-dose conversion factors can be found on the DE and DF cards for each MCNP input case, and are the same as used in the original cases.

Table 2-5. ANSI/ANS-6.1.1-1977 Photon Flux-to-Dose Conversion Factors

Energy (MeV)	DF(E) (rem/hr)/(p/cm^{2}s)	Energy (MeV)	DF(E) (rem/hr)/(p/cm^{2}s)
0.01	3.96E-06	1.40	2.51E-06
0.03	5.82E-07	1.80	2.99E-06
0.05	2.90E-07	2.20	3.42E-06
0.07	2.58E-07	2.60	3.82E-06
0.10	2.83E-07	2.80	4.01E-06
0.15	3.79E-07	3.25	4.41E-06
0.20	5.01E-07	3.75	4.83E-06
0.25	6.31E-07	4.25	5.23E-06
0.30	7.59E-07	4.75	5.60E-06
0.35	8.78E-07	5.00	5.80E-06
0.40	9.85E-07	5.25	6.01E-06
0.45	1.08E-06	5.75	6.37E-06
0.50	1.17E-06	6.25	6.74E-06
0.55	1.27E-06	6.75	7.11E-06
0.60	1.36E-06	7.50	7.66E-06
0.65	1.44E-06	9.00	8.77E-06
0.70	1.52E-06	11.00	1.03E-05
0.80	1.68E-06	13.00	1.18E-05
1.00	1.98E-06	15.00	1.33E-05

Table 2-6. ANSI/ANS-6.1.1-1977 Neutron Flux-to-Dose Conversion Factors

Energy, E (MeV)	DF(E) (rem/hr)/(n/cm2-s)	Quality Factor
2.50E-08	3.67E-06	2
1.00E-07	3.67E-06	2
1.00E-06	4.46E-06	2
1.00E-05	4.54E-06	2
1.00E-04	4.18E-06	2
1.00E-03	3.76E-06	2
1.00E-02	3.56E-06	2.5
1.00E-01	2.17E-05	7.5
5.00E-01	9.26E-05	11
1	1.32E-04	11
2.5	1.25E-04	9
5	1.56E-04	8
7	1.47E-04	7
10	1.47E-04	6.5
14	2.08E-04	7.5
20	2.27E-04	8

3.0 ASSUMPTIONS

All assumptions from Reference 6 remain applicable. No new assumptions were made in this calculation.

4.0 REFERENCES

1. CCNPP Calculation CA06721, "Source Terms for ISFSI 32P Burnup Extension," Rev. 0
2. CCNPP Calculation CA06058, "ISFSI 24P 5-Phase Site Dose Rates," Rev. 0.
3. CCNPP Calculation CA05925, "Calvert Cliffs ISFSI/NUHOMS-24P HSM Dose Rates," Rev. 0.
4. CCNPP Calculation CA03945, "NUHOMS 24P Forest Fire Evaluation," Rev. 0000.
5. CCNPP Calculation CA06629, "NUHOMS 32P Forest Fire Evaluation, " Rev. 0000.
6. CCNPP Calculation CA06293, Rev. 0000, "NUHOMS-32P HSM Dose Rates for Calvert Cliffs ISFSI," Transnuclear Calculation 1095-50, Rev. 0.
7. CCNPP Engineering Service Package ES200100653.
8. CCNPP Drawing 84081, "ISFSF Horizontal Storage Modules Concrete Sections," Rev. 0000.
9. CCNPP Drawing 84075, "Independent Spent Fuel Storage Facility Site Plan," Rev. 0000.
10. CCNPP Calculation CA06585, "Verification of MCNP5 on PCD4307," Rev. 0
11. CCNPP Calculation CA06588, "MCNP5 Shielding Validation," Rev. 0
12. LANL Document LA-UR-03-1987, "MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, Volume I: Overview and Theory" Los Alamos National Laboratory, April 2003.
13. LANL Document LA-CP-03-0245, "MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, Volume II: Users Guide" Los Alamos National Laboratory, April 2003.
14. LANL Document LA-CP-03-0284, "MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, Volume III: Developers Guide" Los Alamos National Laboratory, April 2003.
15. CCNPP Calculation Change Notice CA06327-0001, Rev. 0000.
16. CCNPP Engineering Evaluation ES200600365-001, Rev. 0000.
17. NUH-002, Topical Report for the NUTECH Horizontal Modular Storage System for Irradiated Nuclear Fuel – NUHOMS-24P," Rev. 1A.

5.0 METHOD OF ANALYSIS

The MCNP5 code (Ref. 12-14) was utilized to calculate gamma (primary and capture) and neutron dose rates at the locations of interest. MCNP5 is a general-purpose Monte-Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport, including the capability to calculate k_{eff} for critical systems. The code simulates transport of individual particles in a user-defined three-dimensional configuration of materials, and records user-specified information (tallies) on their average behavior. For this application it is being used in both photon-only mode (direct gamma) and coupled neutron-photon mode (neutron and capture gamma). The code has the capability of considering photon source energies from 1 keV to 1000 MeV and neutron energies from 10^{-11} to 20 MeV.

6.0 CALCULATION AND COMPUTATIONS

6.1 HSM Dose Rates

Table 6-1 presents the results of the extended burnup 32P neutron dose rate cases, and provides a comparison against the current 32P dose rates. Values in bold font represent results reported in the ISFSI USAR Table 12.7-1. Only unshielded dose rates show significant increases with the new extended burnup source. Dose rates in heavily shielded locations are similar or slightly lower than for the current 32P due to the fact that the highest energy group is now 14 MeV rather than 20 MeV as with the previous 8-group spectrum (original top group went from 6 to 20 MeV).

Table 6-1. NUHOMS 32P Base and Extended Burnup HSM Neutron Dose Rates

Location	Target ID	MCNP Tally Cell	Tally No.	Results for NUHOMS-32P		Results for NUHOMS-32P+		32P/32P+ % Change
				Dose Rate (mrem/hour)	Relative Error	Dose Rate (mrem/hour)	Relative Error	
HSM Top/Side	H1	20	304	**0.57**	3.52%	**0.46**	2.41%	-18.59%
South Outlet	-	21	314	1.04	4.57%	1.00	2.53%	-3.69%
Door Outside	H3	22	324	**5.79**	1.81%	**5.82**	0.98%	0.57%
Door Inside	H4	23	334	**1075**	0.45%	**1246**	0.25%	15.93%
Near Inlet	H5	24	344	**0.96**	5.97%	**0.98**	3.45%	2.31%
Door 1 meter	H6	25	354	**2.97**	1.89%	**2.97**	1.17%	0.00%
North Outlet	H2	26	364	**1.20**	4.18%	**1.29**	2.25%	6.90%
South Outlet, 1ft	-	27	374	0.70	5.60%	0.61	3.40%	-12.80%
North Outlet, 1ft	-	28	384	0.62	4.90%	0.65	3.00%	5.17%
Door Inside Ring	-	30	404	914	0.42%	1056	0.23%	15.55%

Table 6-2 presents the results from the direct gamma dose rate cases for the extended burnup 32P and the current burnup 32P DSC for comparison. Capture gamma dose rates are also calculated in the neutron dose output files, however, they remain less than 1.6% of the total dose and are therefore not reported (consistent with Reference 6). All extended burnup dose rates show an increase for the extended burnup 32P, with the exception of those at the inlet vent, which show a 10% decrease.

This effect was traced to the differences between the *mcplib02* photon libraries used in the original MCNP4B calculation used for the base 32P, and the newer *mcplib04* libraries used for the MCNP5 calculations performed herein for the extended burnup 32P. MCNP5 contains two new continuous-energy photoatomic libraries. The *mcplib03* library contains data for elements Z equal 1 to 94. This library is an extension of the *mcplib02* library. *Mcplib02* and *mcplib03* contain identical cross-section, fluorescence and form factor data. *Mcplib03* has been

extended to include Compton profile data suitable for calculating the Doppler broadening of the energy for Compton scattered photons. The core of the *mcplib04* library is a completely new set of data taken from ENDF/B-VI release 8 including cross section, form factor, scattering function and fluorescence data. These data are derived from EPDL97. Tables are included in this library for elements Z equal 1 to 100 (finally providing tables for elements Z equal 95 to 100) in the energy range 1 keV to 100 GeV. These tables are significantly denser (i.e. they contain more energy points in the tabulation) and therefore more accurately represent the cross-section data than the earlier photon libraries. In addition to these core data, *mcplib04* has been extended to include the same Compton profile data as found on *mcplib03*.

The original base 32P input deck (nubg12c) was rerun unchanged and for the same number of histories with MCNP5, which automatically selects the *mcplib04* library if none is specified. As shown in Table 6-2a, most locations show only a few percent change. However, in cells 22, 24, and 25, the deviation is on the order of an 18-27% reduction. When rerun again with MCNP5, but with the *mcplib02* library specified, most of the difference in these locations is eliminated (see Table 6-2a).

Note that Reference 3 benchmarking (p. 68) indicates calculated inlet dose rates for the inlet vent dose (cell 24) of the 24P HSM model (MCNP4C *mcplib02*) were conservative by 60% when compared with measured dose rates. Therefore, the reduction seen in dose rates at the inlet vent for the extended burnup 32P in Table 6-2 is a result of improved accuracy in the model afforded by use of MCNP5 and the *mcplib04* photon libraries.

Table 6-2. NUHOMS 32P Base and Extended Burnup HSM Direct Gamma Dose Rates

Location	Target ID	MCNP Tally Cell	Tally No.	Base NUHOMS-32P		Extended Burnup NUHOMS-32P		32P/32P+ % Change
				Dose Rate (mrem/hour)	Relative Error	Dose Rate (mrem/hour)	Relative Error	
HSM Top/Side	H1	20	204	**9.3**	6.49%	**13.0**	7.72%	40.13%
South Outlet	-	21	214	45.7	4.41%	54.6	4.76%	19.52%
Door Outside	H3[a]	22	224	**5.0**	12.90%	**6.1**	15.30%	21.89%
Door Inside	-	23	234	2131.5	2.36%	2766.7	2.90%	29.80%
Near Inlet	H5	24	244	**66.9**	6.47%	**60.0**	7.50%	-10.34%
Door 1 meter	H6[a]	25	254	**3.8**	13.00%	**4.5**	14.95%	17.99%
North Outlet	H2	26	264	**54.3**	4.58%	**74.1**	5.46%	36.42%
South Outlet, 1ft	-	27	274	23.0	8.04%	26.5	6.53%	15.27%
North Outlet, 1ft	-	28	284	23.7	5.31%	32.7	6.40%	38.33%
Door Inside Ring	H4	30	304	**2943.3**	1.77%	**3411.9**	1.97%	15.92%

Note: a) The values in the USAR for 32P are multiplied by 1+2RE due to RE > 10%

Table 6-2a. NUHOMS 32P Base HSM Gamma Dose Rates with Different Code Versions/Libraries

Location	Tally Cell	mcnp4B mcplib02 (Ref. 6 nubg12co)		mcnp5 mcplib04 (CD case nubg12co)		mcnp5 mcplib02 (CD case n2bg12co)		Code + Library % Change	Code Only % Change
		Dose Rate (mrem/hour)	Relative Error	Dose Rate (mrem/hour)	Relative Error	Dose Rate (mrem/hour)	Relative Error		
HSM Top/Side	20	9.3	6.49%	8.7	6.10%	8.5	6.22%	-6.67%	-8.55%
South Outlet	21	45.7	4.41%	44.3	4.25%	42.3	4.50%	-2.94%	-7.42%
Door Outside	22	5.0	12.90%	3.7	14.89%	4.4	13.54%	-26.96%	-12.49%
Door Inside	23	2131.5	2.36%	2006.0	2.49%	2066.6	2.38%	-5.89%	-3.04%
Near Inlet	24	66.9	6.47%	50.8	6.66%	63.8	6.49%	-24.13%	-4.75%
Door 1 meter	25	3.8	13.00%	3.1	14.32%	3.1	13.32%	-17.99%	-16.63%
North Outlet	26	54.3	4.58%	52.0	4.64%	53.2	4.45%	-4.33%	-2.06%
South Outlet, 1ft	27	23.0	8.04%	20.6	6.29%	22.3	7.72%	-10.58%	-2.97%
North Outlet, 1ft	28	23.7	5.31%	22.6	5.49%	23.7	5.64%	-4.25%	0.35%
Door Inside Ring	30	2943.3	1.77%	2799.6	1.73%	2894.5	1.82%	-4.88%	-1.66%

Table 6-3 provides the sum of the neutron and gamma dose rates. In summing the neutron and gamma dose rates, those with relative errors greater than 10% were multiplied by a factor of 1+2RE, for consistency with the method used to account for uncertainty in Reference 6. All total dose rates show an increase for the the extended burnup 32P compared to the base 32P at the current burnup limit, with the exception of the inlet vent dose rates. The reason for the drop in the inlet vent dose rate is discussed above. Note that the value used for the total dose rate of target H4 (inside door) in the USAR is the sum of the maximum neutron and maximum gamma dose rates from tally cells 23 and 30, and thus the total dose rates for thes locations are not indicated in bold in Table 6-3.

Table 6-3. NUHOMS 32P Base and Extended Burnup HSM Total Dose Rates (mrem/hr)

Location	MCNP Tally Cell	Base 32P	Extended Burnup 32P	32P+/32P % Change
HSM Top/Side	20	**9.9**	**13.5**	36.75%
South Outlet	21	46.7	55.6	19.01%
Door Outside	22	**12.1**	**13.8**	14.12%
Door Inside	23	3206.4	4012.9	25.15%
Near Inlet	24	**67.9**	**61.0**	-10.16%
Door 1 meter	25	**7.7**	**8.8**	13.32%
North Outlet	26	**55.5**	**75.4**	35.78%
South Outlet, 1ft	27	23.7	27.1	14.44%
North Outlet, 1ft	28	24.3	33.4	37.48%
Door Inside Ring	30	3857.2	4467.9	15.83%

6.2 Fully Loaded Site Dose Rates

Tables 6-4 and 6-5 present the current and extended burnup 32P gamma and neutron dose rates in the North-South direction, respectively. Tables 6-6 and 6-7 present the current and extended burnup 32P gamm and neutron dose rates in the East-West direction, respectively. Table 2-1 provides the MCNP output filename from which each result was taken. All cases were run with the with the weight windows used in the final cases from Reference 6 and for the same number of histories. In the case of the east-west gamma dose models, the inial runs did not show an acceptable relative error, and thus were run again using the weight windows from the previous runs to produce the cases listed in Table 2-1 and the results in Table 6-6. Also, as in Reference 6, all neutron dose rates at the 3000 ft distance come from case Xnsn57o.

Table 6-4 NUHOMS-32P Base and Extended Burnup Site Gamma Dose Rates as a function of Distance in the North-South Direction

Distance (feet)	Base NUHOMS-32P				Extended Burnup NUHOMS-32P				32P/32P+ % Change
	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	
10	7.01E+00	0.1205	0.1046	8.70E+00	4.31E+00	0.1265	0.1615	5.40E+00	-37.89%
30	1.24E+00	0.1381	0.1013	1.58E+00	1.64E+00	0.2046	0.3238	2.32E+00	46.41%
60	4.42E-01	0.1468	0.1091	5.71E-01	7.13E-01	0.2339	0.5313	1.05E+00	83.23%
100	1.82E-01	0.1169	0.136	2.25E-01	2.62E-01	0.2023	0.5626	3.69E-01	63.96%
300	3.35E-02	0.0691	0.1384	3.35E-02	4.74E-02	0.1343	0.6235	6.01E-02	79.36%
600	6.59E-03	0.0606	0.0642	6.59E-03	9.33E-03	0.1100	0.2591	1.14E-02	72.66%
1000	1.06E-03	0.0756	0.1383	1.06E-03	1.35E-03	0.1866	0.8529	1.86E-03	75.80%
3000	1.95E-07	0.0908	0.105	1.95E-07	3.08E-07	0.1463	0.1189	3.98E-07	104.00%

Table 6-5 NUHOMS-32P Base and Extended Burnup Site Neutron Dose Rates as a function of Distance in the North-South Direction

Distance (feet)	Base NUHOMS-32P				Extended Burnup NUHOMS-32P				32P/32P+ % Change
	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	
10	1.41E+00	0.054	0.0231	1.41E+00	1.68E+00	0.1545	0.5749	2.20E+00	55.79%
30	6.44E-01	0.0446	0.0638	6.44E-01	7.15E-01	0.0563	0.1975	7.15E-01	11.12%
60	2.69E-01	0.0278	0.0471	2.69E-01	2.95E-01	0.029	0.0565	2.95E-01	9.39%
100	1.24E-01	0.0351	0.08	1.24E-01	1.42E-01	0.0546	0.2277	1.42E-01	14.52%
300	1.46E-02	0.0712	0.0816	1.46E-02	1.51E-02	0.0762	0.1627	1.51E-02	3.94%
600	2.99E-03	0.0883	0.4889	2.99E-03	2.71E-03	0.075	0.3397	2.71E-03	-9.52%
1000	5.97E-04	0.0973	0.1493	7.14E-04	5.65E-04	0.0802	0.1002	5.65E-04	-20.88%
3000	2.05E-06	0.3629	0.8604	3.54E-06	1.26E-06*	0.2543*	0.5293*	1.90E-06	-46.20%

* - Results from Tally 175 of *Xnsn57o*

Table 6-6 NUHOMS-32P Base and Extended Burnup Site Gamma Dose Rates as a function of Distance in the East-West Direction

Distance (feet)	Base NUHOMS-32P				Extended Burnup NUHOMS-32P				32P/32P+ % Change
	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	
10	1.65E+00	0.1456	0.1581	2.13E+00	1.54E+00	0.0769	0.1885	1.54E+00	-27.72%
30	6.00E-01	0.1202	0.1284	7.44E-01	7.85E-01	0.1240	0.1322	9.80E-01	31.77%
60	2.78E-01	0.0693	0.0382	2.78E-01	3.65E-01	0.1080	0.1285	4.44E-01	59.44%
100	1.74E-01	0.0965	0.0935	2.08E-01	1.85E-01	0.1431	0.1090	2.38E-01	14.68%
300	3.52E-02	0.1122	0.0675	4.31E-02	3.68E-02	0.2826	0.2729	5.76E-02	33.58%
600	7.47E-03	0.0498	0.079	7.47E-03	8.41E-03	0.2455	0.6579	1.25E-02	67.77%
1000	1.06E-03	0.0850	0.3678	1.06E-03	1.45E-03	0.0742	0.1701	1.45E-03	36.59%
3000	5.47E-07	0.1624	0.3463	7.25E-07	1.41E-06	0.1496	0.1342	1.84E-06	153.16%

Table 6-7 NUHOMS-32P Base and Extended Burnup Site Neutron Dose Rates as a function of Distance in the East-West Direction

Distance (feet)	Base NUHOMS-32P				Extended Burnup NUHOMS-32P				32P/32P+ % Change
	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	MCNP Dose Rate (mR/hr)	Relative Error	VOV	Final Dose Rate (mR/hr)	
10	3.20E-01	0.0667	0.0568	3.20E-01	3.18E-01	0.0715	0.2028	3.18E-01	-0.76%
30	2.30E-01	0.0404	0.0437	2.30E-01	2.29E-01	0.0374	0.0469	2.29E-01	-0.74%
60	1.47E-01	0.0590	0.5318	1.47E-01	1.45E-01	0.0274	0.1074	1.45E-01	-1.55%
100	8.14E-02	0.0369	0.0732	8.14E-02	1.14E-01	0.1110	0.5494	1.39E-01	70.52%
300	1.54E-02	0.0403	0.072	1.54E-02	1.69E-02	0.0643	0.3621	1.69E-02	9.61%
600	3.32E-03	0.0760	0.1997	3.32E-03	3.32E-03	0.1098	0.4072	4.05E-03	22.13%
1000	5.64E-04	0.0710	0.3139	5.64E-04	4.83E-04	0.0710	0.2813	4.83E-04	-14.47%
3000	2.84E-06	0.3026	0.3084	4.55E-06	1.18E-06*	0.2067*	0.1751*	1.67E-06	-63.23%

* - Results from Tally 275 of *Xnsn57o*

Figures 6-1 and 6-2 provide a visual comparison of the total site dose rates in the north-south and east-west directions, respectively, with the current USAR Figure 7.4-1 and 7.4-2 curves which bound both the 24P and base 32P designs. Tables 6-8 and 6-9 summarize the total dose rates from References 2 and 6 utilized to generate the current bounding figures in the USAR, and also summarizes the new total dose rates for the extended burnup 32P and defines new bounding values for use in the USAR. As in Reference 6, in summing the neutron and gamma dose rates, those with relative errors greater than 10% were multiplied by a factor of 1+2RE. New bounding site dose figures are provided in Section 8.

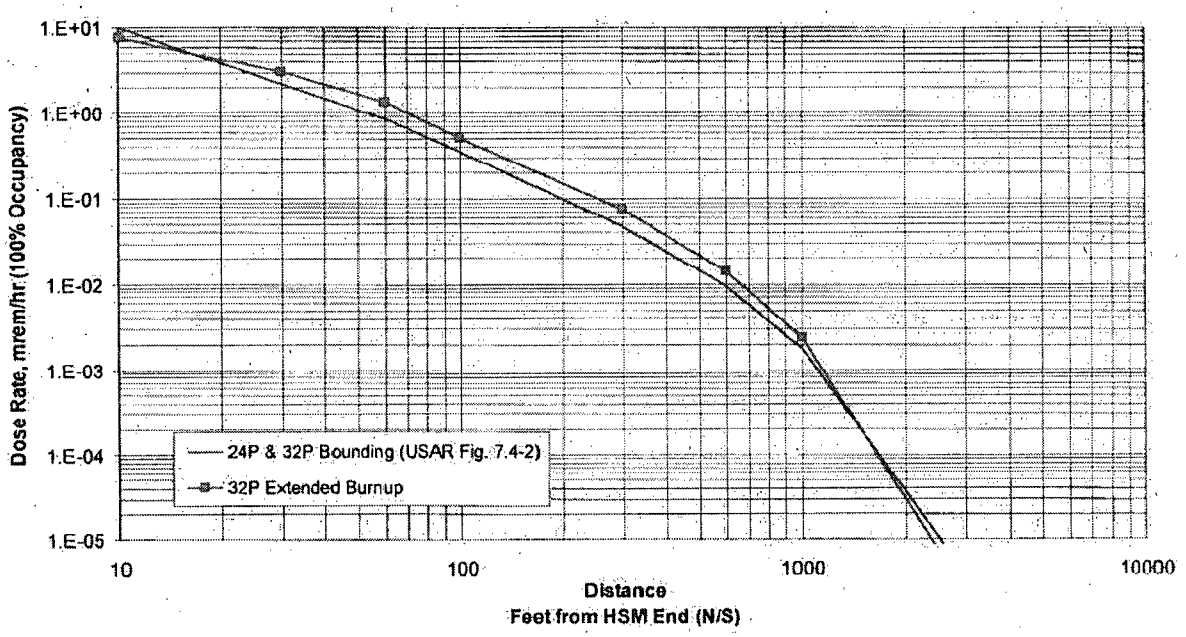

Figure 6-1. Current and Extended Burnup 32P Total Site Dose Rate in North-South Direction for a Fully Loaded ISFSI

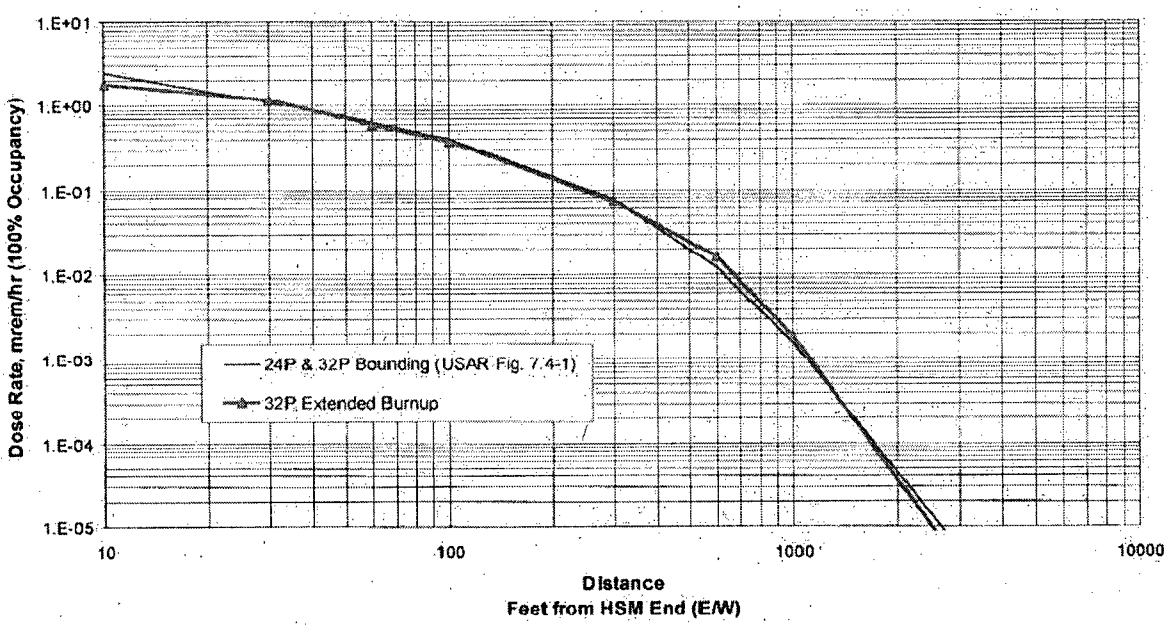

Figure 6-2. Current and Extended Burnup 32P Total Site Dose Rate in East-West Direction for a Fully Loaded ISFSI

Table 6-8 Bounding Site Total Dose Rates (mrem/hr) as a function of Distance in the North-South Direction

Distance (ft)	24P (Ref. 2)	32P	24P/32P Bounding (USAR Fig 7.4-2)	Extended Burnup 32P	24P/32P/32P Ex BU Bounding
10	5.70E+00	1.01E+01	1.01E+01	7.60E+00	1.01E+01
30	1.52E+00	2.23E+00	2.23E+00	3.03E+00	3.03E+00
50	7.34E-01	-	-	-	-
60	-	8.41E-01	8.41E-01	1.34E+00	1.34E+00
80	4.24E-01	-	-	-	-
100	3.00E-01	3.49E-01	3.49E-01	5.11E-01	5.11E-01
300	4.69E-02	4.81E-02	4.81E-02	7.52E-02	7.52E-02
600	9.11E-03	9.59E-03	9.59E-03	1.41E-02	1.41E-02
1000	1.16E-03	1.77E-03	1.77E-03	2.42E-03	2.42E-03
3000	2.76E-06	3.73E-06	3.73E-06	2.30E-06	3.73E-06

Table 6-9 Bounding Site Total Dose Rates (mrem/hr) as a function of Distance in the East-West Direction

Distance (ft)	24P (Ref. 2)	32P	24P/32P Bounding (USAR Fig 7.4-1)	Extended Burnup 32P	24P/32P/32P Ex BU Bounding
10	2.06E+00	2.45E+00	2.45E+00	1.86E+00	2.45E+00
30	-	9.74E-01	-	1.21E+00	-
31.6	1.07E+00	-	1.07E+00	-	1.21E+00
50.0	7.57E-01	-	7.57E-01	-	7.57E-01
60.0	-	4.25E-01	-	5.89E-01	-
80.0	4.93E-01	-	4.93E-01	-	4.93E-01
100.0	3.94E-01	2.89E-01	3.94E-01	3.77E-01	3.94E-01
300.0	7.86E-02	5.85E-02	7.86E-02	7.45E-02	7.86E-02
600.0	1.20E-02	1.08E-02	1.20E-02	1.66E-02	1.66E-02
1000.0	1.44E-03	1.62E-03	1.62E-03	1.93E-03	1.93E-03
3000.0	3.44E-06	5.28E-06	5.28E-06	3.51E-06	5.28E-06

6.3 ISFSI Fence Dose During Seismic Restraint Installation

The ISFSI USAR (p. 7.4-2) also provides a calculation of the maximum dose outside the ISFSI site fence during seismic restraint installation. During the seismic restraint installation, a person standing outside the ISFSI security fense would be exposed to radiation from all closed/loaded HSMs as well as from the HSM where the seismic restraint is being installed. The dose contribution from each of these sources is as follows:

- Site: Reference 9 shows that the outer fence is 94 feet from the HSMs in the N/S direction, and 53 feet from the HSMs in the E/W direction. Linearly interpolating from the bounding results of Tables 6-8 and 6-9, the maximum doses at these locations from a site consisting of 120 loaded HSMs of extended burnup 32Ps, base 32Ps or 24Ps is 0.64 mrem/hr in the N/S direction, and 0.73 mrem/hr in the E/W direction.

- Seismic Restraint Installation: The minimum distance between the DSC surface and an individual at the closest approach to the outer ISFSI security fence (E/W portion of the fence) is estimated to be 66.7' (ISFSI USAR p. 7.4-2 and Ref. 9). Note that at 66.7' from the DSC surface an individual at the outer security fence will not be directly in front of the HSM and can only see a fraction of the DSC end surface because it is partially shielded by the transfer cask, HSM front wall, and HSM door which is raised 2 feet from the closed position during seismic restraint installation. Table 6-10 provides the dose rate 66.7' directly in front of an HSM and unobstructed by the transfer cask. For the neutron case, the door is conservatively assumed to be fully open, and for the photon case the door is assumed to be open to the 2' level, which is consistent with the manner in which the base 32P was modeled and is basis captured in ISFSI-03. The latter is termed the "original" gamma model, and the results of this model for both the base and extended burnup 32P HSM are provided in Table 6-10.

  It was noted while modifying the model (*pXbg09e*; see Table 2-1) for the extended burnup source that it differs from the model used in Section 6.1 in that the reflective plains at the sides and back of the single HSM (130, 204, and 215) were made non-reflective. As a result, this model represents a single HSM module with only one foot thick concrete shielding on the E-W sides sitting on a pad and surrounded by air, which is highly conservative (see Figure 6-3). As shown in References 8 and 9 and Figure 6-4, the HSMs at CCNPP are formed into 12-packs which have three foot thick concrete shields at either east-west end. A "revised" gamma model (*pXbg9eM*) was constructed which thickened the concrete shielding to 3-foot on one side to investigate the effect of more accurately modeling the HSM (see Figure 6-3). The results of this revised model are also included in Table 6-10, and demonstrate that much of the dose at the 66.7' front tally results from the "original" model are from shine from the artificially thin side walls. The revised model remains conservative as only one side was increased to it's actual thickness.

The ISFSI USAR indicates that seismic restraint installation requires a maximum of 5 minutes (0.08 hours) and can nominally be done in 1 minute (0.017 hours). Thus, based on the total doses in Table 6-10, a person just outside the fence would conservatively receive a maximum of 1.49 mrem (0.08 hr x 18.6 mrem/hr) during the seismic restraint installation process using the original model, or 0.82 mrem (.08 hr x 10.2 mrem/hr) using the revised model. If that person remained outside the fence for an entire hour during the seismic restraint installation, their dose would conservatively not exceed 2.22 mrem using the original seismic restraint installation model (1.49 mrem from seismic restraint installation + 0.73 mrem from the fully loaded ISFSI site) or 1.55 mrem using the revised seismic restraint installation model (0.82 mrem + 0.73 mrem site). The revised seismic restraint installiton model demonstrates that the extended burnup 32P fence dose is within the 10CFR20.105 requirement that no individual (member of the public) may receive greater than 2 mrem in any 1 hour.

Table 6-10. NUHOMS 32P Base and Extended Burnup Seismic Restraint Installation Dose Rates at Fence

Case	Location	MCNP Tally Cell	Tally No.	Base NUHOMS-32P (Ref. 6)		Extended Burnup NUHOMS-32P		32P/ 32P+ % Change
				Dose Rate (mrem/hour)	Relative Error	Dose Rate (mrem/hour)	Relative Error	
Neutron	Open Door @ 66.7 ft	31	414	1.65	2.03%	1.93	1.33%	16.99%
Gamma Original	2' Open Door @ 66.7 ft	31	314	15.2	6.52%	16.7	9.52%	9.48%
Gamma Revised	2' Open Door w/ 3' sides @ 66.7 ft	31	314	-	-	8.18	8.18%	-
Total Original	2' Open Door @ 66.7 ft	31	-	17.1	-	18.6	-	9.1%
Total Revised	2' Open Door w/ 3' sides @ 66.7 ft	31	-	-	-	10.2	-	-

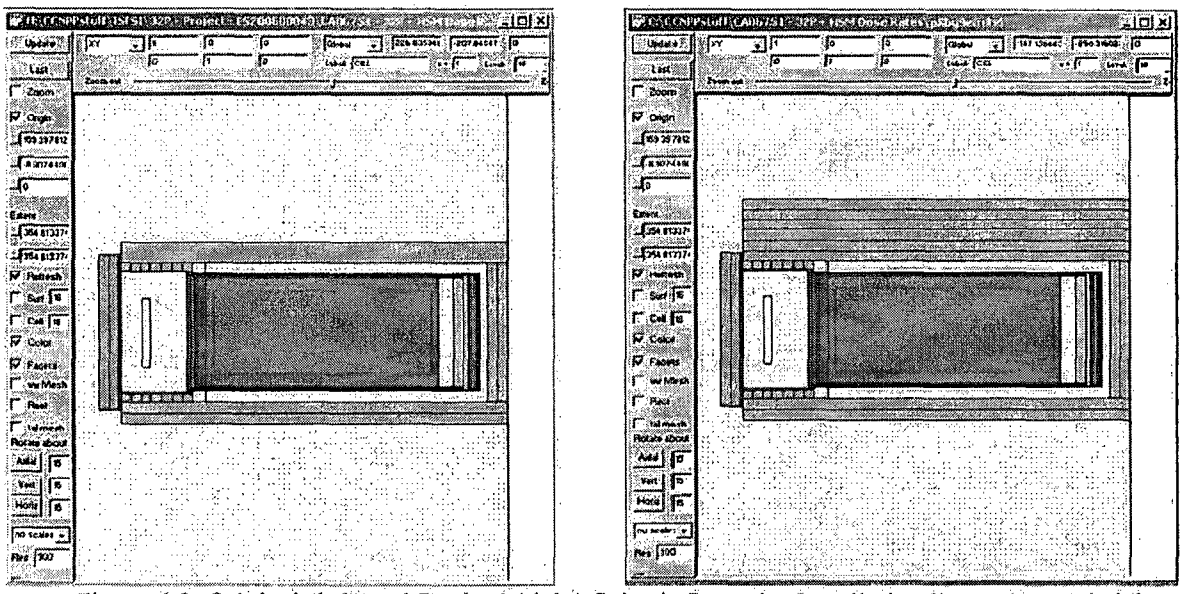

Figure 6-3. Original (left) and Revised (right) Seismic Restraint Installation Fence Dose Models

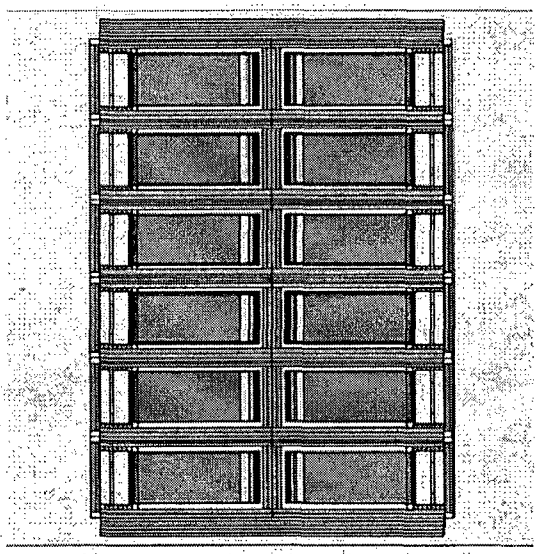

Figure 6-4. HSM 12-Pack Arrangement.

6.4 Dose Rate for Forest Fire Induced Spalling

UFSAR Section 12.8.2.10 postulates a forest fire occurring in the woods adjacent to the Calvert Cliffs ISFSI. The damage to the wall, based on the HSM wall temperature gradient resulting from the fire will be limited to a thickness of 6" for the 32P (Reference 5), which was increased over the 4.5" predicted for the 24P (Reference 4). This depth will not change for the extended burnup 32P as the heat load is not being increased. The effect of the surface cracking and spalling will be minimal with respect to the load capacity of the HSM walls, but will reduce the effective shielding thickness and increase dose rates outside of the HSM.

Reference 4 indicates that a 12" reduction in concrete thickness would produce a factor of 20 increase in dose rate at the HSM surface. This translates to an increase by a factor of 3 for a 4.5" reduction in concrete thickness, and a factor of 4.5 for a 6" reduction in concrete thickness. The original NUHOMS-24P design goal was that the spalling not increase dose rates to a level beyond which repair actions could be performed by conventional methods (1 rem/hr). Table 6-11 presents the dose rates calculated for the 24P, and base and extended burnup 32P designs using the above mentioned multipliers and the base total dose rates from Table 6-3. In addition, the extended burnup HSM model from Section 6.1 was rerun with the concrete on top reduced in thickness by 6 inches, and the results are also presented in Table 6-11. The MCNP model confirms that the original method is conservative. In all cases, the dose rate is below the 1 rem/hr design goal for spalling repair. Thus, it can be concluded that the extended burnup 32P DSC would also not adversely impact the ability to repair spalled concrete following a forest fire.

Table 6-11. HSM Dose Rates for Forest Fire Induced Spalling

Design	Method	Depth of Spallation (inches)	Dose Multiplier	Unspalled Total Dose Rate (mrem/hr)	Spalled Total Dose Rate (mrem/hr)
24P	multiplier	4.5	3.1	12.5	38.4
Base 32P	multiplier	6	4.5	9.9	44.3
Extended Burnup 32P+	multiplier	6	4.5	13.5	60.4
Extended Burnup 32P+	MCNP5	6	n/a	13.5	30.6*

*29.3 mrem/hr gamma from *pXb12cfo* and 1.3 mrem/hr neutron from *nXb12dfo*

In addition, the impact of forest fire induced spalling must be evaluated against the requirements of 10CFR72.106, which establishes an accident dose limit of 5 rem at the site boundary. ISFSI USAR Section 2.1.2.2 indicates that the minimum distances from the ISFSI to the site boundary is 3900 feet. From the results of Tables 6-8 and 6-9 the maximum dose rate at 3000 feet from an ISFSI site consisting of 120 loaded HSMs of extended burnup 32Ps is the same as the bounding dose for the 24P or the base 32P in both the N/S and E/W directions. Therefore, the extended burnup meets this requirement in the same manner as the 24P and base 32P designs.

6.5 Neutron and Gamma Flux at the HSM Concrete Inside Surface

The ISFSI USAR Section 8.1.1.5 determines that the effects of radiation on concrete from a filled 24P DSC are negligible. A similar evaluation is performed for the current 32P DSC in ISFSI USAR Section 12.8.1.1.5. Both are based on the original evaluation performed in Section 8.1.1.5 of the NUHOMS-24P Topical Report (Reference 17). The impacts of neutron and gamma radiation from the extended burnup 32P are as follows:

- Neutron: In the case of neutron irradiation, the NUHOMS 24P Topical Report determines that an estimated 50-year fluence of 1.2E+14 n/cm^2 will not impact the structural integrity of the concrete. For the current 32P an estimated 50-year fluence of 3.4E+14 n/cm^2 based on scaling of the original 24P (conservative given that the 32P egg-crate basket provides additional neutron absorbtion in the radial direction) results was also considered negligible. For the extended burnup 32P HSM, case *nXbg12d* from Section 6.1 was rerun with the Section 2.6 dose conversion factors removed, and neutron flux cell (F4) and surface (F2) tallies added for the inner regions of the HSM (new case output identified as *nXbg12Ho*). Note that the MCNP results must be divided by a factor of 1000 as the mrem/rem factor was not removed from the tally multiplier card (FMx). A desctiption of the tally locations and the associated results is presented in Table 6-12 below. A maximum neutron flux of 1.7E+5 n/cm^{2}s occurs in the steel thermal shield above the DSC (which is closer to the DSC than any HSM concrete). This yields a conservative 50-year fluence of 2.7E+14 n/cm^2 (1.7E5 x 50y x 8760 h/y x 3600 s/h) by assuming no decay in the neutron source strength. This fluence is below that previously considered negligible for the current 32P.

- Gamma: In the case of gamma irradiation, the NUHOMS-24P Topical Report (Reference 17) determined a maximum gamma flux of 6.8E+10 MeV/cm^{2}s for the 24P HSM concrete. The temperature rise in concrete due to this flux was considered negligible per ANS/ANSI 6.4-1977. In the case of the extended burnup 32P, case p*Xbg12c* from Section 6.1 was rerun with the Section 2.6 dose conversion factors removed, the factor of 1000 mrem/rem conversion factor was removed from the tally multiplier card, and photon energy flux cell (*F4) and surface (*F2) tallies were added for the inner regions of the HSM (new case output identified as p*Xbg12Mo*). The maximum calculated gamma flux of 1.32E+9 MeV/cm^{2}s occurs at the bottom surface of the steel thermal shield above the DSC (which is closer to the DSC than any HSM concrete). This is below the value previously considered to result in negligible gamma heating of the HSM concrete.

Thus, the effects of both neutron and gamma radiation on the HSM concrete are determined to remain negligible for an extended burnup 32P DSC.

Table 6-12. Neutron and Gamma Fluxes at HSM Inside Surfaces

Description	Tally Cell or *Surface*	Neutron Flux (*nXbg12Ho*)		Gamma Flux (*pXbg12Mo*)	
		Tally No.	n/cm^{2}s	Tally No.	MeV/cm^{2}s
steel thermal shield above DSC	92	804	1.68E+05	904	1.24E+09
inner side wall cell	205	814	4.50E+04	914	3.07E+08
inner roof cell	310	824	5.16E+04	924	3.01E+08
inlet plenum top cell	150	834	7.72E+04	934	5.33E+08
inner inlet plenum top surface	*306*	872	1.43E+05	-	-
top surface steel thermal shield above DSC	*322*	-	-	972	1.16E+09
bot surface steel thermal shield above DSC	*321*	-	-	982	1.32E+09

7.0 DOCUMENTATION OF COMPUTER CODES

MCNP5 (Ref. 12-14), and Excel are the only computer codes used in this analysis. All inputs, outputs, and spreadsheets used in this calculation are included on the CD-ROM associated with this calculation and are summarized in Table 7-1 below.

MCNP5 was executed on Constellation Energy safety related machine PCD4307 and has been verified and validated per the CCNPP Quality Assurance Program (Refs. 10 and 11). For MCNP5, the output files are the input filename with an "o" at the end, while the runtpe files have an "r" at the end.

Microsoft Excel was used as a tool for carrying out simple and repetitive calculations and for generating data tables.

Table 7-1. Directory Listing of CD-ROM

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 Volume in drive C has no label.
 Volume Serial Number is 48A4-16B7

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06/16/2007  06:07 PM           514,612 n2bg12co
06/17/2007  12:02 AM            26,696 n3bg12c
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06/15/2007  09:48 PM            26,488 nubg12c
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09/15/2006  03:59 PM           573,882 nXbg09ho
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Table 7-1. Directory Listing of CD-ROM

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06/29/2007	05:48 PM	747,645	nXbg12Ho
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08/25/2006	11:29 AM	30,059	nXbg09h
12/16/2006	09:24 AM	28,372	pXb12cf
12/16/2006	09:18 AM	28,067	pXbg12c
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Table 7-1. Directory Listing of CD-ROM

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09/21/2006	01:18 PM	34,885	Xnsn13
09/21/2006	01:18 PM	34,885	Xnsn14
08/31/2006	02:00 PM	34,809	Xnsn15
12/29/2006	01:17 AM	35,795	Xnsp17
12/29/2006	01:18 AM	35,795	Xnsp24
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8.0 RESULTS AND CONCLUSIONS

Table 8-1 summarizes the HSM gamma and neutron dose rates for the extended burnup NUHOMS-32P DSC in the format used in the ISFSI USAR. The results have been rounded up to the nearest tenth mrem/hr for conservatism, with the exception of the doses inside the door, which were rounded up to the nearest mrem/hr. All ISFSI Technical Specifications remain satisfied.

Table 8-1. NUHOMS 32P Extended Burnup Dose Rates (mrem/hr) for ISFSI USAR

	Neutron	Gamma	Total	Technical Specification Limit
1. HSM Wall or Roof	0.5	13.0	13.5	20
2. HSM Air Outlet	1.3	74.1	75.4	100
3. Center of Door	5.9	8.0	13.9	100
4. Doorway (Maximum 1 ft into Opening	1247	3412	4659	None
5. Air Inlet Vent	1.0	60.0	61.0	100
6. 1m from HSM Door	3.0	5.9	8.9	None

Sections 6.3 and 6.4 show that the fence line and site dose limits are met for the extended burnup 32P for both the seismic restraint installation activity and the forest fire accident. Section 6.5 demonstrates that the extended burnup 32P neutron and gamma fluence will have a neglible impact on the HSM concrete integrity over 50 years.

Figures 8-1 and 8-2 present the new site total dose rates to bound a fully loaded site of 24P, base 32P, or extended burnup 32P HSMs. These figures would be utilized for ISFSI USAR Figures 7.4-1 and 7.4-2.

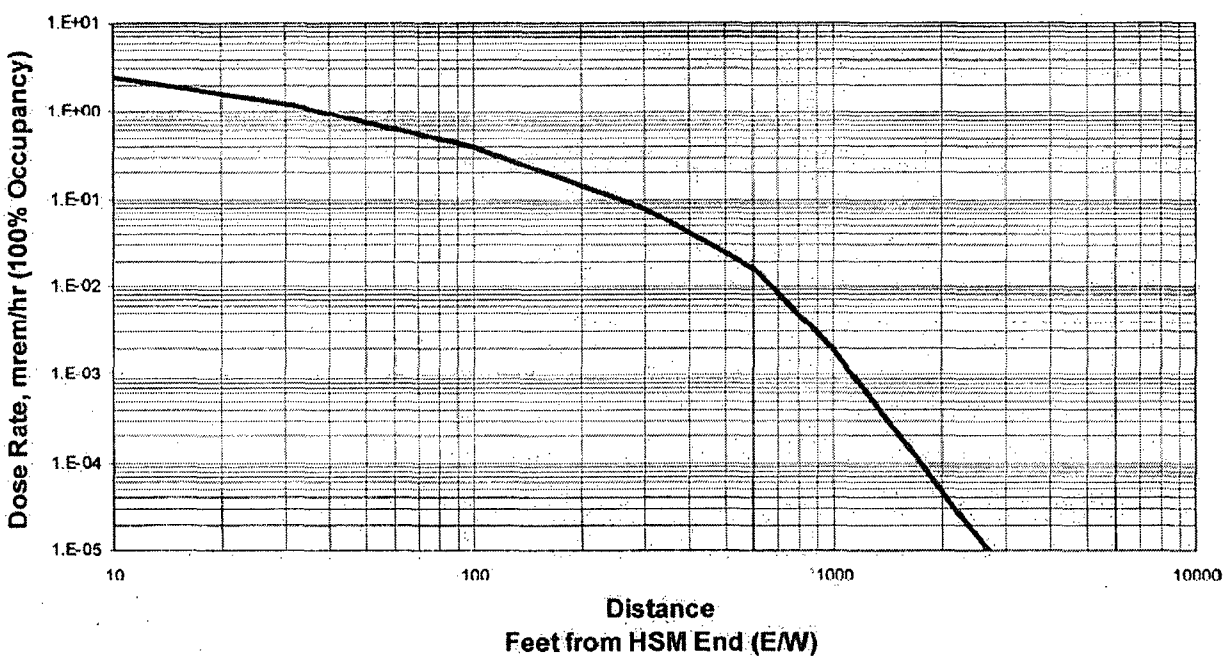

Figure 8-1. ISFSI USAR Figure 7.4-1 Bounding Extended Burnup 32P, 32P and 24P DSC 5-Phase E/W Site Dose Rates

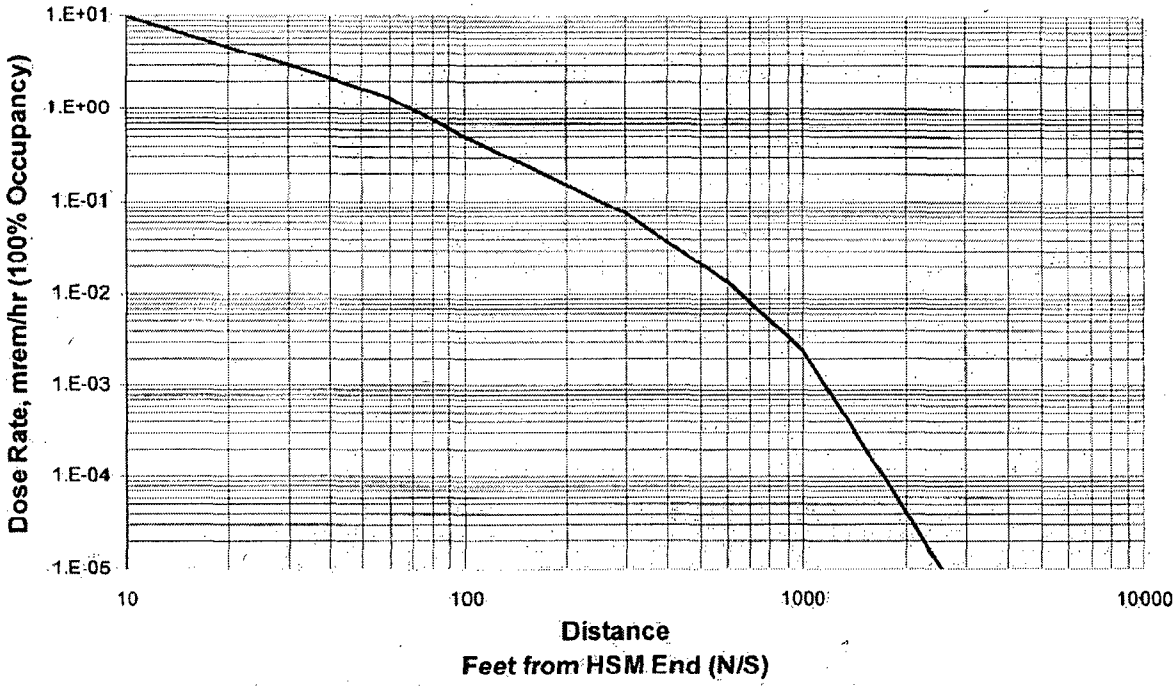

Figure 8-2. ISFSI USAR Figure 7.4-2 Bounding Extended Burnup 32P, 32P and 24P DSC 5-Phase N/S Site Dose Rates