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LETTER REPORT

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Author: Georgeta Radulescu

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Prepared by
Oak Ridge National Laboratory
P. O. Box 2008
Oak Ridge, Tennessee 37831-6170
managed by
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1. INTRODUCTION

This technical letter report documents work performed to meet the requirements of Task 4, titled Radiation Transport Evaluations, which is described in the ORNL FY11 Work Package for Repository Science/Criticality Analysis FTOR11UF0334 – DOE-NE Fuel Cycle Technologies Used Fuel Disposition Campaign (WBS: 1.02.08.03).

The purpose of the work is (1) to determine total dose rate values on the outer surfaces of a representative spent nuclear fuel (SNF) dry storage/transportation cask and on the outer surfaces of disposal canisters proposed for clay/shale and borehole repositories and (2) to determine the energy deposited by alpha and beta particles in moist air surrounding a UO_2 fuel pellet. The calculation results presented in this letter report may serve as reference data for determining the production rates of radiolysis products.

The computer codes Scale [1] and MCNPX [2] were used to carry out the depletion, decay, and Monte Carlo transport calculations presented in this letter report. The TRITON [3] sequence in Scale 6.1 was used to perform two-dimensional (2-D) depletion calculations that determined nuclide concentrations at the end of a fuel irradiation period. The discharge nuclide concentrations were decayed out to 5×10^5 years using ORIGEN [4], which is the depletion and decay code in Scale 6.1, to determine gamma and neutron source terms and nuclide concentrations as a function of decay time. BETA-S 6 [5] was used to generate beta radiation source terms based on the ORIGEN nuclide concentration calculations. A development version of ORIGEN was used to generate alpha radiation source terms. Neutron and gamma radiation transport calculations for SNF storage/disposal packages were performed using MAVRIC [6], the Scale 6.1 Monte Carlo shielding analysis capability. The MAVRIC calculations were optimized so that the statistical errors associated with the calculated surface dose rates were relatively small (e.g., less than 5%). MCNPX was used to determine the energy deposited by alpha and beta radiation in moist air surrounding a UO_2 fuel pellet.

The calculated values of dose rate on SNF package surfaces and energy absorption rate for moist air in contact with external package surfaces are presented in Sect. 2; the calculated values of energy deposited by alpha and beta radiation in moist air surrounding a fuel pellet are presented in Sect. 3.

2. DOSE RATE CALCULATIONS FOR SNF STORAGE/DISPOSAL PACKAGES

This section describes the representative analysis models used in Monte Carlo transport calculations for SNF storage/disposal packages and the calculated dose rate values. The fuel assembly selected for dose rate calculations is the Westinghouse (W) 17 × 17 optimized fuel assembly (OFA). The design parameters for this assembly type were obtained from [7]. Typical PWR assembly photon and neutron source axial profiles available in MAVRIC were specified in the input decks.

The values of dose rate on the outer surfaces of SNF storage/disposal packages were determined for fuel assemblies of 5.0 wt% ^{235}U initial enrichment and 60 GWd/MTU burnup and for the following decay times: 0, 10, 20, 40, 100, 200, and 300 years. Gamma and neutron source terms were used in the active fuel region and ^{60}Co activation source terms were used in the assembly hardware regions.

The dose rate values calculated using MAVRIC and the relationship between rad/h and eV/g/s (1 rad/h = 1.7338×10^{10} eV/g/s) were used to determine total photon and neutron energy absorbed in a gram of moist air per second. The energy absorption rate values presented in this letter report are applicable to moist air of varying density because the ANSI/ANS-6.1.1-1977 flux-to-dose factors were used in the MAVRIC dose rate calculations, which have been shown [8] to lead to slightly higher energy absorption for moist air. The relationship between rad/h and eV/g/s was obtained using the conversion factors available in [9]:

1 rad = 0.01 Gy
1 Gy =1 J/kg
1 eV = 1.602177E-19 J
1 kg = 1000 g
1 h = 3600 s

The dose rate values used to derive energy absorption rate values as described above were extracted from MAVRIC 3dmap electronic files. Those files contain dose rate values for a user-defined 3-dimensional cartesian mesh that is superimposed over the geometry model. MAVRIC 3dmap electronic files are available for all SNF storage/disposal packages analyzed in this letter report and may be used to obtain additional dose rate values of interest.

2.1 SNF STORAGE CASKS

The values of dose rate on the outer surfaces of a representative SNF transportation/dry storage cask were determined assuming a 2 × 3 array of casks placed on a concrete surface, which is illustrated in Fig. 1. The representative cask model consisted of 32 W 17 × 17 OFA assemblies [7] placed inside a HI-STAR 100 transport/storage package [10]. The multi-purpose canister has an 8.5-in. thick steel lid and a 2.5-in. thick base steel plate. The HI-STAR 100 overpack is a cylindrical steel vessel, which includes an 8.5-in. thick shell, a 6-in. thick bottom plate, and a 6-in. thick closure lid, with an exterior neutron shield containing boron carbide. The overpack outer radius is 121 cm; the radius of top and bottom plates is 106 cm. The fuel assemblies inside the canister cavity were surrounded by void.

Color coded dose rate values generated using the Meshview utility in Scale6.1 are illustrated in Fig. 2 for the 20-year decay time. The dose rate map is shown for a vertical (y-z) plane through the center of the coordinate system.

The maximum values of dose rate on the outside surfaces of the overpack and multi-purpose canister as well as the corresponding energy absorption rate values for moist air are tabulated in Table 1 as a function of decay time. Three different cask center-to-center spacing values were considered: 11 ft (335 cm), 13 ft (396 cm), and 15 ft (457 cm). The results of the calculations showed that the cask array configuration is primarily important for the discharge fuel dose rates. The maximum dose rate values on the cask outer radial surface were 230, 280, 295, and 315 rad/h for an isolated cask, a 15-ft cask spacing, a 13-ft cask spacing, and an 11-ft cask spacing, respectively. For the decay times considered, the differences between the results based on a cask array and on a single cask were relatively small. For example, the maximum dose rate values on the outer radial surface of a cask containing SNF cooled for 10 years were 2.6, 2.71, 2.72, and 2.75 rad/h for an isolated cask, a 15-ft cask spacing, a 13-ft cask spacing, and an 11-ft cask spacing, respectively. The minimum values of dose rate on the external surfaces of the overpack and multi-purpose canister as well as the corresponding energy absorption rate values for moist air are tabulated in Table 2.

Typical dose rate distributions on (1) outer radial surface along the z axis, (2) outer top surface along the y axis, and (3) outer bottom surface along the y axis are shown for the overpack and for the multi-purpose canister in Fig. 3 and Fig. 4, respectively, for the 20-year decay time. Axial distribution values of energy absorption rate for moist air are tabulated in Appendix A, Tables A-1 and A-2 for the overpack and the multi-purpose canister, respectively.

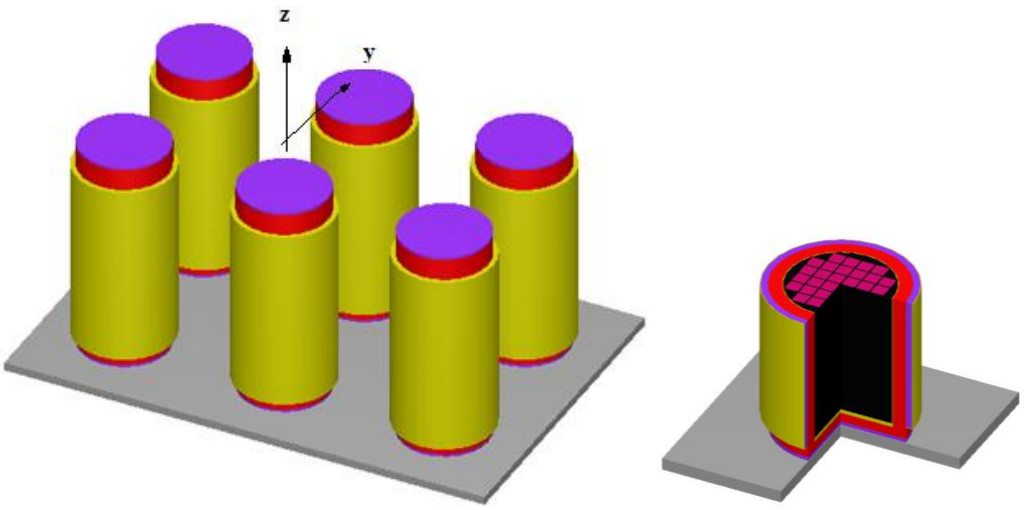


Fig. 1. Illustration of the calculation model for storage casks.

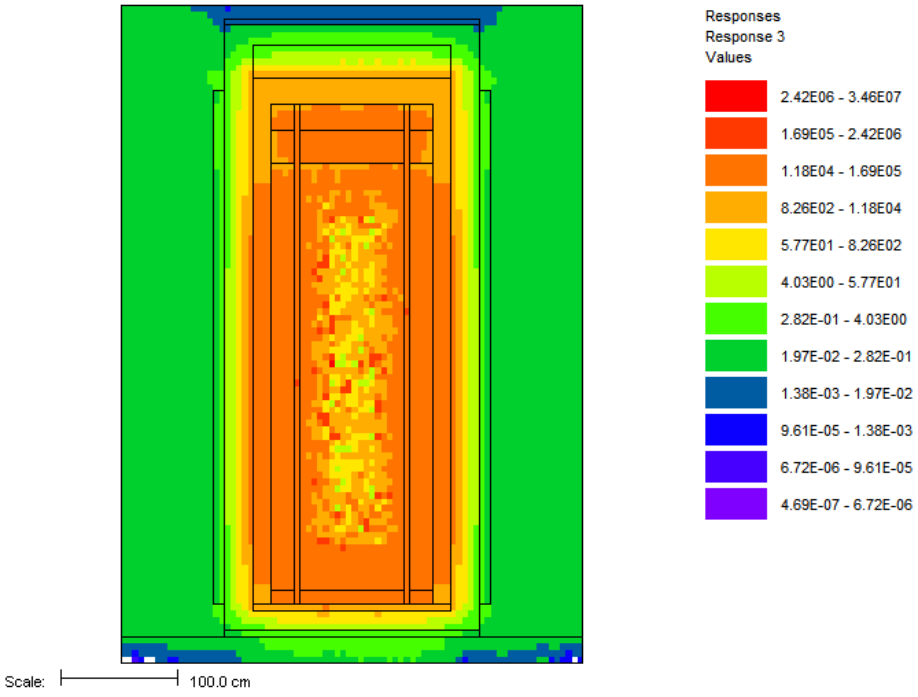


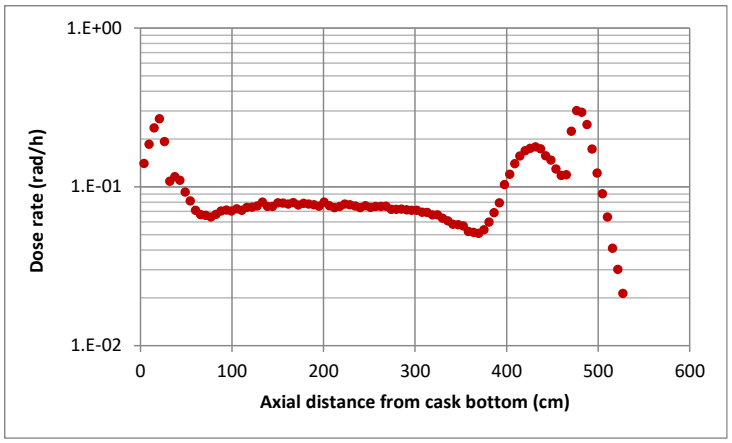
Fig. 2. Dose rate values (rad/h) in the (y-z) plane through the center of the cask model. 20-year decay time.

Table 1. Maximum surface dose rates for a transportation/dry storage cask and energy absorption rate for moist air

	Overpack outer surfaces			Multi-purpose canister outer surfaces		
	Radial	**Top**	**Bottom**	**Radial**	**Top**	**Bottom**
Decay Time (yr)	**Dose rate (rad/h)**					
0	3.2E+02	2.0E+00	2.5E+02	3.9E+06	4.4E+01	5.3E+04
10	2.8E+00	3.0E-02	9.0E+00	1.9E+04	4.2E+00	2.7E+03
20	2.2E+00	2.0E-02	2.8E+00	1.2E+04	1.7E+00	5.8E+02
40	1.2E+00	1.0E-02	7.0E-01	8.8E+03	1.0E+00	9.5E+01
100	3.0E-02	1.0E-03	5.0E-02	2.1E+03	7.0E-02	1.0E+01
200	1.0E-02	6.0E-04	2.0E-02	2.1E+02	3.0E-02	3.0E+00
300	9.0E-03	5.0E-04	1.8E-02	2.2E+01	3.0E-02	3.0E-01
	Energy absorption rate (eV/g/s)					
0	5.46E+12	3.47E+10	4.33E+12	6.76E+16	7.63E+11	9.19E+14
10	4.85E+10	1.21E+09	1.56E+11	3.29E+14	7.28E+10	4.68E+13
20	3.81E+10	3.47E+08	4.85E+10	2.08E+14	2.95E+10	1.01E+13
40	2.08E+10	1.73E+08	1.21E+10	1.53E+14	1.73E+10	1.65E+12
100	5.20E+08	1.73E+07	8.67E+08	3.64E+13	1.21E+09	1.73E+11
200	1.73E+08	1.04E+07	3.47E+08	3.64E+12	5.20E+08	5.20E+10
300	1.56E+08	8.67E+06	3.12E+08	3.73E+11	5.20E+08	5.20E+09

Table 2. Minimum surface dose rates for a transportation/dry storage cask and energy absorption rate for moist air

	Overpack outer surfaces			Multi-purpose canister outer surfaces		
	Radial	**Top**	**Bottom**	**Radial**	**Top**	**Bottom**
Decay Time (yr)	**Dose rate (rad/h)**					
0	2.5E-01	1.0E-01	7.7E+00	3.1E+01	6.9E+00	3.5E+01
10	1.0E-01	3.0E-02	1.2E-01	6.0E-01	5.7E-01	3.6E+02
20	5.0E-02	1.0E-03	3.0E-02	3.0E-01	3.4E-01	2.5E+02
40	2.0E-02	6.0E-02	1.0E-01	1.6E-01	3.0E-01	8.0E+00
100	2.9E-04	1.0E-03	8.0E-03	2.0E-02	2.5E-02	5.0E+00
200	9.5E-05	4.0E-05	1.0E-03	9.0E-03	1.0E-02	1.0E+00
300	8.0E-05	1.6E-04	1.0E-03	8.0E-03	1.0E-02	2.0E-01
	Energy absorption rate (eV/g/s)					
0	4.33E+09	1.73E+09	1.33E+11	5.37E+11	1.20E+11	6.07E+11
10	1.73E+09	5.20E+08	2.08E+09	1.04E+10	9.88E+09	6.19E+12
20	8.67E+08	1.73E+07	5.20E+08	5.20E+09	5.89E+09	4.33E+12
40	3.47E+08	1.04E+09	1.73E+09	2.77E+09	5.20E+09	1.39E+11
100	5.03E+06	1.73E+07	1.39E+08	3.47E+08	4.33E+08	8.67E+10
200	1.65E+06	6.94E+05	1.73E+07	1.56E+08	1.73E+08	1.73E+10
300	1.39E+06	2.77E+06	1.73E+07	1.39E+08	1.73E+08	3.47E+09



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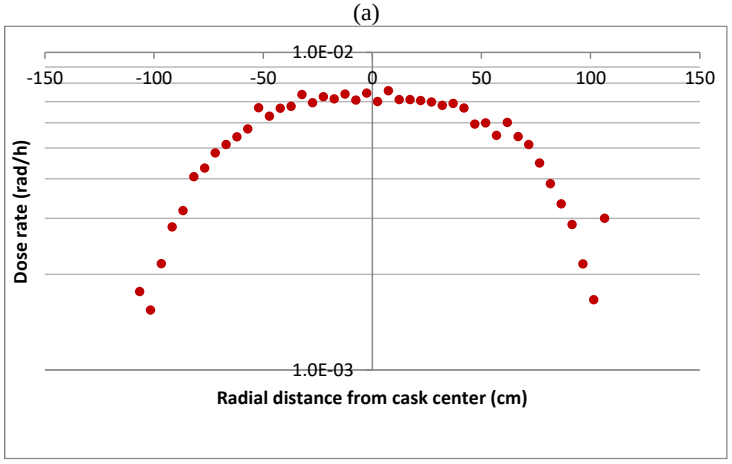

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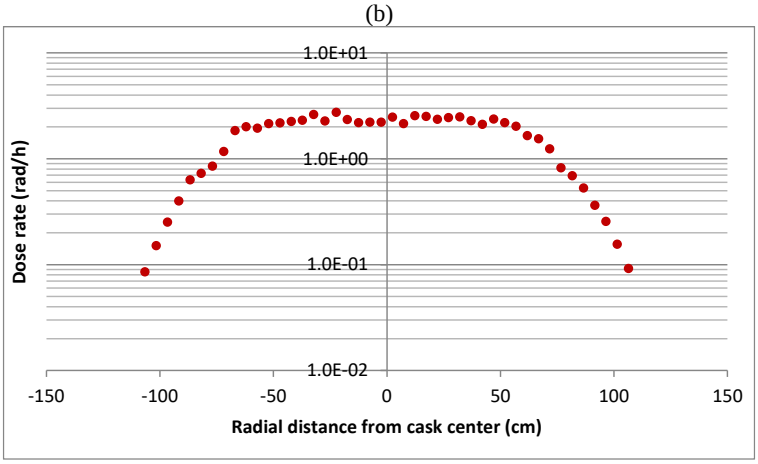
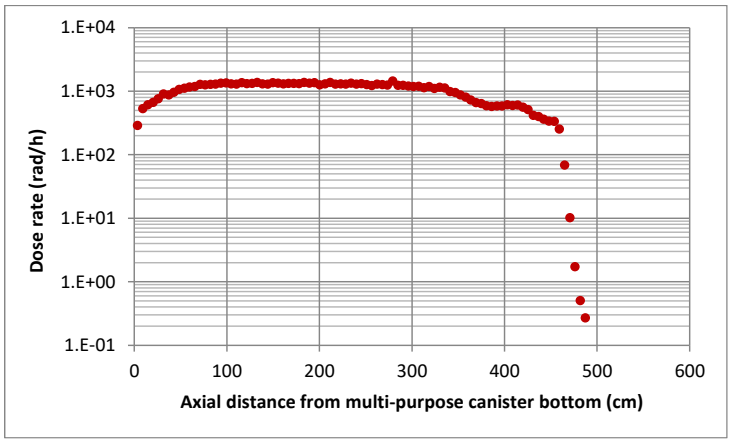
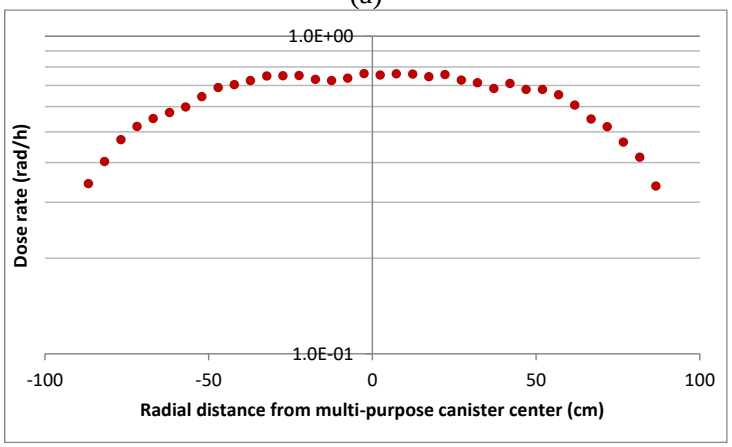


(c)

Fig. 3. Typical dose rate distributions on overpack (a) outer radial surface along the z axis; (b) outer top surface along the y axis; and (c) outer bottom surface along the y axis. 20-year decay time.



(a)



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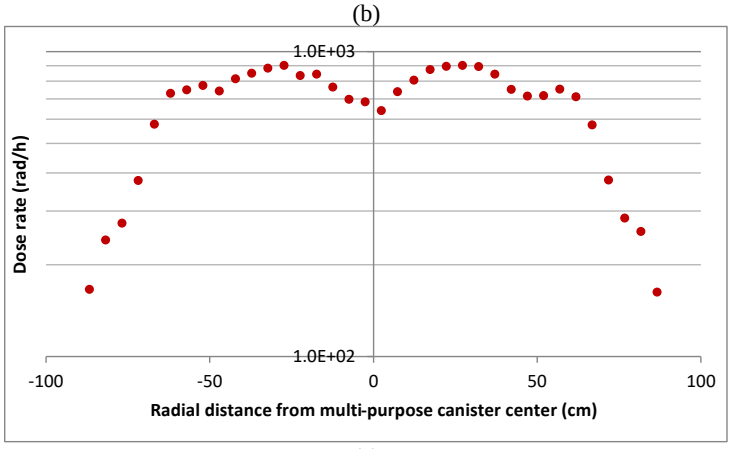


(c)

Fig. 4. Typical dose rate distributions on the multi-purpose canister (a) outer radial surface along the z axis; (b) outer top surface along the y axis; and (c) outer bottom surface along the y axis. 20-year decay time.

2.2 CLAY/SHALE DISPOSAL CANISTER

The copper canister with iron inserts proposed for use in the Swedish repository program was the representative canister analyzed for the clay/shale repository concept. The canister outer shell has an outer radius of 52.5 cm and accommodates four PWR assemblies. The canister configuration and dimensions were obtained from [11] (SKB TR-10-14). The calculation model included a chain of three such canisters. A view of the model with the top and front-right quarter sections removed is shown in Fig. 5.

The maximum and minimum dose rate values on the outer surfaces of a canister as well as the calculated energy absorption rate, in eV per second per gram, for moist air are presented in Table 3 as a function of decay time. Color coded dose rate values generated using the Meshview utility Scale 6.1 for the 1×10^3-year decay time are illustrated in Fig. 9 for a vertical (y-z) plane through the center of the coordinate system. Typical dose rate distributions on canister (1) outer radial surface along the z axis, (2) outer top surface along the y axis, and (3) outer bottom surface along the y axis are shown in Fig. 10 for the 1×10^3-year decay time. Axial distribution values of energy absorption rate for moist air are tabulated in Appendix A, Tables A-3 and A-4 for the 60- and 1×10^3-year decay times, respectively.

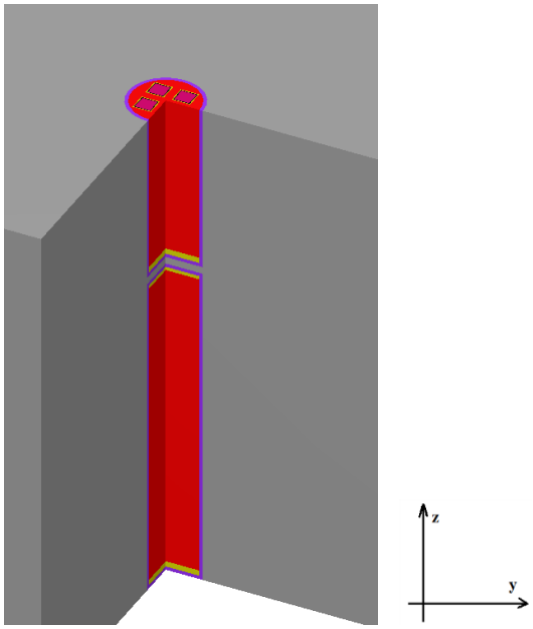


Fig. 5. Illustration of the calculation model for a clay/shale disposal canister.

Table 3. Dose rate on outer surfaces of a clay/shale disposal canister and energy absorption rate for moist air

	Radial surface		Top surface		Bottom surface	
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Decay time (yr)	**dose rate value (rad/h)**					
0	3.8E+04	9.3E+00	5.7E+03	6.6E+01	5.3E+03	7.4E+01
30	5.0E+01	3.3E-01	2.4E+01	4.0E-01	1.8E+01	4.4E-01
60	2.1E+01	1.0E-01	3.0E+00	9.0E-02	2.4E+00	1.2E-01
150	2.7E+00	1.8E-02	2.0E-01	1.6E-02	2.0E-01	2.0E-02
300	2.2E-01	1.3E-02	5.0E-02	1.0E-02	6.0E-02	1.3E-02
600	1.1E-01	1.0E-02	4.0E-02	9.6E-03	5.0E-02	1.1E-02
1×10^3	1.0E-01	1.0E-02	4.0E-02	9.0E-03	4.0E-02	1.0E-02
3×10^3	7.0E-02	8.0E-03	2.6E-02	6.0E-03	3.0E-02	8.0E-03
1×10^4	4.0E-02	4.0E-03	1.2E-02	3.0E-03	1.5E-02	3.4E-03
2.5×10^4	2.0E-02	1.3E-03	5.0E-03	1.0E-03	6.0E-03	1.2E-03
5×10^4	2.0E-02	9.2E-04	4.0E-03	7.9E-04	5.0E-03	8.6E-04
1×10^5	2.5E-02	7.4E-04	5.0E-03	6.6E-04	7.0E-03	7.8E-04
5×10^5	1.7E-02	3.7E-04	4.0E-03	3.3E-04	3.0E-03	3.7E-04
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Decay time (yr)	**energy absorption rate value (eV/g/s)**					
0	6.59E+14	1.61E+11	9.88E+13	1.14E+12	9.19E+13	1.28E+12
30	8.58E+11	5.72E+09	4.20E+11	6.94E+09	3.19E+11	7.63E+09
60	3.64E+11	1.73E+09	5.20E+10	1.56E+09	4.16E+10	2.08E+09
150	4.68E+10	3.12E+08	3.47E+09	2.77E+08	3.47E+09	3.47E+08
300	3.81E+09	2.25E+08	8.67E+08	1.73E+08	1.04E+09	2.25E+08
600	1.91E+09	1.73E+08	6.94E+08	1.66E+08	8.67E+08	1.91E+08
1×10^3	1.73E+09	1.73E+08	6.94E+08	1.56E+08	6.94E+08	1.73E+08
3×10^3	1.21E+09	1.39E+08	4.51E+08	1.04E+08	5.20E+08	1.39E+08
1×10^4	6.94E+08	6.94E+07	2.08E+08	5.20E+07	2.60E+08	5.89E+07
2.5×10^4	3.47E+08	2.25E+07	8.67E+07	1.73E+07	1.04E+08	2.08E+07
5×10^4	3.47E+08	1.60E+07	6.94E+07	1.37E+07	8.67E+07	1.49E+07
1×10^5	4.33E+08	1.28E+07	8.67E+07	1.14E+07	1.21E+08	1.35E+07
5×10^5	2.95E+08	6.41E+06	6.94E+07	5.72E+06	5.20E+07	6.41E+06

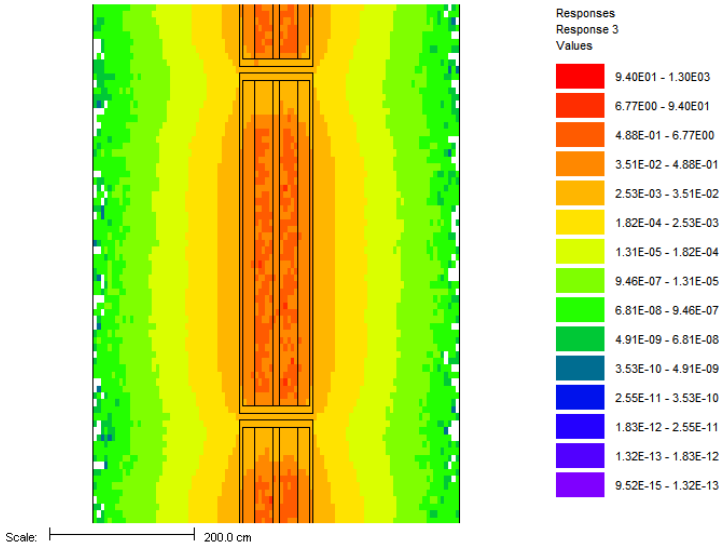
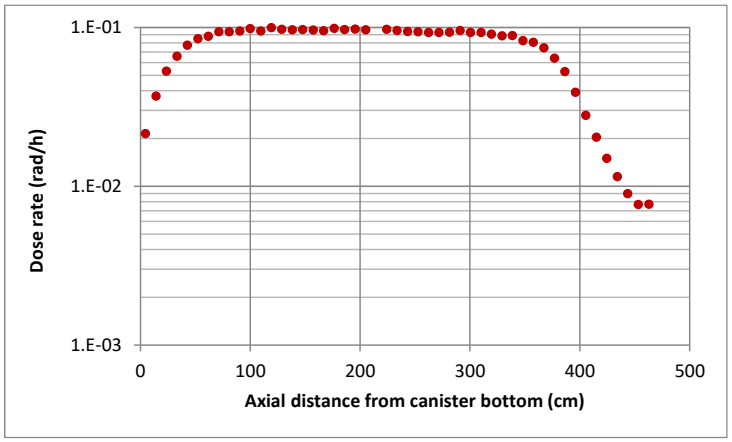
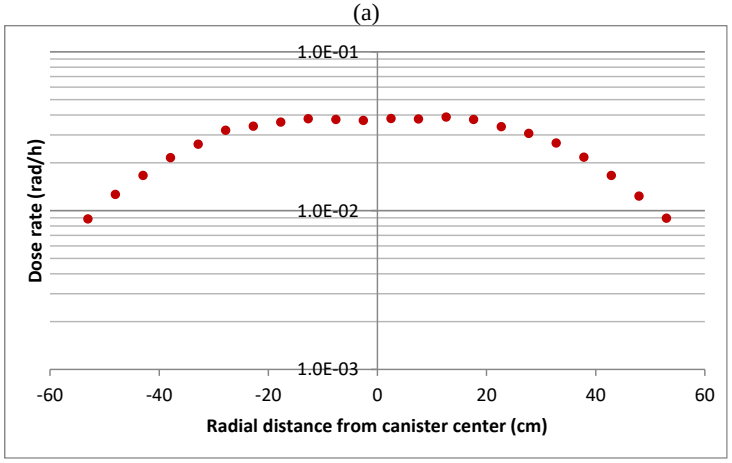


Fig. 6. Dose rate values (rad/h) in the (y-z) plane through the center of the model for a clay/shale disposal canister. 1×10^3-year decay time.



(a)



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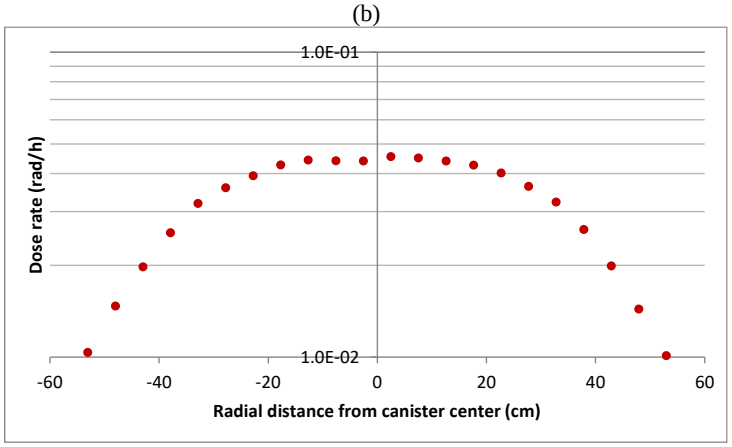


(c)

Fig. 7. Typical dose rate distributions on canister (a) outer radial surface along z axis; (b) outer top surface along y axis; and (c) outer bottom surface along y axis. 1×10^3-year decay time.

2.3 BOREHOLE DISPOSAL CANISTER

The calculation model for a representative borehole disposal canister, which is illustrated in Fig. 8, was developed based on the information provided in [12] (SAND2009-4401). For this repository option, a fuel assembly is placed in a canister made of standard oilfield casing 5 m tall and having an inner diameter of 12-1/2 in. (31.8 cm) and an outside diameter of 13-3/8 in. (34 cm). Bentonite is used as a buffer/seal material because of its low permeability, high sorption capacity, self-sealing characteristics, and durability.

Color coded dose rate values are illustrated in Fig. 9 for a vertical (y-z) plane through the center of the coordinate system for the 30-year decay time. The maximum and minimum dose rate values on the outer surfaces of a canister as well as the calculated energy absorption rate, in eV per second per gram, for moist air are provided in Table 4 as a function of decay time. Typical dose rate distributions on canister (a) outer radial surface along the z axis, (b) outer top surface along the y axis, and (c) outer bottom surface along the y axis are shown in Fig. 10 for the 30-year decay time. Axial distribution values of energy absorption rate for moist air are tabulated in Appendix A, Tables A-5 and A-6 for the 30- and 5×10^4-year decay times, respectively.

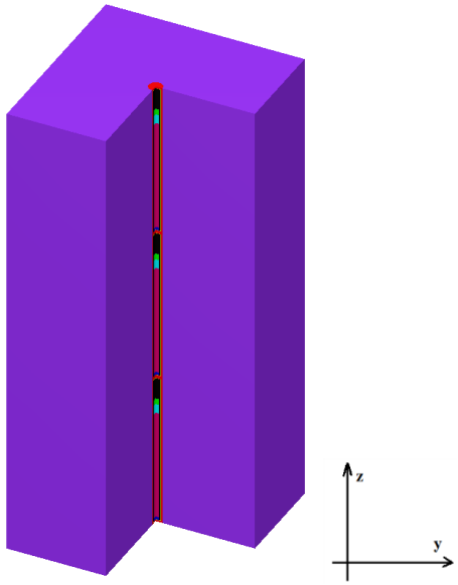


Fig. 8. Illustration of the calculation model for a borehole disposal canister.

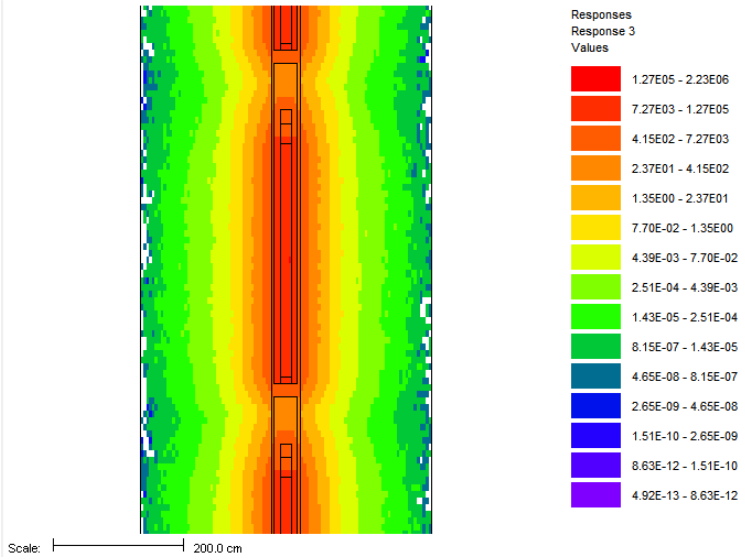
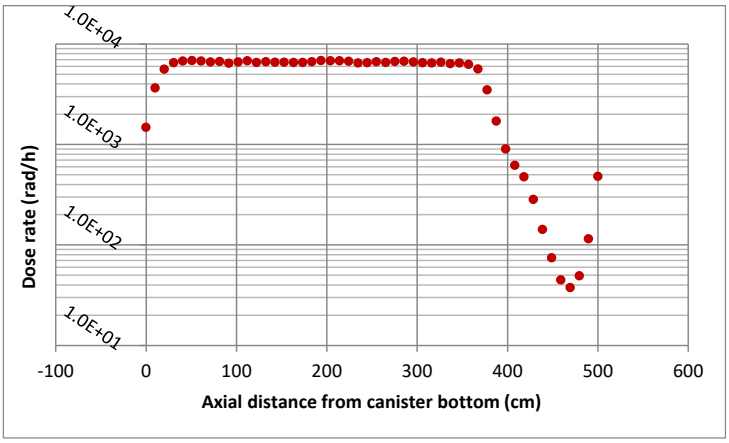


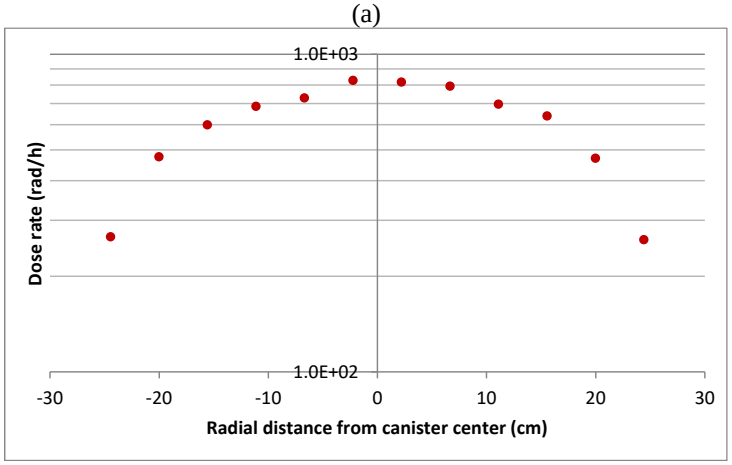
Fig. 9. Dose rate values (rad/h) in the (y-z) plane through the center of the model for a borehole disposal canister. 30-year decay time.

Table 4. Dose rate on outside surfaces of a borehole disposal canister and energy absorption rate for moist air

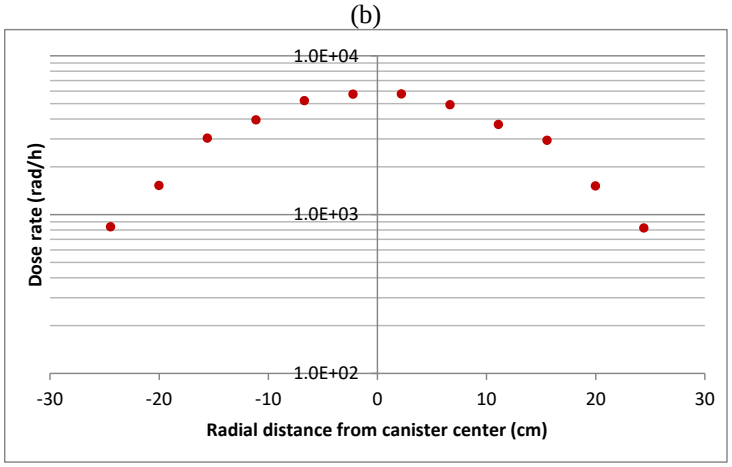
	Radial surface		**Top surface**		**Bottom surface**	
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Decay time (yr)	**dose rate value (rad/h)**					
0	1.0E+06	7.8E+03	2.1E+05	1.4E+05	1.1E+06	4.7E+05
30	4.6E+03	3.7E+01	8.4E+02	4.7E+02	5.8E+03	1.5E+03
60	1.3E+03	5.7E+00	2.2E+02	1.7E+02	1.4E+03	5.7E+02
150	1.7E+02	6.0E-01	2.6E+01	2.1E+01	1.6E+02	7.2E+01
300	5.3E+00	2.0E-02	9.0E-01	7.0E-01	5.0E+00	2.4E+00
600	2.0E-01	5.0E-03	4.0E-02	3.0E-02	2.0E-01	9.0E-02
1×10^3	2.0E-01	4.0E-03	4.0E-03	3.0E-02	2.0E-01	8.0E-02
3×10^3	1.7E-01	3.0E-03	3.0E-02	3.0E-02	1.4E-01	8.0E-02
1×10^4	1.5E-01	2.0E-03	2.5E-02	2.0E-02	1.3E-01	7.0E-02
2.5×10^4	1.8E-01	1.0E-03	4.0E-02	2.7E-02	1.7E-01	8.0E-02
5×10^4	2.7E-01	2.3E-03	6.0E-02	3.4E-02	2.3E-01	1.2E-01
1×10^5	3.7E-01	2.6E-03	7.0E-02	5.0E-02	3.4E-01	1.6E-01
5×10^5	2.8E-01	2.0E-03	6.0E-02	4.0E-02	2.7E-01	1.1E-01
	Maximum	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**
Decay time (yr)	**energy absorption rate value (eV/g/s)**					
0	1.73E+16	1.35E+14	3.64E+15	2.43E+15	1.91E+16	8.15E+15
30	7.98E+13	6.48E+11	1.46E+13	8.18E+12	1.01E+14	2.60E+13
60	2.25E+13	9.88E+10	3.81E+12	2.90E+12	2.43E+13	9.88E+12
150	2.95E+12	1.04E+10	4.51E+11	3.59E+11	2.77E+12	1.25E+12
300	9.19E+10	3.47E+08	1.56E+10	1.21E+10	8.67E+10	4.16E+10
600	3.47E+09	8.67E+07	6.94E+08	5.20E+08	3.47E+09	1.56E+09
1×10^3	3.47E+09	6.94E+07	6.94E+07	5.20E+08	3.47E+09	1.39E+09
3×10^3	2.95E+09	5.20E+07	5.20E+08	5.20E+08	2.43E+09	1.39E+09
1×10^4	2.60E+09	3.47E+07	4.33E+08	3.47E+08	2.25E+09	1.21E+09
2.5×10^4	3.12E+09	1.73E+07	6.94E+08	4.68E+08	2.95E+09	1.39E+09
5×10^4	4.68E+09	3.99E+07	1.04E+09	5.92E+08	3.99E+09	2.08E+09
1×10^5	6.41E+09	4.51E+07	1.21E+09	8.67E+08	5.89E+09	2.77E+09
5×10^5	4.85E+09	3.47E+07	1.04E+09	6.94E+08	4.68E+09	1.91E+09



(a)



(b)



(c)

Fig. 10. Typical dose rate distributions on canister (a) outer radial surface along z axis; (b) outer top surface along y axis; and (c) outer bottom surface along y axis. 30-year decay time.

3. ENERGY DEPOSITED IN WATER SURROUNDING A FUEL PELLET

Energy deposition values were determined for moist air/water surrounding a fuel pellet as a function of assembly average burnup, decay time, and moist air mass density. The assembly average burnup values considered are: 25, 40, and 60 GWd/MTU. The decay times considered are: 0, 30, 60, 150, 300, 600, 1×10^3, 3×10^3, 1×10^4, 2.5×10^4, 5×10^4, 1×10^5, and 5×10^5 years. Three mass density values were considered for the moist air surrounding a fuel pellet: 0.1, 0.5, and 1 g/cm^3. The fuel pellet density used in calculations was 95% of UO_2 theoretical density, i.e., 10.412 g/cm^3.

Alpha and beta radiation source terms for the 60-GWd/MTU burnup value were generated considering (1) power variation along the pellet radius, a phenomenon which is more pronounced for high burnup values, and (2) a uniform radial power profile; the alpha and beta radiation source terms for the 25- and 40-GWd/MTU burnup values were generated using a uniform radial power profile. The power production at the center of a fuel rod is slightly less than that at the surface because neutron capture takes place mainly at the fuel pellet surface. The distributions of fissile material, fission rate, and fission products in irradiated fuel develop peaks at the pellet surface as fuel burnup increases [13, 14]. Hence, the properties of high-burnup fuel pellets are far more heterogeneous than those of low-burnup fuel. The fuel self-shielding effect was taken into account in the alpha and beta source term calculations by using a more detailed depletion calculation model for the 60-GWd/MTU assembly average burnup. For this burnup value, the 2-D depletion calculations used a fuel pellet model consisting of ten concentric rings of equal surface areas and a fuel radial temperature profile. Radiation source terms corresponding to the outer fuel rings were used in Monte Carlo transport calculations. Plots of alpha and beta source spectra at various decay times for the 230-μm thick outer pellet ring are illustrated in Fig. 11 and Fig. 12, respectively.

Charged particles, such as beta and alpha particles originating from radioactive decay processes in SNF, travel a short distance from the site of origin. Due to their electrical charge, alpha and beta particles are subject to the coulombic forces from electrons and nuclei within the material through which they pass. In addition to the electronic energy loss due to Coulomb interactions, charged particles lose kinetic energy due to nuclear processes such as nuclear interactions and emission of bremsstrahlung or Cerenkov radiation. The ability of a material to stop beta particles depends primarily on the number of electrons in that material. Energetic beta particles passing through high Z materials have the potential to generate a significant amount of bremsstrahlung radiation. An alpha ion loses only a fraction of its energy in collisions with atomic electrons. These ions undergo a continuous slowing down process in which a small amount of energy is transferred from the ions to the absorber. This work used MCNPX to model the transport of alpha and beta particles in matter. A mathematical model is often employed in dose calculations for determining the production rates of radiolysis products [15].

The MCNPX model used in calculating particle energy deposition describes a fuel pellet subdivided into concentric cylindrical annuli and surrounded by 10-μm thick cylindrical annuli of moist air totaling a 500-μm thick layer. Alpha and beta particles emitted within the inner fuel pellet region are completely absorbed into the fuel; therefore, these particles were sampled only from a very thin fuel pellet outer layer. The thicknesses of the outer fuel layers used in sampling alpha and beta particles were 30 and 800 μm, respectively. The MCNPX calculations for electron transport also considered the bremsstrahlung radiation emitted as a result of the acceleration of electrons by nuclei. The calculated values of energy deposited within each moist air/water layer, in eV per second per gram of moist air/water, are presented in Table 5 through Table 13. The energy deposition values for the 60-GWd/MTU burnup presented in Table 5 through Table 7 were obtained considering varying radial power. Figures 9 through 13 present plots of energy deposition as a function of distance from the fuel pellet surface for the 60-GWd/MTU burnup value. As seen in these figures, the beta radiation has a significant contribution to the total energy deposited in moist air only beyond the range of the alpha particles and for the 0-year decay time. The

decay of short-lived nuclides produces significant beta source intensity (~ 2×10^{18} betas/s/1 MTU for the 60-GWd/MTU burnup value).

The impact of a more detailed depletion modeling approach, which takes into account radial power variation, on alpha and beta source term calculations is indicated in Table 14. This table presents the values of the percentage relative difference between the energy deposition values based on a varying radial power profile and the energy deposition values based on uniform radial power for the 60-GWd/MTU assembly average burnup and a moist air density of 0.1 g/cm^3. The relative differences vary from ~ 10% to ~ 50% depending on the dominating type of radiation, decay time, and distance from the pellet surface.

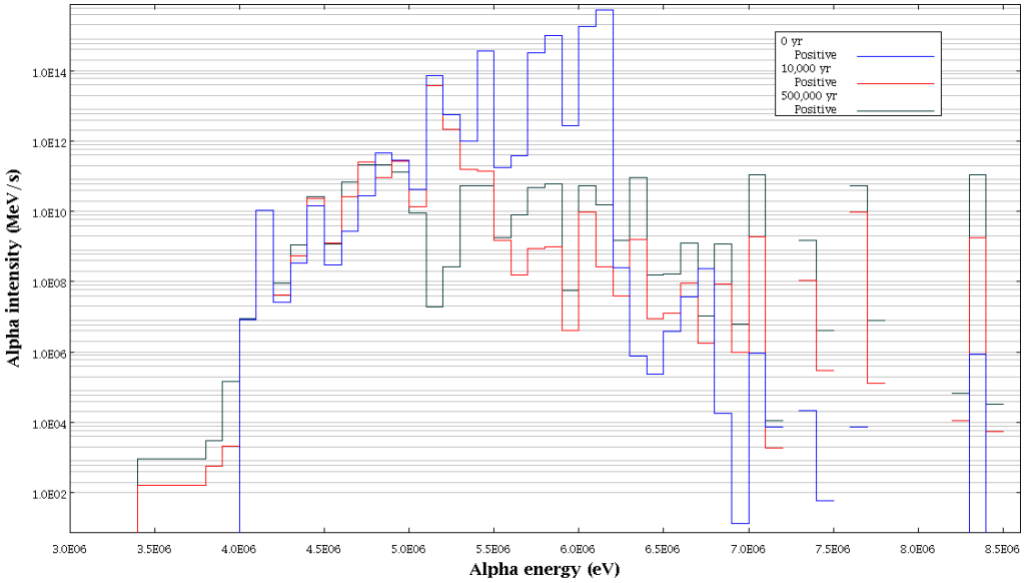


Fig. 11. Alpha source spectra for the outer fuel pellet ring for 0-, 1×10^4-, and 5×10^5-year decay times. Source intensity in alphas/s/1 MTU; 60 GWd/MTU average assembly burnup.

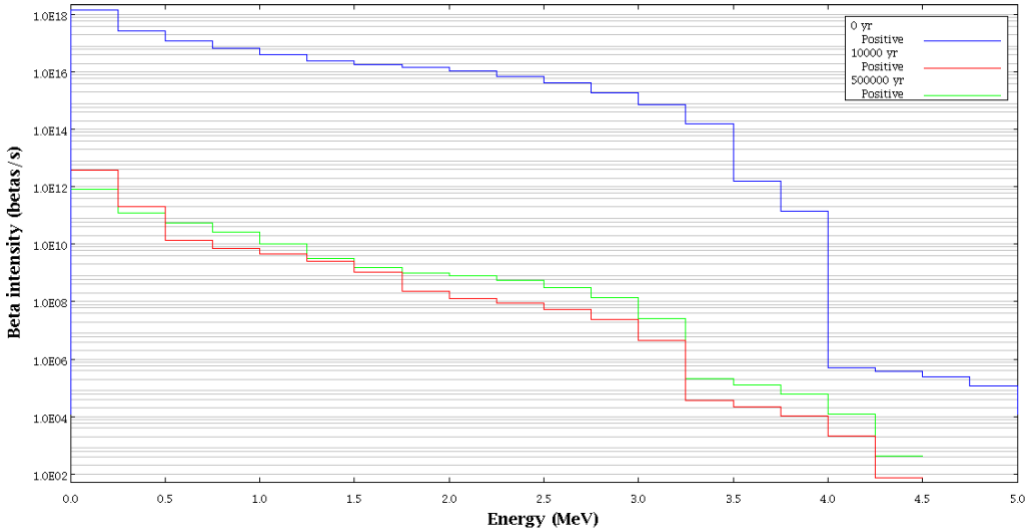


Fig. 12. Beta source spectra for the outer pellet ring for 0-, 1×10^4-, and 5×10^5-year decay times. Source intensity in betas/s/1 MTU; 60 GWd/MTU average assembly burnup.

Table 5. Energy (eV) deposited per second per gram of moist air of 0.1-g/cm^3 density: 60 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.70E+17	1.05E+16	7.50E+15	4.74E+15	3.35E+15	2.13E+15	1.35E+15	4.84E+14	2.85E+14	1.34E+14	5.92E+13	2.05E+13	8.85E+12
20	2.52E+17	9.53E+15	6.82E+15	4.29E+15	3.03E+15	1.92E+15	1.22E+15	4.35E+14	2.56E+14	1.21E+14	5.32E+13	1.85E+13	8.04E+12
30	2.43E+17	8.80E+15	6.26E+15	3.91E+15	2.76E+15	1.75E+15	1.10E+15	3.93E+14	2.31E+14	1.09E+14	4.81E+13	1.67E+13	7.35E+12
40	2.32E+17	8.15E+15	5.77E+15	3.58E+15	2.52E+15	1.60E+15	1.01E+15	3.58E+14	2.10E+14	9.91E+13	4.37E+13	1.53E+13	6.78E+12
50	2.24E+17	7.59E+15	5.35E+15	3.30E+15	2.32E+15	1.47E+15	9.25E+14	3.27E+14	1.92E+14	9.05E+13	3.99E+13	1.40E+13	6.27E+12
60	2.20E+17	7.11E+15	4.97E+15	3.04E+15	2.13E+15	1.35E+15	8.52E+14	3.00E+14	1.76E+14	8.29E+13	3.66E+13	1.29E+13	5.83E+12
70	2.12E+17	6.65E+15	4.63E+15	2.81E+15	1.97E+15	1.25E+15	7.86E+14	2.76E+14	1.62E+14	7.62E+13	3.37E+13	1.18E+13	5.42E+12
80	2.05E+17	6.23E+15	4.32E+15	2.61E+15	1.82E+15	1.15E+15	7.26E+14	2.53E+14	1.49E+14	7.00E+13	3.09E+13	1.09E+13	5.05E+12
90	2.03E+17	5.87E+15	4.04E+15	2.42E+15	1.69E+15	1.07E+15	6.70E+14	2.33E+14	1.37E+14	6.44E+13	2.85E+13	1.01E+13	4.72E+12
100	1.95E+17	5.51E+15	3.78E+15	2.24E+15	1.56E+15	9.87E+14	6.19E+14	2.15E+14	1.26E+14	5.92E+13	2.62E+13	9.30E+12	4.40E+12
110	1.91E+17	5.19E+15	3.53E+15	2.08E+15	1.45E+15	9.13E+14	5.72E+14	1.97E+14	1.16E+14	5.44E+13	2.41E+13	8.58E+12	4.11E+12
120	1.88E+17	4.90E+15	3.31E+15	1.93E+15	1.34E+15	8.42E+14	5.27E+14	1.81E+14	1.06E+14	4.99E+13	2.21E+13	7.90E+12	3.84E+12
130	1.81E+17	4.59E+15	3.09E+15	1.78E+15	1.23E+15	7.77E+14	4.86E+14	1.66E+14	9.70E+13	4.57E+13	2.02E+13	7.27E+12	3.59E+12
140	1.80E+17	4.34E+15	2.89E+15	1.65E+15	1.14E+15	7.15E+14	4.47E+14	1.52E+14	8.87E+13	4.18E+13	1.85E+13	6.69E+12	3.35E+12
150	1.77E+17	4.09E+15	2.70E+15	1.52E+15	1.05E+15	6.58E+14	4.10E+14	1.39E+14	8.10E+13	3.82E+13	1.69E+13	6.14E+12	3.12E+12
160	1.73E+17	3.84E+15	2.52E+15	1.40E+15	9.61E+14	6.04E+14	3.76E+14	1.27E+14	7.39E+13	3.48E+13	1.54E+13	5.62E+12	2.91E+12
170	1.70E+17	3.62E+15	2.36E+15	1.29E+15	8.82E+14	5.54E+14	3.44E+14	1.15E+14	6.70E+13	3.16E+13	1.40E+13	5.14E+12	2.71E+12
180	1.67E+17	3.42E+15	2.21E+15	1.19E+15	8.07E+14	5.06E+14	3.14E+14	1.04E+14	6.05E+13	2.85E+13	1.27E+13	4.68E+12	2.52E+12
190	1.65E+17	3.22E+15	2.06E+15	1.09E+15	7.36E+14	4.61E+14	2.85E+14	9.36E+13	5.44E+13	2.56E+13	1.14E+13	4.24E+12	2.34E+12
200	1.57E+17	2.99E+15	1.90E+15	9.91E+14	6.68E+14	4.18E+14	2.58E+14	8.38E+13	4.86E+13	2.29E+13	1.02E+13	3.83E+12	2.17E+12
210	1.55E+17	2.82E+15	1.77E+15	9.01E+14	6.04E+14	3.77E+14	2.32E+14	7.45E+13	4.31E+13	2.03E+13	9.08E+12	3.45E+12	2.01E+12
220	1.56E+17	2.67E+15	1.65E+15	8.17E+14	5.43E+14	3.38E+14	2.08E+14	6.60E+13	3.81E+13	1.80E+13	8.05E+12	3.09E+12	1.86E+12
230	1.53E+17	2.50E+15	1.52E+15	7.36E+14	4.86E+14	3.02E+14	1.85E+14	5.80E+13	3.34E+13	1.57E+13	7.08E+12	2.76E+12	1.72E+12
240	1.50E+17	2.35E+15	1.41E+15	6.60E+14	4.32E+14	2.68E+14	1.64E+14	5.05E+13	2.90E+13	1.37E+13	6.17E+12	2.45E+12	1.59E+12
250	1.44E+17	2.185E+15	1.29E+15	5.89E+14	3.82E+14	2.36E+14	1.44E+14	4.36E+13	2.50E+13	1.18E+13	5.34E+12	2.17E+12	1.47E+12

Table 5. Energy (eV) deposited per second per gram of moist air of 0.1-g/cm^3 density: 60 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	1.43E+17	2.05E+15	1.19E+15	5.23E+14	3.35E+14	2.07E+14	1.25E+14	3.73E+13	2.14E+13	1.01E+13	4.59E+12	1.91E+12	1.36E+12
270	1.41E+17	1.92E+15	1.10E+15	4.61E+14	2.91E+14	1.79E+14	1.08E+14	3.15E+13	1.80E+13	8.48E+12	3.89E+12	1.67E+12	1.25E+12
280	1.39E+17	1.79E+15	1.01E+15	4.04E+14	2.51E+14	1.54E+14	9.25E+13	2.62E+13	1.49E+13	7.02E+12	3.25E+12	1.44E+12	1.15E+12
290	1.39E+17	1.70E+15	9.36E+14	3.53E+14	2.14E+14	1.31E+14	7.80E+13	2.13E+13	1.20E+13	5.70E+12	2.67E+12	1.25E+12	1.06E+12
300	1.40E+17	1.61E+15	8.70E+14	3.06E+14	1.80E+14	1.09E+14	6.48E+13	1.70E+13	9.49E+12	4.51E+12	2.15E+12	1.07E+12	9.80E+11
310	1.36E+17	1.50E+15	7.95E+14	2.61E+14	1.49E+14	8.97E+13	5.27E+13	1.30E+13	7.22E+12	3.44E+12	1.68E+12	9.08E+11	9.03E+11
320	1.30E+17	1.38E+15	7.19E+14	2.20E+14	1.21E+14	7.20E+13	4.19E+13	9.67E+12	5.28E+12	2.53E+12	1.28E+12	7.68E+11	8.33E+11
330	1.30E+17	1.31E+15	6.66E+14	1.84E+14	9.51E+13	5.62E+13	3.23E+13	6.84E+12	3.67E+12	1.78E+12	9.58E+11	6.57E+11	7.77E+11
340	1.30E+17	1.24E+15	6.16E+14	1.52E+14	7.24E+13	4.22E+13	2.39E+13	4.49E+12	2.34E+12	1.17E+12	6.90E+11	5.64E+11	7.27E+11
350	1.26E+17	1.16E+15	5.64E+14	1.23E+14	5.32E+13	3.05E+13	1.70E+13	2.68E+12	1.33E+12	7.00E+11	4.85E+11	4.87E+11	6.79E+11
360	1.26E+17	1.11E+15	5.29E+14	1.00E+14	3.73E+13	2.09E+13	1.14E+13	1.43E+12	6.58E+11	3.86E+11	3.45E+11	4.30E+11	6.37E+11
370	1.25E+17	1.07E+15	4.97E+14	8.16E+13	2.44E+13	1.33E+13	7.10E+12	6.91E+11	2.88E+11	2.14E+11	2.64E+11	3.88E+11	5.97E+11
380	1.23E+17	1.01E+15	4.67E+14	6.66E+13	1.45E+13	7.56E+12	4.03E+12	3.72E+11	1.61E+11	1.53E+11	2.28E+11	3.58E+11	5.58E+11
390	1.23E+17	9.88E+14	4.50E+14	5.66E+13	7.72E+12	3.69E+12	2.01E+12	2.71E+11	1.48E+11	1.44E+11	2.15E+11	3.36E+11	5.24E+11
400	1.20E+17	9.49E+14	4.30E+14	4.98E+13	3.57E+12	1.34E+12	7.87E+11	2.10E+11	1.39E+11	1.35E+11	2.01E+11	3.14E+11	4.90E+11
410	1.18E+17	9.22E+14	4.18E+14	4.65E+13	1.84E+12	3.66E+11	2.81E+11	1.86E+11	1.36E+11	1.29E+11	1.90E+11	2.94E+11	4.59E+11
420	1.17E+17	9.08E+14	4.14E+14	4.61E+13	1.58E+12	2.21E+11	2.03E+11	1.77E+11	1.30E+11	1.22E+11	1.78E+11	2.75E+11	4.30E+11
430	1.13E+17	8.68E+14	3.97E+14	4.44E+13	1.52E+12	2.10E+11	1.94E+11	1.70E+11	1.25E+11	1.15E+11	1.67E+11	2.57E+11	4.01E+11
440	1.13E+17	8.62E+14	3.95E+14	4.42E+13	1.51E+12	2.10E+11	1.95E+11	1.71E+11	1.24E+11	1.12E+11	1.58E+11	2.42E+11	3.77E+11
450	1.11E+17	8.46E+14	3.88E+14	4.36E+13	1.49E+12	2.03E+11	1.89E+11	1.65E+11	1.19E+11	1.06E+11	1.49E+11	2.27E+11	3.53E+11
460	1.10E+17	8.43E+14	3.87E+14	4.34E+13	1.48E+12	2.01E+11	1.88E+11	1.65E+11	1.18E+11	1.02E+11	1.41E+11	2.14E+11	3.31E+11
470	1.05E+17	8.14E+14	3.75E+14	4.22E+13	1.42E+12	1.87E+11	1.76E+11	1.54E+11	1.10E+11	9.48E+10	1.31E+11	1.98E+11	3.08E+11
480	1.06E+17	8.12E+14	3.72E+14	4.18E+13	1.42E+12	1.95E+11	1.83E+11	1.60E+11	1.13E+11	9.45E+10	1.27E+11	1.89E+11	2.92E+11
490	1.03E+17	7.99E+14	3.68E+14	4.14E+13	1.39E+12	1.80E+11	1.69E+11	1.48E+11	1.05E+11	8.72E+10	1.17E+11	1.75E+11	2.71E+11
500	1.00E+17	7.67E+14	3.52E+14	3.96E+13	1.34E+12	1.78E+11	1.67E+11	1.46E+11	1.03E+11	8.41E+10	1.11E+11	1.65E+11	2.53E+11

Table 6. Energy (eV) deposited per second per gram of moist air of 0.5-g/cm^3 density: 60 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.88E+17	9.33E+15	6.57E+15	4.04E+15	2.84E+15	1.80E+15	1.14E+15	4.05E+14	2.38E+14	1.12E+14	4.95E+13	1.73E+13	7.60E+12
20	1.29E+17	3.38E+15	2.30E+15	1.35E+15	9.41E+14	5.95E+14	3.74E+14	1.31E+14	7.66E+13	3.61E+13	1.60E+13	5.64E+12	2.62E+12
30	7.92E+16	1.70E+15	1.12E+15	6.21E+14	4.26E+14	2.68E+14	1.68E+14	5.73E+13	3.35E+13	1.58E+13	7.00E+12	2.52E+12	1.25E+12
40	5.57E+16	9.79E+14	6.15E+14	3.14E+14	2.10E+14	1.32E+14	8.18E+13	2.71E+13	1.58E+13	7.43E+12	3.31E+12	1.23E+12	6.65E+11
50	4.20E+16	5.98E+14	3.53E+14	1.58E+14	1.02E+14	6.33E+13	3.88E+13	1.22E+13	7.02E+12	3.31E+12	1.49E+12	5.86E+11	3.69E+11
60	3.35E+16	3.83E+14	2.09E+14	7.49E+13	4.45E+13	2.72E+13	1.64E+13	4.66E+12	2.64E+12	1.25E+12	5.81E+11	2.61E+11	2.08E+11
70	2.73E+16	2.56E+14	1.28E+14	3.13E+13	1.49E+13	8.77E+12	5.06E+12	1.12E+12	6.04E+11	2.94E+11	1.57E+11	1.06E+11	1.23E+11
80	2.30E+16	1.86E+14	8.63E+13	1.21E+13	2.43E+12	1.26E+12	6.88E+11	8.81E+10	4.28E+10	3.08E+10	3.64E+10	5.20E+10	7.83E+10
90	2.00E+16	1.52E+14	6.98E+13	7.84E+12	2.74E+11	4.04E+10	3.59E+10	2.95E+10	2.08E+10	1.72E+10	2.30E+10	3.42E+10	5.16E+10
100	1.75E+16	1.33E+14	6.12E+13	6.89E+12	2.33E+11	3.10E+10	2.91E+10	2.54E+10	1.75E+10	1.32E+10	1.64E+10	2.35E+10	3.47E+10
110	1.56E+16	1.19E+14	5.47E+13	6.17E+12	2.08E+11	2.73E+10	2.57E+10	2.23E+10	1.50E+10	1.05E+10	1.21E+10	1.66E+10	2.35E+10
120	1.40E+16	1.07E+14	4.93E+13	5.56E+12	1.86E+11	2.42E+10	2.27E+10	1.97E+10	1.30E+10	8.53E+09	9.00E+09	1.17E+10	1.59E+10
130	1.28E+16	9.75E+13	4.50E+13	5.08E+12	1.70E+11	2.16E+10	2.03E+10	1.76E+10	1.15E+10	7.12E+09	6.96E+09	8.62E+09	1.11E+10
140	1.15E+16	8.85E+13	4.09E+13	4.63E+12	1.54E+11	1.91E+10	1.79E+10	1.56E+10	1.01E+10	6.00E+09	5.56E+09	6.57E+09	7.93E+09
150	1.07E+16	8.17E+13	3.78E+13	4.27E+12	1.42E+11	1.75E+10	1.65E+10	1.43E+10	9.22E+09	5.40E+09	4.83E+09	5.50E+09	6.06E+09
160	9.85E+15	7.57E+13	3.51E+13	3.97E+12	1.31E+11	1.58E+10	1.48E+10	1.29E+10	8.29E+09	4.82E+09	4.26E+09	4.76E+09	4.88E+09
170	9.10E+15	6.97E+13	3.23E+13	3.66E+12	1.21E+11	1.44E+10	1.35E+10	1.17E+10	7.54E+09	4.38E+09	3.86E+09	4.30E+09	4.30E+09
180	8.43E+15	6.47E+13	3.00E+13	3.40E+12	1.12E+11	1.33E+10	1.25E+10	1.08E+10	6.96E+09	4.05E+09	3.57E+09	3.98E+09	3.98E+09
190	7.93E+15	6.07E+13	2.81E+13	3.19E+12	1.05E+11	1.25E+10	1.17E+10	1.01E+10	6.55E+09	3.81E+09	3.36E+09	3.74E+09	3.74E+09
200	7.40E+15	5.68E+13	2.64E+13	2.99E+12	9.79E+10	1.13E+10	1.06E+10	9.20E+09	5.94E+09	3.47E+09	3.08E+09	3.45E+09	3.45E+09
210	6.92E+15	5.33E+13	2.48E+13	2.82E+12	9.19E+10	1.04E+10	9.75E+09	8.44E+09	5.45E+09	3.18E+09	2.83E+09	3.19E+09	3.19E+09
220	6.48E+15	4.99E+13	2.32E+13	2.64E+12	8.57E+10	9.45E+09	8.89E+09	7.70E+09	4.97E+09	2.91E+09	2.61E+09	2.95E+09	2.95E+09
230	6.05E+15	4.68E+13	2.18E+13	2.48E+12	8.03E+10	8.68E+09	8.16E+09	7.07E+09	4.56E+09	2.67E+09	2.40E+09	2.72E+09	2.72E+09
240	5.76E+15	4.46E+13	2.08E+13	2.37E+12	7.65E+10	8.24E+09	7.75E+09	6.71E+09	4.33E+09	2.54E+09	2.28E+09	2.59E+09	2.59E+09
250	5.43E+15	4.19E+13	1.96E+13	2.23E+12	7.19E+10	7.71E+09	7.25E+09	6.28E+09	4.05E+09	2.38E+09	2.14E+09	2.44E+09	2.44E+09

Table 6. Energy (eV) deposited per second per gram of moist air of 0.5-g/cm^3 density: 60 GWd/MTU average assembly burnup (continued)

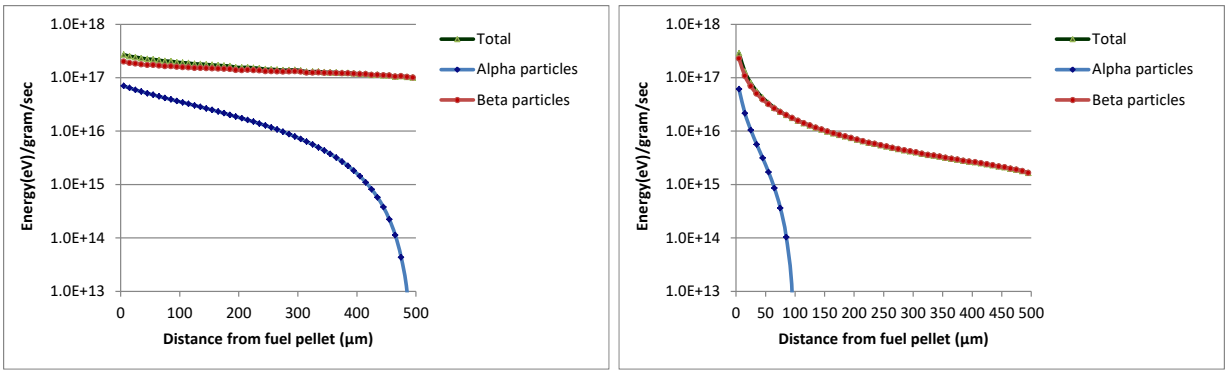
Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	5.13E+15	3.98E+13	1.86E+13	2.12E+12	6.82E+10	7.03E+09	6.61E+09	5.72E+09	3.69E+09	2.17E+09	1.98E+09	2.26E+09	2.26E+09
270	4.86E+15	3.77E+13	1.76E+13	2.01E+12	6.43E+10	6.54E+09	6.15E+09	5.32E+09	3.44E+09	2.03E+09	1.85E+09	2.13E+09	2.13E+09
280	4.60E+15	3.57E+13	1.67E+13	1.91E+12	6.10E+10	6.13E+09	5.76E+09	4.99E+09	3.22E+09	1.90E+09	1.74E+09	2.00E+09	2.00E+09
290	4.37E+15	3.40E+13	1.59E+13	1.82E+12	5.79E+10	5.64E+09	5.31E+09	4.59E+09	2.97E+09	1.76E+09	1.62E+09	1.87E+09	1.87E+09
300	4.19E+15	3.26E+13	1.53E+13	1.75E+12	5.55E+10	5.35E+09	5.03E+09	4.36E+09	2.81E+09	1.67E+09	1.54E+09	1.79E+09	1.79E+09
310	4.00E+15	3.12E+13	1.46E+13	1.67E+12	5.29E+10	5.03E+09	4.73E+09	4.10E+09	2.65E+09	1.57E+09	1.46E+09	1.69E+09	1.69E+09
320	3.77E+15	2.93E+13	1.38E+13	1.58E+12	4.97E+10	4.57E+09	4.30E+09	3.72E+09	2.41E+09	1.44E+09	1.34E+09	1.57E+09	1.57E+09
330	3.58E+15	2.80E+13	1.32E+13	1.51E+12	4.73E+10	4.15E+09	3.90E+09	3.38E+09	2.18E+09	1.31E+09	1.24E+09	1.47E+09	1.47E+09
340	3.49E+15	2.73E+13	1.28E+13	1.47E+12	4.62E+10	4.16E+09	3.92E+09	3.39E+09	2.19E+09	1.31E+09	1.23E+09	1.44E+09	1.44E+09
350	3.35E+15	2.62E+13	1.24E+13	1.41E+12	4.44E+10	3.95E+09	3.72E+09	3.22E+09	2.08E+09	1.24E+09	1.17E+09	1.38E+09	1.38E+09
360	3.17E+15	2.49E+13	1.17E+13	1.34E+12	4.20E+10	3.63E+09	3.42E+09	2.96E+09	1.91E+09	1.15E+09	1.09E+09	1.29E+09	1.29E+09
370	3.04E+15	2.39E+13	1.13E+13	1.29E+12	4.02E+10	3.34E+09	3.14E+09	2.72E+09	1.76E+09	1.06E+09	1.01E+09	1.21E+09	1.21E+09
380	2.93E+15	2.30E+13	1.09E+13	1.24E+12	3.87E+10	3.22E+09	3.03E+09	2.62E+09	1.70E+09	1.03E+09	9.81E+08	1.17E+09	1.17E+09
390	2.79E+15	2.19E+13	1.04E+13	1.19E+12	3.68E+10	2.97E+09	2.79E+09	2.42E+09	1.56E+09	9.48E+08	9.14E+08	1.10E+09	1.10E+09
400	2.68E+15	2.10E+13	9.95E+12	1.14E+12	3.53E+10	2.86E+09	2.69E+09	2.33E+09	1.51E+09	9.16E+08	8.82E+08	1.06E+09	1.06E+09
410	2.60E+15	2.04E+13	9.68E+12	1.11E+12	3.43E+10	2.71E+09	2.55E+09	2.21E+09	1.43E+09	8.72E+08	8.46E+08	1.02E+09	1.02E+09
420	2.50E+15	1.96E+13	9.28E+12	1.06E+12	3.29E+10	2.65E+09	2.49E+09	2.16E+09	1.40E+09	8.49E+08	8.18E+08	9.82E+08	9.82E+08
430	2.39E+15	1.89E+13	8.95E+12	1.03E+12	3.16E+10	2.41E+09	2.27E+09	1.97E+09	1.28E+09	7.81E+08	7.62E+08	9.22E+08	9.22E+08
440	2.29E+15	1.81E+13	8.58E+12	9.86E+11	3.03E+10	2.28E+09	2.15E+09	1.86E+09	1.21E+09	7.38E+08	7.23E+08	8.77E+08	8.77E+08
450	2.17E+15	1.72E+13	8.19E+12	9.42E+11	2.87E+10	2.00E+09	1.88E+09	1.63E+09	1.06E+09	6.53E+08	6.52E+08	8.03E+08	8.03E+08
460	2.10E+15	1.66E+13	7.88E+12	9.06E+11	2.76E+10	1.97E+09	1.85E+09	1.60E+09	1.04E+09	6.44E+08	6.40E+08	7.84E+08	7.84E+08
470	1.98E+15	1.57E+13	7.46E+12	8.58E+11	2.60E+10	1.76E+09	1.66E+09	1.44E+09	9.36E+08	5.85E+08	5.90E+08	7.28E+08	7.28E+08
480	1.89E+15	1.49E+13	7.11E+12	8.18E+11	2.47E+10	1.61E+09	1.52E+09	1.31E+09	8.56E+08	5.39E+08	5.49E+08	6.83E+08	6.83E+08
490	1.78E+15	1.42E+13	6.75E+12	7.76E+11	2.34E+10	1.51E+09	1.42E+09	1.23E+09	8.02E+08	5.05E+08	5.15E+08	6.41E+08	6.41E+08
500	1.65E+15	1.30E+13	6.23E+12	7.18E+11	2.15E+10	1.27E+09	1.19E+09	1.03E+09	6.77E+08	4.35E+08	4.54E+08	5.74E+08	5.74E+08

Table 7. Energy (eV) deposited per second per gram of water: 60 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.80E+17	8.15E+15	5.64E+15	6.77E+15	4.73E+15	3.00E+15	1.89E+15	6.68E+14	3.92E+14	1.85E+14	8.16E+13	2.86E+13	1.29E+13
20	1.20E+17	2.31E+15	1.48E+15	1.57E+15	1.06E+15	6.67E+14	4.16E+14	1.40E+14	8.19E+13	3.86E+13	1.71E+13	6.25E+12	3.22E+12
30	7.18E+16	9.16E+14	5.20E+14	4.17E+14	2.59E+14	1.60E+14	9.75E+13	2.96E+13	1.70E+13	8.02E+12	3.65E+12	1.50E+12	1.04E+12
40	4.97E+16	4.39E+14	2.11E+14	8.20E+13	3.09E+13	1.78E+13	1.02E+13	2.13E+12	1.14E+12	5.77E+11	3.50E+11	2.93E+11	3.76E+11
50	3.74E+16	2.91E+14	1.34E+14	3.02E+13	1.01E+12	1.30E+11	1.22E+11	1.06E+11	7.36E+10	5.84E+10	7.52E+10	1.10E+11	1.64E+11
60	2.99E+16	2.32E+14	1.07E+14	2.42E+13	8.07E+11	1.01E+11	9.50E+10	8.26E+10	5.51E+10	3.74E+10	4.11E+10	5.51E+10	7.63E+10
70	2.48E+16	1.94E+14	9.01E+13	2.04E+13	6.72E+11	8.05E+10	7.56E+10	6.56E+10	4.27E+10	2.60E+10	2.49E+10	3.02E+10	3.75E+10
80	2.11E+16	1.66E+14	7.70E+13	1.75E+13	5.71E+11	6.56E+10	6.16E+10	5.34E+10	3.45E+10	2.02E+10	1.82E+10	2.07E+10	2.19E+10
90	1.81E+16	1.43E+14	6.64E+13	1.51E+13	4.91E+11	5.51E+10	5.18E+10	4.48E+10	2.89E+10	1.69E+10	1.50E+10	1.68E+10	1.68E+10
100	1.59E+16	1.26E+14	5.86E+13	1.33E+13	4.31E+11	4.67E+10	4.39E+10	3.80E+10	2.45E+10	1.43E+10	1.29E+10	1.45E+10	1.45E+10
110	1.40E+16	1.11E+14	5.21E+13	1.19E+13	3.80E+11	3.91E+10	3.67E+10	3.18E+10	2.05E+10	1.21E+10	1.09E+10	1.25E+10	1.25E+10
120	1.26E+16	9.99E+13	4.68E+13	1.07E+13	3.41E+11	3.46E+10	3.25E+10	2.81E+10	1.82E+10	1.07E+10	9.73E+09	1.11E+10	1.11E+10
130	1.11E+16	8.92E+13	4.19E+13	9.56E+12	3.03E+11	2.92E+10	2.74E+10	2.37E+10	1.53E+10	9.07E+09	8.33E+09	9.62E+09	9.62E+09
140	1.02E+16	8.15E+13	3.83E+13	8.74E+12	2.77E+11	2.62E+10	2.46E+10	2.13E+10	1.38E+10	8.17E+09	7.53E+09	8.73E+09	8.73E+09
150	9.26E+15	7.44E+13	3.50E+13	8.00E+12	2.52E+11	2.31E+10	2.18E+10	1.88E+10	1.22E+10	7.25E+09	6.72E+09	7.82E+09	7.82E+09
160	8.45E+15	6.83E+13	3.22E+13	7.37E+12	2.31E+11	2.01E+10	1.89E+10	1.63E+10	1.06E+10	6.32E+09	5.93E+09	6.98E+09	6.98E+09
170	7.67E+15	6.23E+13	2.95E+13	6.75E+12	2.09E+11	1.71E+10	1.61E+10	1.39E+10	8.99E+09	5.41E+09	5.16E+09	6.15E+09	6.15E+09
180	7.11E+15	5.79E+13	2.74E+13	6.29E+12	1.95E+11	1.56E+10	1.46E+10	1.27E+10	8.19E+09	4.94E+09	4.73E+09	5.65E+09	5.65E+09
190	6.63E+15	5.38E+13	2.55E+13	5.85E+12	1.81E+11	1.44E+10	1.35E+10	1.17E+10	7.57E+09	4.58E+09	4.39E+09	5.25E+09	5.25E+09
200	6.10E+15	4.98E+13	2.36E+13	5.42E+12	1.67E+11	1.29E+10	1.21E+10	1.05E+10	6.80E+09	4.12E+09	3.97E+09	4.77E+09	4.77E+09
210	4.91E+15	4.32E+13	2.05E+13	4.72E+12	1.45E+11	1.08E+10	1.02E+10	8.79E+09	5.63E+09	3.31E+09	3.10E+09	3.66E+09	3.66E+09
220	4.59E+15	4.05E+13	1.93E+13	4.43E+12	1.35E+11	9.72E+09	9.15E+09	7.90E+09	5.06E+09	2.99E+09	2.82E+09	3.36E+09	3.36E+09
230	4.29E+15	3.81E+13	1.82E+13	4.18E+12	1.27E+11	8.70E+09	8.19E+09	7.07E+09	4.53E+09	2.68E+09	2.56E+09	3.08E+09	3.08E+09
240	4.06E+15	3.60E+13	1.72E+13	3.95E+12	1.20E+11	8.28E+09	7.79E+09	6.72E+09	4.31E+09	2.55E+09	2.43E+09	2.92E+09	2.92E+09
250	3.80E+15	3.38E+13	1.62E+13	3.72E+12	1.12E+11	7.21E+09	6.79E+09	5.85E+09	3.75E+09	2.24E+09	2.17E+09	2.64E+09	2.64E+09

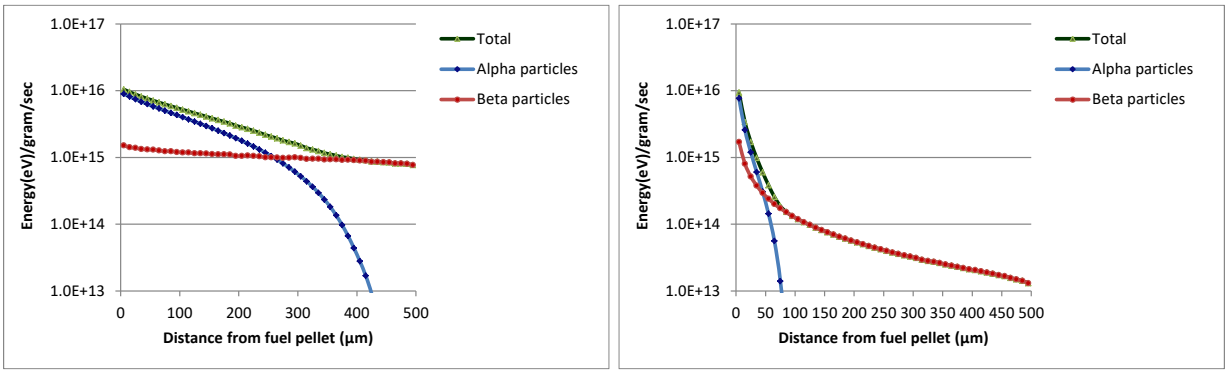
Table 7. Energy (eV) deposited per second per gram of water: 60 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	3.58E+15	3.19E+13	1.53E+13	3.52E+12	1.06E+11	6.41E+09	6.04E+09	5.21E+09	3.34E+09	2.01E+09	1.98E+09	2.43E+09	2.43E+09
270	3.38E+15	3.02E+13	1.44E+13	3.33E+12	9.97E+10	5.97E+09	5.62E+09	4.85E+09	3.11E+09	1.88E+09	1.86E+09	2.29E+09	2.29E+09
280	3.20E+15	2.87E+13	1.37E+13	3.17E+12	9.47E+10	5.45E+09	5.14E+09	4.43E+09	2.84E+09	1.72E+09	1.71E+09	2.13E+09	2.13E+09
290	3.00E+15	2.70E+13	1.30E+13	3.00E+12	8.88E+10	4.68E+09	4.41E+09	3.80E+09	2.44E+09	1.49E+09	1.52E+09	1.93E+09	1.93E+09
300	2.82E+15	2.53E+13	1.22E+13	2.82E+12	8.31E+10	4.12E+09	3.88E+09	3.35E+09	2.15E+09	1.34E+09	1.39E+09	1.77E+09	1.77E+09
310	2.69E+15	2.43E+13	1.17E+13	2.70E+12	7.95E+10	3.91E+09	3.69E+09	3.18E+09	2.05E+09	1.27E+09	1.32E+09	1.69E+09	1.69E+09
320	2.57E+15	2.32E+13	1.12E+13	2.58E+12	7.59E+10	3.64E+09	3.43E+09	2.95E+09	1.90E+09	1.18E+09	1.24E+09	1.59E+09	1.59E+09
330	2.43E+15	2.19E+13	1.06E+13	2.45E+12	7.16E+10	3.25E+09	3.06E+09	2.64E+09	1.70E+09	1.07E+09	1.14E+09	1.48E+09	1.48E+09
340	2.32E+15	2.10E+13	1.01E+13	2.34E+12	6.82E+10	2.90E+09	2.73E+09	2.35E+09	1.52E+09	9.75E+08	1.06E+09	1.38E+09	1.38E+09
350	2.21E+15	2.00E+13	9.64E+12	2.23E+12	6.49E+10	2.66E+09	2.51E+09	2.16E+09	1.40E+09	9.01E+08	9.87E+08	1.30E+09	1.30E+09
360	2.10E+15	1.91E+13	9.21E+12	2.13E+12	6.19E+10	2.39E+09	2.26E+09	1.94E+09	1.26E+09	8.21E+08	9.14E+08	1.22E+09	1.22E+09
370	2.02E+15	1.83E+13	8.87E+12	2.05E+12	5.94E+10	2.24E+09	2.12E+09	1.82E+09	1.18E+09	7.76E+08	8.70E+08	1.16E+09	1.16E+09
380	1.93E+15	1.75E+13	8.47E+12	1.96E+12	5.67E+10	2.07E+09	1.95E+09	1.68E+09	1.09E+09	7.23E+08	8.18E+08	1.10E+09	1.10E+09
390	1.84E+15	1.67E+13	8.07E+12	1.87E+12	5.39E+10	1.91E+09	1.80E+09	1.55E+09	1.01E+09	6.75E+08	7.70E+08	1.04E+09	1.04E+09
400	1.76E+15	1.60E+13	7.72E+12	1.79E+12	5.14E+10	1.75E+09	1.65E+09	1.42E+09	9.30E+08	6.28E+08	7.24E+08	9.79E+08	9.79E+08
410	1.68E+15	1.53E+13	7.41E+12	1.72E+12	4.93E+10	1.62E+09	1.53E+09	1.32E+09	8.63E+08	5.89E+08	6.85E+08	9.30E+08	9.30E+08
420	1.61E+15	1.46E+13	7.07E+12	1.64E+12	4.69E+10	1.50E+09	1.41E+09	1.22E+09	8.00E+08	5.50E+08	6.45E+08	8.79E+08	8.79E+08
430	1.55E+15	1.41E+13	6.82E+12	1.58E+12	4.52E+10	1.43E+09	1.34E+09	1.16E+09	7.64E+08	5.29E+08	6.23E+08	8.48E+08	8.48E+08
440	1.49E+15	1.35E+13	6.54E+12	1.52E+12	4.33E+10	1.33E+09	1.25E+09	1.08E+09	7.11E+08	4.95E+08	5.87E+08	8.03E+08	8.03E+08
450	1.42E+15	1.29E+13	6.25E+12	1.45E+12	4.13E+10	1.20E+09	1.13E+09	9.74E+08	6.45E+08	4.57E+08	5.51E+08	7.58E+08	7.58E+08
460	1.36E+15	1.24E+13	5.99E+12	1.39E+12	3.95E+10	1.10E+09	1.03E+09	8.94E+08	5.96E+08	4.29E+08	5.22E+08	7.20E+08	7.20E+08
470	1.29E+15	1.17E+13	5.67E+12	1.31E+12	3.73E+10	1.03E+09	9.73E+08	8.41E+08	5.63E+08	4.07E+08	4.95E+08	6.81E+08	6.81E+08
480	1.23E+15	1.11E+13	5.38E+12	1.25E+12	3.53E+10	9.27E+08	8.71E+08	7.55E+08	5.11E+08	3.79E+08	4.66E+08	6.41E+08	6.41E+08
490	1.16E+15	1.04E+13	5.06E+12	1.17E+12	3.32E+10	8.58E+08	8.07E+08	6.99E+08	4.75E+08	3.55E+08	4.37E+08	6.01E+08	6.01E+08
500	1.06E+15	9.56E+12	4.64E+12	1.07E+12	3.03E+10	7.29E+08	6.84E+08	5.95E+08	4.09E+08	3.15E+08	3.95E+08	5.45E+08	5.45E+08



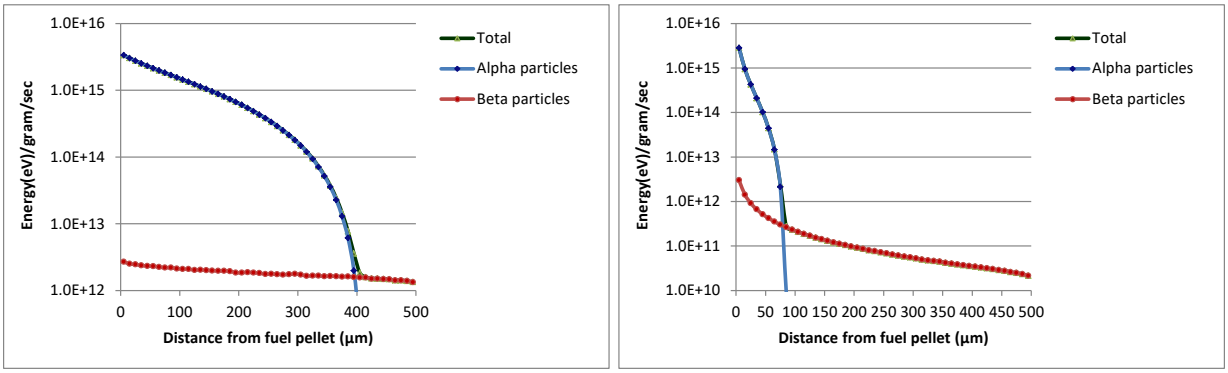
(a) (b)

Fig. 13. Energy (eV) deposited per second per gram of moist air. Most air density of (a) 0.1 g/cm^3; (b) 0.5 g/cm^3. 60-GWd/MTU assembly average burnup; discharge fuel compositions.



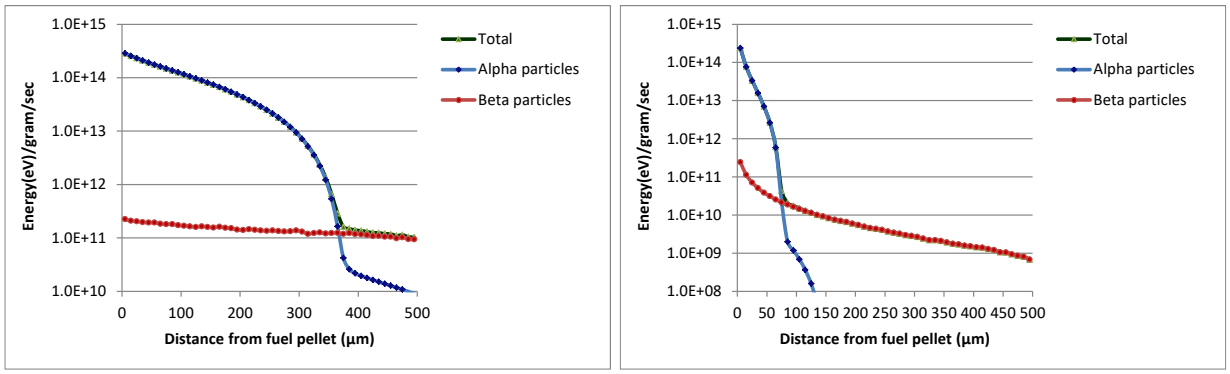
(a) (b)

Fig. 14. Energy (eV) deposited per second per gram of moist air. Most air density of (a) 0.1 g/cm^3; (b) 0.5 g/cm^3. 60-GWd/MTU assembly average burnup; 30-year decay time.



(a) (b)

Fig. 15. Energy (eV) deposited per second per gram of moist air. Most air density of (a) 0.1 g/cm^3; (b) 0.5 g/cm^3. 60-GWd/MTU assembly average burnup; 300-year decay time.



(a) (b)

Fig. 16. Energy (eV) deposited per second per gram of moist air. Most air density of (a) 0.1 g/cm^3; (b) 0.5 g/cm^3. 60-GWd/MTU assembly average burnup; 1×10^4-year decay time.

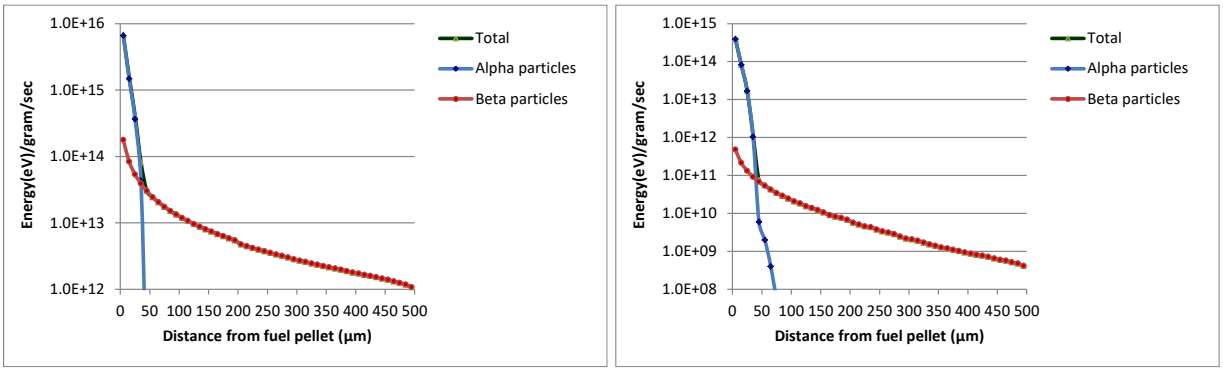


Fig. 17. Energy (eV) deposited per second per gram of water. (a) 150-year decay time; (b) 1×10^4-year decay time. 60-GWd/MTU assembly average burnup.

Table 8. Energy (eV) deposited per second per gram of moist air of 0.1-g/cm^3 density: 40 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.01E+17	3.67E+15	2.96E+15	2.03E+15	1.47E+15	9.57E+14	6.21E+14	2.44E+14	1.46E+14	7.01E+13	3.12E+13	1.07E+13	4.54E+12
20	1.88E+17	3.35E+15	2.70E+15	1.84E+15	1.33E+15	8.65E+14	5.61E+14	2.20E+14	1.32E+14	6.30E+13	2.80E+13	9.68E+12	4.13E+12
30	1.83E+17	3.10E+15	2.48E+15	1.68E+15	1.21E+15	7.87E+14	5.09E+14	1.98E+14	1.19E+14	5.69E+13	2.53E+13	8.77E+12	3.78E+12
40	1.76E+17	2.88E+15	2.29E+15	1.54E+15	1.11E+15	7.19E+14	4.65E+14	1.80E+14	1.08E+14	5.17E+13	2.31E+13	8.00E+12	3.48E+12
50	1.70E+17	2.69E+15	2.12E+15	1.42E+15	1.02E+15	6.60E+14	4.26E+14	1.65E+14	9.87E+13	4.72E+13	2.11E+13	7.33E+12	3.22E+12
60	1.69E+17	2.54E+15	1.98E+15	1.31E+15	9.37E+14	6.08E+14	3.92E+14	1.51E+14	9.05E+13	4.33E+13	1.93E+13	6.74E+12	2.99E+12
70	1.65E+17	2.38E+15	1.85E+15	1.21E+15	8.65E+14	5.61E+14	3.62E+14	1.39E+14	8.32E+13	3.98E+13	1.78E+13	6.21E+12	2.78E+12
80	1.60E+17	2.24E+15	1.73E+15	1.12E+15	8.00E+14	5.18E+14	3.34E+14	1.28E+14	7.64E+13	3.66E+13	1.63E+13	5.73E+12	2.59E+12
90	1.59E+17	2.12E+15	1.62E+15	1.04E+15	7.40E+14	4.79E+14	3.08E+14	1.17E+14	7.02E+13	3.36E+13	1.50E+13	5.29E+12	2.42E+12
100	1.54E+17	2.00E+15	1.52E+15	9.64E+14	6.84E+14	4.43E+14	2.85E+14	1.08E+14	6.46E+13	3.09E+13	1.38E+13	4.89E+12	2.26E+12
110	1.51E+17	1.89E+15	1.42E+15	8.95E+14	6.34E+14	4.09E+14	2.63E+14	9.94E+13	5.93E+13	2.84E+13	1.27E+13	4.51E+12	2.11E+12
120	1.50E+17	1.80E+15	1.34E+15	8.29E+14	5.85E+14	3.78E+14	2.42E+14	9.12E+13	5.44E+13	2.61E+13	1.17E+13	4.16E+12	1.97E+12
130	1.45E+17	1.69E+15	1.25E+15	7.67E+14	5.40E+14	3.48E+14	2.23E+14	8.35E+13	4.98E+13	2.39E+13	1.07E+13	3.83E+12	1.84E+12
140	1.46E+17	1.62E+15	1.18E+15	7.09E+14	4.97E+14	3.20E+14	2.05E+14	7.64E+13	4.56E+13	2.18E+13	9.79E+12	3.52E+12	1.72E+12
150	1.44E+17	1.53E+15	1.10E+15	6.55E+14	4.58E+14	2.95E+14	1.88E+14	6.98E+13	4.16E+13	1.99E+13	8.95E+12	3.24E+12	1.60E+12
160	1.42E+17	1.45E+15	1.03E+15	6.04E+14	4.21E+14	2.70E+14	1.73E+14	6.37E+13	3.79E+13	1.82E+13	8.16E+12	2.97E+12	1.49E+12
170	1.40E+17	1.38E+15	9.68E+14	5.57E+14	3.86E+14	2.48E+14	1.58E+14	5.78E+13	3.44E+13	1.65E+13	7.41E+12	2.71E+12	1.39E+12
180	1.38E+17	1.31E+15	9.12E+14	5.13E+14	3.53E+14	2.26E+14	1.44E+14	5.23E+13	3.11E+13	1.49E+13	6.70E+12	2.47E+12	1.29E+12
190	1.37E+17	1.25E+15	8.55E+14	4.70E+14	3.22E+14	2.06E+14	1.31E+14	4.70E+13	2.79E+13	1.34E+13	6.03E+12	2.24E+12	1.20E+12
200	1.31E+17	1.16E+15	7.91E+14	4.28E+14	2.92E+14	1.87E+14	1.18E+14	4.20E+13	2.49E+13	1.20E+13	5.40E+12	2.03E+12	1.11E+12
210	1.30E+17	1.11E+15	7.42E+14	3.90E+14	2.64E+14	1.68E+14	1.06E+14	3.74E+13	2.21E+13	1.06E+13	4.81E+12	1.83E+12	1.03E+12
220	1.32E+17	1.07E+15	6.97E+14	3.54E+14	2.37E+14	1.51E+14	9.49E+13	3.30E+13	1.95E+13	9.37E+12	4.26E+12	1.64E+12	9.56E+11
230	1.29E+17	1.01E+15	6.48E+14	3.19E+14	2.12E+14	1.35E+14	8.44E+13	2.90E+13	1.71E+13	8.22E+12	3.75E+12	1.47E+12	8.84E+11
240	1.27E+17	9.55E+14	6.04E+14	2.87E+14	1.88E+14	1.19E+14	7.45E+13	2.52E+13	1.48E+13	7.14E+12	3.27E+12	1.31E+12	8.17E+11
250	1.23E+17	8.94E+14	5.56E+14	2.56E+14	1.66E+14	1.05E+14	6.54E+13	2.18E+13	1.28E+13	6.15E+12	2.83E+12	1.16E+12	7.52E+11

Table 8. Energy (eV) deposited per second per gram of moist air of 0.1-g/cm^3 density: 40 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	1.23E+17	8.53E+14	5.19E+14	2.28E+14	1.46E+14	9.18E+13	5.69E+13	1.86E+13	1.09E+13	5.26E+12	2.44E+12	1.02E+12	6.94E+11
270	1.22E+17	8.12E+14	4.84E+14	2.02E+14	1.27E+14	7.95E+13	4.90E+13	1.57E+13	9.17E+12	4.42E+12	2.07E+12	8.93E+11	6.38E+11
280	1.20E+17	7.68E+14	4.49E+14	1.78E+14	1.09E+14	6.81E+13	4.18E+13	1.30E+13	7.57E+12	3.66E+12	1.73E+12	7.76E+11	5.87E+11
290	1.21E+17	7.41E+14	4.22E+14	1.56E+14	9.31E+13	5.78E+13	3.52E+13	1.06E+13	6.12E+12	2.97E+12	1.42E+12	6.72E+11	5.41E+11
300	1.22E+17	7.18E+14	3.98E+14	1.36E+14	7.83E+13	4.82E+13	2.91E+13	8.37E+12	4.82E+12	2.35E+12	1.15E+12	5.79E+11	4.99E+11
310	1.19E+17	6.80E+14	3.69E+14	1.17E+14	6.46E+13	3.95E+13	2.36E+13	6.40E+12	3.65E+12	1.79E+12	9.00E+11	4.94E+11	4.60E+11
320	1.14E+17	6.36E+14	3.39E+14	9.90E+13	5.22E+13	3.16E+13	1.87E+13	4.72E+12	2.66E+12	1.32E+12	6.89E+11	4.19E+11	4.24E+11
330	1.15E+17	6.15E+14	3.19E+14	8.36E+13	4.11E+13	2.46E+13	1.43E+13	3.30E+12	1.83E+12	9.26E+11	5.16E+11	3.60E+11	3.95E+11
340	1.15E+17	5.95E+14	3.01E+14	6.99E+13	3.12E+13	1.84E+13	1.05E+13	2.13E+12	1.16E+12	6.04E+11	3.74E+11	3.10E+11	3.69E+11
350	1.12E+17	5.66E+14	2.80E+14	5.79E+13	2.29E+13	1.32E+13	7.39E+12	1.24E+12	6.44E+11	3.60E+11	2.64E+11	2.68E+11	3.44E+11
360	1.12E+17	5.52E+14	2.68E+14	4.83E+13	1.61E+13	9.00E+12	4.91E+12	6.23E+11	3.02E+11	1.97E+11	1.89E+11	2.37E+11	3.21E+11
370	1.12E+17	5.38E+14	2.56E+14	4.04E+13	1.05E+13	5.66E+12	3.02E+12	2.69E+11	1.17E+11	1.08E+11	1.45E+11	2.13E+11	3.00E+11
380	1.10E+17	5.21E+14	2.45E+14	3.41E+13	6.29E+12	3.21E+12	1.70E+12	1.28E+11	5.84E+10	7.72E+10	1.26E+11	1.96E+11	2.79E+11
390	1.11E+17	5.15E+14	2.39E+14	2.99E+13	3.42E+12	1.55E+12	8.32E+11	8.83E+10	5.44E+10	7.29E+10	1.18E+11	1.84E+11	2.61E+11
400	1.08E+17	5.01E+14	2.32E+14	2.70E+13	1.65E+12	5.41E+11	3.06E+11	6.42E+10	5.14E+10	6.83E+10	1.11E+11	1.71E+11	2.44E+11
410	1.07E+17	4.93E+14	2.28E+14	2.57E+13	9.18E+11	1.24E+11	8.88E+10	5.47E+10	5.00E+10	6.50E+10	1.04E+11	1.61E+11	2.28E+11
420	1.06E+17	4.90E+14	2.27E+14	2.55E+13	8.11E+11	6.26E+10	5.61E+10	5.14E+10	4.77E+10	6.12E+10	9.75E+10	1.50E+11	2.13E+11
430	1.02E+17	4.72E+14	2.18E+14	2.46E+13	7.80E+11	5.94E+10	5.36E+10	4.93E+10	4.54E+10	5.76E+10	9.11E+10	1.40E+11	1.99E+11
440	1.03E+17	4.70E+14	2.18E+14	2.46E+13	7.78E+11	5.95E+10	5.39E+10	4.95E+10	4.49E+10	5.54E+10	8.63E+10	1.32E+11	1.86E+11
450	1.01E+17	4.63E+14	2.15E+14	2.42E+13	7.65E+11	5.73E+10	5.21E+10	4.78E+10	4.29E+10	5.23E+10	8.09E+10	1.23E+11	1.74E+11
460	1.00E+17	4.61E+14	2.14E+14	2.42E+13	7.62E+11	5.71E+10	5.20E+10	4.77E+10	4.23E+10	5.03E+10	7.67E+10	1.16E+11	1.63E+11
470	9.57E+16	4.46E+14	2.08E+14	2.35E+13	7.36E+11	5.30E+10	4.84E+10	4.44E+10	3.92E+10	4.66E+10	7.11E+10	1.08E+11	1.52E+11
480	9.68E+16	4.45E+14	2.06E+14	2.33E+13	7.33E+11	5.54E+10	5.06E+10	4.63E+10	4.02E+10	4.60E+10	6.85E+10	1.02E+11	1.43E+11
490	9.40E+16	4.39E+14	2.04E+14	2.31E+13	7.21E+11	5.09E+10	4.66E+10	4.26E+10	3.70E+10	4.25E+10	6.35E+10	9.51E+10	1.33E+11
500	9.13E+16	4.20E+14	1.95E+14	2.21E+13	6.92E+11	5.06E+10	4.62E+10	4.22E+10	3.63E+10	4.08E+10	6.00E+10	8.92E+10	1.24E+11

Table 9. Energy (eV) deposited per second per gram of moist air of 0.5-g/cm^3 density: 40 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.23E+17	3.34E+15	2.62E+15	1.74E+15	1.25E+15	8.10E+14	5.24E+14	2.04E+14	1.23E+14	5.87E+13	2.61E+13	9.05E+12	3.91E+12
20	1.03E+17	1.24E+15	9.32E+14	5.83E+14	4.13E+14	2.67E+14	1.72E+14	6.58E+13	3.94E+13	1.89E+13	8.42E+12	2.96E+12	1.35E+12
30	6.54E+16	6.50E+14	4.61E+14	2.68E+14	1.86E+14	1.20E+14	7.70E+13	2.88E+13	1.72E+13	8.24E+12	3.70E+12	1.33E+12	6.42E+11
40	4.71E+16	3.90E+14	2.60E+14	1.36E+14	9.20E+13	5.90E+13	3.75E+13	1.36E+13	8.08E+12	3.88E+12	1.75E+12	6.48E+11	3.41E+11
50	3.62E+16	2.51E+14	1.55E+14	6.91E+13	4.45E+13	2.82E+13	1.77E+13	6.09E+12	3.59E+12	1.73E+12	7.90E+11	3.12E+11	1.89E+11
60	2.95E+16	1.72E+14	9.63E+13	3.33E+13	1.94E+13	1.20E+13	7.40E+12	2.31E+12	1.35E+12	6.52E+11	3.09E+11	1.40E+11	1.06E+11
70	2.43E+16	1.24E+14	6.29E+13	1.45E+13	6.44E+12	3.84E+12	2.25E+12	5.39E+11	3.02E+11	1.52E+11	8.46E+10	5.82E+10	6.23E+10
80	2.08E+16	9.72E+13	4.58E+13	6.25E+12	1.06E+12	5.37E+11	2.91E+11	3.38E+10	1.74E+10	1.54E+10	1.99E+10	2.85E+10	3.91E+10
90	1.82E+16	8.27E+13	3.84E+13	4.34E+12	1.40E+11	1.20E+10	1.02E+10	8.51E+09	7.35E+09	8.40E+09	1.25E+10	1.86E+10	2.54E+10
100	1.60E+16	7.28E+13	3.38E+13	3.83E+12	1.20E+11	8.77E+09	8.01E+09	7.28E+09	6.05E+09	6.31E+09	8.84E+09	1.28E+10	1.69E+10
110	1.43E+16	6.50E+13	3.02E+13	3.42E+12	1.07E+11	7.71E+09	7.05E+09	6.38E+09	5.12E+09	4.92E+09	6.46E+09	8.98E+09	1.13E+10
120	1.28E+16	5.86E+13	2.73E+13	3.09E+12	9.66E+10	6.81E+09	6.23E+09	5.61E+09	4.38E+09	3.90E+09	4.78E+09	6.35E+09	7.49E+09
130	1.17E+16	5.34E+13	2.49E+13	2.82E+12	8.81E+10	6.09E+09	5.57E+09	5.01E+09	3.82E+09	3.19E+09	3.67E+09	4.64E+09	5.10E+09
140	1.05E+16	4.86E+13	2.27E+13	2.57E+12	7.99E+10	5.37E+09	4.91E+09	4.41E+09	3.32E+09	2.66E+09	2.91E+09	3.54E+09	3.58E+09
150	9.72E+15	4.49E+13	2.09E+13	2.38E+12	7.38E+10	4.93E+09	4.51E+09	4.05E+09	3.03E+09	2.38E+09	2.54E+09	2.99E+09	2.71E+09
160	8.98E+15	4.16E+13	1.94E+13	2.21E+12	6.83E+10	4.44E+09	4.06E+09	3.64E+09	2.72E+09	2.13E+09	2.25E+09	2.61E+09	2.19E+09
170	8.30E+15	3.83E+13	1.79E+13	2.04E+12	6.29E+10	4.03E+09	3.69E+09	3.31E+09	2.47E+09	1.93E+09	2.04E+09	2.37E+09	1.94E+09
180	7.69E+15	3.56E+13	1.67E+13	1.89E+12	5.85E+10	3.73E+09	3.41E+09	3.05E+09	2.28E+09	1.79E+09	1.89E+09	2.19E+09	1.80E+09
190	7.23E+15	3.34E+13	1.56E+13	1.77E+12	5.47E+10	3.50E+09	3.20E+09	2.87E+09	2.15E+09	1.68E+09	1.78E+09	2.06E+09	1.69E+09
200	6.75E+15	3.13E+13	1.47E+13	1.67E+12	5.12E+10	3.17E+09	2.90E+09	2.60E+09	1.95E+09	1.54E+09	1.63E+09	1.90E+09	1.57E+09
210	6.31E+15	2.94E+13	1.38E+13	1.57E+12	4.81E+10	2.91E+09	2.66E+09	2.38E+09	1.78E+09	1.41E+09	1.50E+09	1.76E+09	1.46E+09
220	5.91E+15	2.75E+13	1.29E+13	1.47E+12	4.50E+10	2.65E+09	2.42E+09	2.17E+09	1.63E+09	1.29E+09	1.39E+09	1.63E+09	1.36E+09
230	5.51E+15	2.59E+13	1.22E+13	1.39E+12	4.22E+10	2.43E+09	2.22E+09	1.99E+09	1.50E+09	1.19E+09	1.28E+09	1.51E+09	1.26E+09
240	5.26E+15	2.46E+13	1.16E+13	1.32E+12	4.02E+10	2.30E+09	2.11E+09	1.89E+09	1.42E+09	1.13E+09	1.21E+09	1.44E+09	1.20E+09
250	4.95E+15	2.32E+13	1.09E+13	1.24E+12	3.78E+10	2.16E+09	1.97E+09	1.77E+09	1.33E+09	1.06E+09	1.14E+09	1.35E+09	1.13E+09

Table 9. Energy (eV) deposited per second per gram of moist air of 0.5-g/cm^3 density: 40 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	4.68E+15	2.21E+13	1.04E+13	1.19E+12	3.59E+10	1.96E+09	1.80E+09	1.61E+09	1.21E+09	9.66E+08	1.05E+09	1.25E+09	1.06E+09
270	4.43E+15	2.09E+13	9.83E+12	1.12E+12	3.40E+10	1.83E+09	1.67E+09	1.50E+09	1.13E+09	9.03E+08	9.88E+08	1.18E+09	1.00E+09
280	4.19E+15	1.98E+13	9.35E+12	1.07E+12	3.22E+10	1.71E+09	1.56E+09	1.40E+09	1.05E+09	8.48E+08	9.29E+08	1.11E+09	9.46E+08
290	3.98E+15	1.89E+13	8.91E+12	1.02E+12	3.07E+10	1.57E+09	1.44E+09	1.29E+09	9.70E+08	7.82E+08	8.64E+08	1.04E+09	8.93E+08
300	3.82E+15	1.81E+13	8.55E+12	9.78E+11	2.94E+10	1.49E+09	1.36E+09	1.22E+09	9.19E+08	7.43E+08	8.23E+08	9.95E+08	8.55E+08
310	3.64E+15	1.73E+13	8.18E+12	9.36E+11	2.81E+10	1.40E+09	1.28E+09	1.15E+09	8.65E+08	7.01E+08	7.79E+08	9.43E+08	8.12E+08
320	3.43E+15	1.63E+13	7.73E+12	8.84E+11	2.65E+10	1.27E+09	1.16E+09	1.04E+09	7.87E+08	6.42E+08	7.20E+08	8.77E+08	7.60E+08
330	3.26E+15	1.56E+13	7.39E+12	8.47E+11	2.52E+10	1.15E+09	1.05E+09	9.43E+08	7.13E+08	5.88E+08	6.67E+08	8.20E+08	7.19E+08
340	3.18E+15	1.52E+13	7.19E+12	8.23E+11	2.46E+10	1.15E+09	1.06E+09	9.48E+08	7.15E+08	5.85E+08	6.59E+08	8.06E+08	7.03E+08
350	3.04E+15	1.46E+13	6.92E+12	7.92E+11	2.36E+10	1.10E+09	1.00E+09	9.00E+08	6.79E+08	5.57E+08	6.28E+08	7.70E+08	6.72E+08
360	2.88E+15	1.39E+13	6.59E+12	7.55E+11	2.24E+10	1.01E+09	9.21E+08	8.25E+08	6.24E+08	5.14E+08	5.84E+08	7.19E+08	6.31E+08
370	2.77E+15	1.33E+13	6.33E+12	7.26E+11	2.15E+10	9.22E+08	8.44E+08	7.56E+08	5.73E+08	4.76E+08	5.47E+08	6.80E+08	6.02E+08
380	2.66E+15	1.28E+13	6.10E+12	6.99E+11	2.07E+10	8.91E+08	8.16E+08	7.32E+08	5.54E+08	4.61E+08	5.29E+08	6.56E+08	5.80E+08
390	2.54E+15	1.23E+13	5.83E+12	6.69E+11	1.98E+10	8.19E+08	7.50E+08	6.72E+08	5.10E+08	4.26E+08	4.93E+08	6.16E+08	5.49E+08
400	2.44E+15	1.18E+13	5.59E+12	6.41E+11	1.90E+10	7.91E+08	7.25E+08	6.49E+08	4.93E+08	4.12E+08	4.76E+08	5.93E+08	5.27E+08
410	2.37E+15	1.14E+13	5.44E+12	6.24E+11	1.84E+10	7.49E+08	6.86E+08	6.15E+08	4.67E+08	3.93E+08	4.57E+08	5.72E+08	5.11E+08
420	2.27E+15	1.10E+13	5.22E+12	5.99E+11	1.77E+10	7.32E+08	6.70E+08	6.01E+08	4.56E+08	3.82E+08	4.42E+08	5.52E+08	4.91E+08
430	2.18E+15	1.06E+13	5.04E+12	5.78E+11	1.70E+10	6.66E+08	6.10E+08	5.47E+08	4.17E+08	3.52E+08	4.13E+08	5.19E+08	4.65E+08
440	2.08E+15	1.01E+13	4.83E+12	5.55E+11	1.63E+10	6.29E+08	5.76E+08	5.16E+08	3.93E+08	3.33E+08	3.91E+08	4.94E+08	4.44E+08
450	1.97E+15	9.67E+12	4.62E+12	5.31E+11	1.55E+10	5.48E+08	5.02E+08	4.50E+08	3.44E+08	2.96E+08	3.55E+08	4.54E+08	4.14E+08
460	1.90E+15	9.32E+12	4.45E+12	5.11E+11	1.49E+10	5.41E+08	4.95E+08	4.44E+08	3.40E+08	2.92E+08	3.48E+08	4.43E+08	4.01E+08
470	1.80E+15	8.82E+12	4.21E+12	4.84E+11	1.41E+10	4.85E+08	4.44E+08	3.98E+08	3.06E+08	2.66E+08	3.21E+08	4.12E+08	3.76E+08
480	1.71E+15	8.40E+12	4.02E+12	4.62E+11	1.34E+10	4.42E+08	4.05E+08	3.63E+08	2.80E+08	2.46E+08	3.00E+08	3.87E+08	3.56E+08
490	1.61E+15	7.98E+12	3.82E+12	4.39E+11	1.27E+10	4.14E+08	3.79E+08	3.40E+08	2.62E+08	2.30E+08	2.81E+08	3.63E+08	3.34E+08
500	1.49E+15	7.36E+12	3.53E+12	4.06E+11	1.17E+10	3.47E+08	3.18E+08	2.85E+08	2.21E+08	1.99E+08	2.49E+08	3.27E+08	3.04E+08

Table 10. Energy (eV) deposited per second per gram of water: 40 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.22E+17	2.97E+15	2.27E+15	2.92E+15	2.08E+15	1.35E+15	8.70E+14	3.37E+14	2.02E+14	9.66E+13	4.31E+13	1.50E+13	6.62E+12
20	1.00E+17	9.07E+14	6.20E+14	6.79E+14	4.65E+14	2.99E+14	1.91E+14	7.06E+13	4.20E+13	2.02E+13	9.06E+12	3.29E+12	1.65E+12
30	6.28E+16	4.01E+14	2.34E+14	1.84E+14	1.13E+14	7.12E+13	4.43E+13	1.48E+13	8.68E+12	4.18E+12	1.94E+12	8.02E+11	5.30E+11
40	4.47E+16	2.22E+14	1.08E+14	3.96E+13	1.34E+13	7.77E+12	4.50E+12	1.01E+12	5.62E+11	2.98E+11	1.89E+11	1.60E+11	1.89E+11
50	3.41E+16	1.59E+14	7.40E+13	1.68E+13	5.24E+11	3.68E+10	3.34E+10	3.04E+10	2.58E+10	2.82E+10	4.08E+10	5.99E+10	8.04E+10
60	2.74E+16	1.28E+14	5.95E+13	1.35E+13	4.20E+11	2.85E+10	2.61E+10	2.35E+10	1.86E+10	1.73E+10	2.20E+10	2.99E+10	3.64E+10
70	2.27E+16	1.07E+14	5.00E+13	1.14E+13	3.51E+11	2.26E+10	2.07E+10	1.86E+10	1.41E+10	1.16E+10	1.31E+10	1.63E+10	1.72E+10
80	1.93E+16	9.14E+13	4.28E+13	9.74E+12	2.99E+11	1.84E+10	1.69E+10	1.51E+10	1.13E+10	8.96E+09	9.59E+09	1.13E+10	9.95E+09
90	1.66E+16	7.88E+13	3.70E+13	8.41E+12	2.58E+11	1.55E+10	1.41E+10	1.27E+10	9.49E+09	7.48E+09	7.95E+09	9.29E+09	7.68E+09
100	1.45E+16	6.94E+13	3.26E+13	7.44E+12	2.27E+11	1.31E+10	1.20E+10	1.07E+10	8.04E+09	6.36E+09	6.82E+09	8.02E+09	6.69E+09
110	1.28E+16	6.17E+13	2.91E+13	6.64E+12	2.01E+11	1.09E+10	9.98E+09	8.95E+09	6.72E+09	5.35E+09	5.81E+09	6.90E+09	5.82E+09
120	1.15E+16	5.54E+13	2.61E+13	5.96E+12	1.80E+11	9.66E+09	8.84E+09	7.92E+09	5.95E+09	4.76E+09	5.18E+09	6.16E+09	5.21E+09
130	1.02E+16	4.96E+13	2.34E+13	5.36E+12	1.61E+11	8.13E+09	7.44E+09	6.67E+09	5.01E+09	4.04E+09	4.45E+09	5.35E+09	4.58E+09
140	9.30E+15	4.53E+13	2.14E+13	4.90E+12	1.47E+11	7.29E+09	6.68E+09	5.98E+09	4.50E+09	3.64E+09	4.02E+09	4.85E+09	4.17E+09
150	8.46E+15	4.15E+13	1.96E+13	4.49E+12	1.34E+11	6.44E+09	5.89E+09	5.28E+09	3.98E+09	3.23E+09	3.60E+09	4.36E+09	3.76E+09
160	7.72E+15	3.81E+13	1.81E+13	4.14E+12	1.23E+11	5.57E+09	5.10E+09	4.57E+09	3.45E+09	2.82E+09	3.18E+09	3.90E+09	3.40E+09
170	7.01E+15	3.48E+13	1.65E+13	3.80E+12	1.12E+11	4.72E+09	4.32E+09	3.87E+09	2.93E+09	2.43E+09	2.78E+09	3.45E+09	3.05E+09
180	6.49E+15	3.24E+13	1.54E+13	3.54E+12	1.04E+11	4.29E+09	3.93E+09	3.52E+09	2.67E+09	2.22E+09	2.55E+09	3.17E+09	2.81E+09
190	6.04E+15	3.01E+13	1.43E+13	3.29E+12	9.70E+10	3.97E+09	3.64E+09	3.26E+09	2.47E+09	2.05E+09	2.37E+09	2.94E+09	2.61E+09
200	5.56E+15	2.79E+13	1.33E+13	3.05E+12	8.98E+10	3.56E+09	3.26E+09	2.92E+09	2.22E+09	1.85E+09	2.14E+09	2.68E+09	2.39E+09
210	4.41E+15	2.43E+13	1.16E+13	2.66E+12	7.80E+10	2.97E+09	2.72E+09	2.43E+09	1.81E+09	1.47E+09	1.66E+09	2.05E+09	1.79E+09
220	4.12E+15	2.27E+13	1.09E+13	2.50E+12	7.30E+10	2.66E+09	2.44E+09	2.18E+09	1.63E+09	1.33E+09	1.52E+09	1.89E+09	1.66E+09
230	3.86E+15	2.14E+13	1.03E+13	2.36E+12	6.88E+10	2.37E+09	2.17E+09	1.94E+09	1.45E+09	1.19E+09	1.38E+09	1.73E+09	1.54E+09
240	3.64E+15	2.03E+13	9.69E+12	2.23E+12	6.50E+10	2.26E+09	2.07E+09	1.85E+09	1.38E+09	1.14E+09	1.31E+09	1.64E+09	1.46E+09
250	3.41E+15	1.91E+13	9.13E+12	2.10E+12	6.10E+10	1.96E+09	1.79E+09	1.60E+09	1.20E+09	9.98E+08	1.17E+09	1.49E+09	1.35E+09

Table 10. Energy (eV) deposited per second per gram of water: 40 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	3.21E+15	1.80E+13	8.65E+12	1.99E+12	5.76E+10	1.74E+09	1.59E+09	1.42E+09	1.07E+09	9.01E+08	1.07E+09	1.38E+09	1.25E+09
270	3.03E+15	1.70E+13	8.18E+12	1.88E+12	5.44E+10	1.62E+09	1.48E+09	1.32E+09	9.96E+08	8.42E+08	1.01E+09	1.29E+09	1.18E+09
280	2.87E+15	1.62E+13	7.79E+12	1.80E+12	5.18E+10	1.47E+09	1.35E+09	1.20E+09	9.05E+08	7.69E+08	9.31E+08	1.21E+09	1.11E+09
290	2.69E+15	1.53E+13	7.36E+12	1.70E+12	4.87E+10	1.25E+09	1.15E+09	1.02E+09	7.74E+08	6.72E+08	8.34E+08	1.10E+09	1.03E+09
300	2.52E+15	1.44E+13	6.93E+12	1.60E+12	4.57E+10	1.10E+09	1.01E+09	9.01E+08	6.85E+08	6.04E+08	7.61E+08	1.01E+09	9.51E+08
310	2.41E+15	1.38E+13	6.63E+12	1.53E+12	4.37E+10	1.04E+09	9.59E+08	8.55E+08	6.50E+08	5.75E+08	7.26E+08	9.65E+08	9.08E+08
320	2.30E+15	1.32E+13	6.34E+12	1.47E+12	4.18E+10	9.69E+08	8.89E+08	7.93E+08	6.03E+08	5.36E+08	6.82E+08	9.11E+08	8.61E+08
330	2.17E+15	1.25E+13	6.02E+12	1.39E+12	3.96E+10	8.63E+08	7.92E+08	7.06E+08	5.40E+08	4.88E+08	6.30E+08	8.48E+08	8.06E+08
340	2.07E+15	1.19E+13	5.77E+12	1.33E+12	3.78E+10	7.68E+08	7.05E+08	6.29E+08	4.84E+08	4.45E+08	5.84E+08	7.94E+08	7.60E+08
350	1.97E+15	1.14E+13	5.50E+12	1.27E+12	3.60E+10	7.02E+08	6.45E+08	5.75E+08	4.43E+08	4.12E+08	5.47E+08	7.48E+08	7.20E+08
360	1.88E+15	1.09E+13	5.26E+12	1.22E+12	3.43E+10	6.29E+08	5.78E+08	5.15E+08	3.99E+08	3.77E+08	5.08E+08	7.00E+08	6.78E+08
370	1.81E+15	1.05E+13	5.06E+12	1.17E+12	3.30E+10	5.89E+08	5.41E+08	4.82E+08	3.75E+08	3.57E+08	4.84E+08	6.70E+08	6.51E+08
380	1.72E+15	1.00E+13	4.84E+12	1.12E+12	3.16E+10	5.43E+08	4.99E+08	4.45E+08	3.47E+08	3.33E+08	4.55E+08	6.33E+08	6.17E+08
390	1.64E+15	9.53E+12	4.61E+12	1.07E+12	3.00E+10	5.00E+08	4.59E+08	4.09E+08	3.21E+08	3.12E+08	4.29E+08	5.99E+08	5.84E+08
400	1.57E+15	9.13E+12	4.42E+12	1.02E+12	2.87E+10	4.59E+08	4.21E+08	3.76E+08	2.96E+08	2.91E+08	4.05E+08	5.66E+08	5.54E+08
410	1.50E+15	8.77E+12	4.25E+12	9.82E+11	2.76E+10	4.24E+08	3.89E+08	3.47E+08	2.75E+08	2.74E+08	3.83E+08	5.38E+08	5.27E+08
420	1.43E+15	8.36E+12	4.05E+12	9.37E+11	2.63E+10	3.92E+08	3.59E+08	3.21E+08	2.55E+08	2.57E+08	3.61E+08	5.09E+08	5.00E+08
430	1.38E+15	8.07E+12	3.91E+12	9.04E+11	2.53E+10	3.74E+08	3.43E+08	3.06E+08	2.45E+08	2.47E+08	3.49E+08	4.91E+08	4.82E+08
440	1.32E+15	7.74E+12	3.75E+12	8.67E+11	2.43E+10	3.47E+08	3.18E+08	2.84E+08	2.27E+08	2.31E+08	3.29E+08	4.66E+08	4.58E+08
450	1.26E+15	7.40E+12	3.59E+12	8.30E+11	2.32E+10	3.12E+08	2.86E+08	2.56E+08	2.07E+08	2.15E+08	3.10E+08	4.41E+08	4.34E+08
460	1.21E+15	7.10E+12	3.44E+12	7.96E+11	2.22E+10	2.87E+08	2.63E+08	2.36E+08	1.92E+08	2.03E+08	2.94E+08	4.18E+08	4.12E+08
470	1.14E+15	6.72E+12	3.26E+12	7.52E+11	2.10E+10	2.71E+08	2.48E+08	2.23E+08	1.82E+08	1.92E+08	2.78E+08	3.96E+08	3.89E+08
480	1.09E+15	6.39E+12	3.10E+12	7.15E+11	1.99E+10	2.45E+08	2.23E+08	2.01E+08	1.67E+08	1.80E+08	2.62E+08	3.73E+08	3.65E+08
490	1.02E+15	6.01E+12	2.91E+12	6.73E+11	1.87E+10	2.28E+08	2.08E+08	1.87E+08	1.56E+08	1.69E+08	2.46E+08	3.49E+08	3.41E+08
500	9.38E+14	5.51E+12	2.67E+12	6.17E+11	1.71E+10	1.94E+08	1.77E+08	1.60E+08	1.36E+08	1.51E+08	2.22E+08	3.17E+08	3.10E+08

Table 11. Energy (eV) deposited per second per gram of moist air of 0.1-g/cm^3 density: 25 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	1.80E+17	2.37E+15	1.94E+15	1.35E+15	1.02E+15	6.88E+14	4.56E+14	1.91E+14	1.17E+14	5.75E+13	2.55E+13	8.08E+12	3.01E+12
20	1.69E+17	2.17E+15	1.76E+15	1.23E+15	9.21E+14	6.22E+14	4.12E+14	1.72E+14	1.05E+14	5.17E+13	2.30E+13	7.28E+12	2.74E+12
30	1.65E+17	2.03E+15	1.63E+15	1.12E+15	8.38E+14	5.65E+14	3.74E+14	1.55E+14	9.52E+13	4.66E+13	2.07E+13	6.59E+12	2.50E+12
40	1.59E+17	1.89E+15	1.51E+15	1.02E+15	7.66E+14	5.17E+14	3.41E+14	1.41E+14	8.66E+13	4.24E+13	1.89E+13	6.01E+12	2.31E+12
50	1.54E+17	1.78E+15	1.41E+15	9.43E+14	7.03E+14	4.74E+14	3.13E+14	1.29E+14	7.90E+13	3.87E+13	1.72E+13	5.51E+12	2.14E+12
60	1.54E+17	1.69E+15	1.32E+15	8.71E+14	6.48E+14	4.36E+14	2.88E+14	1.18E+14	7.25E+13	3.55E+13	1.58E+13	5.06E+12	1.99E+12
70	1.50E+17	1.60E+15	1.24E+15	8.07E+14	5.98E+14	4.03E+14	2.65E+14	1.09E+14	6.66E+13	3.26E+13	1.45E+13	4.67E+12	1.85E+12
80	1.45E+17	1.52E+15	1.16E+15	7.48E+14	5.53E+14	3.72E+14	2.45E+14	1.00E+14	6.12E+13	3.00E+13	1.34E+13	4.30E+12	1.72E+12
90	1.45E+17	1.45E+15	1.10E+15	6.95E+14	5.12E+14	3.44E+14	2.26E+14	9.20E+13	5.63E+13	2.76E+13	1.23E+13	3.97E+12	1.61E+12
100	1.41E+17	1.38E+15	1.03E+15	6.44E+14	4.73E+14	3.18E+14	2.08E+14	8.46E+13	5.17E+13	2.54E+13	1.13E+13	3.66E+12	1.50E+12
110	1.39E+17	1.32E+15	9.71E+14	5.98E+14	4.38E+14	2.94E+14	1.93E+14	7.78E+13	4.75E+13	2.33E+13	1.04E+13	3.38E+12	1.41E+12
120	1.37E+17	1.27E+15	9.20E+14	5.55E+14	4.04E+14	2.71E+14	1.77E+14	7.14E+13	4.36E+13	2.14E+13	9.54E+12	3.11E+12	1.31E+12
130	1.34E+17	1.20E+15	8.63E+14	5.14E+14	3.73E+14	2.50E+14	1.63E+14	6.54E+13	3.99E+13	1.96E+13	8.74E+12	2.87E+12	1.23E+12
140	1.34E+17	1.16E+15	8.19E+14	4.76E+14	3.44E+14	2.30E+14	1.50E+14	5.98E+13	3.65E+13	1.79E+13	8.00E+12	2.64E+12	1.15E+12
150	1.33E+17	1.11E+15	7.74E+14	4.41E+14	3.16E+14	2.11E+14	1.38E+14	5.47E+13	3.33E+13	1.63E+13	7.32E+12	2.42E+12	1.07E+12
160	1.31E+17	1.06E+15	7.31E+14	4.07E+14	2.91E+14	1.94E+14	1.26E+14	4.98E+13	3.04E+13	1.49E+13	6.67E+12	2.22E+12	9.97E+11
170	1.29E+17	1.01E+15	6.89E+14	3.75E+14	2.67E+14	1.78E+14	1.15E+14	4.52E+13	2.75E+13	1.35E+13	6.06E+12	2.03E+12	9.30E+11
180	1.28E+17	9.83E+14	6.56E+14	3.46E+14	2.44E+14	1.62E+14	1.05E+14	4.09E+13	2.49E+13	1.22E+13	5.48E+12	1.84E+12	8.65E+11
190	1.27E+17	9.45E+14	6.21E+14	3.18E+14	2.22E+14	1.47E+14	9.54E+13	3.68E+13	2.23E+13	1.10E+13	4.93E+12	1.67E+12	8.04E+11
200	1.21E+17	8.87E+14	5.78E+14	2.90E+14	2.02E+14	1.33E+14	8.62E+13	3.29E+13	2.00E+13	9.80E+12	4.41E+12	1.51E+12	7.45E+11
210	1.21E+17	8.57E+14	5.48E+14	2.65E+14	1.82E+14	1.20E+14	7.74E+13	2.92E+13	1.77E+13	8.69E+12	3.92E+12	1.36E+12	6.92E+11
220	1.22E+17	8.35E+14	5.22E+14	2.42E+14	1.64E+14	1.08E+14	6.92E+13	2.58E+13	1.56E+13	7.68E+12	3.48E+12	1.22E+12	6.42E+11
230	1.21E+17	8.00E+14	4.91E+14	2.19E+14	1.46E+14	9.61E+13	6.15E+13	2.27E+13	1.37E+13	6.74E+12	3.06E+12	1.09E+12	5.95E+11
240	1.19E+17	7.69E+14	4.64E+14	1.98E+14	1.30E+14	8.51E+13	5.42E+13	1.97E+13	1.19E+13	5.85E+12	2.66E+12	9.67E+11	5.50E+11
250	1.15E+17	7.27E+14	4.32E+14	1.77E+14	1.15E+14	7.49E+13	4.76E+13	1.70E+13	1.02E+13	5.04E+12	2.31E+12	8.54E+11	5.08E+11

Table 11. Energy (eV) deposited per second per gram of moist air of 0.1-g/cm^3 density: 25 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	1.15E+17	7.05E+14	4.09E+14	1.59E+14	1.00E+14	6.54E+13	4.14E+13	1.45E+13	8.74E+12	4.31E+12	1.98E+12	7.51E+11	4.69E+11
270	1.14E+17	6.82E+14	3.88E+14	1.41E+14	8.73E+13	5.66E+13	3.56E+13	1.23E+13	7.34E+12	3.62E+12	1.68E+12	6.56E+11	4.32E+11
280	1.12E+17	6.55E+14	3.65E+14	1.25E+14	7.51E+13	4.85E+13	3.03E+13	1.01E+13	6.06E+12	3.00E+12	1.40E+12	5.68E+11	3.98E+11
290	1.13E+17	6.42E+14	3.50E+14	1.11E+14	6.40E+13	4.10E+13	2.55E+13	8.24E+12	4.90E+12	2.43E+12	1.15E+12	4.89E+11	3.68E+11
300	1.15E+17	6.34E+14	3.37E+14	9.81E+13	5.38E+13	3.42E+13	2.10E+13	6.52E+12	3.86E+12	1.92E+12	9.24E+11	4.19E+11	3.41E+11
310	1.12E+17	6.08E+14	3.18E+14	8.54E+13	4.44E+13	2.79E+13	1.70E+13	4.98E+12	2.92E+12	1.46E+12	7.21E+11	3.55E+11	3.14E+11
320	1.07E+17	5.76E+14	2.97E+14	7.35E+13	3.58E+13	2.23E+13	1.34E+13	3.66E+12	2.13E+12	1.07E+12	5.48E+11	2.98E+11	2.90E+11
330	1.08E+17	5.66E+14	2.85E+14	6.35E+13	2.82E+13	1.73E+13	1.02E+13	2.56E+12	1.47E+12	7.53E+11	4.06E+11	2.54E+11	2.71E+11
340	1.08E+17	5.55E+14	2.74E+14	5.46E+13	2.15E+13	1.29E+13	7.51E+12	1.65E+12	9.25E+11	4.89E+11	2.89E+11	2.16E+11	2.53E+11
350	1.06E+17	5.35E+14	2.60E+14	4.65E+13	1.57E+13	9.25E+12	5.25E+12	9.53E+11	5.15E+11	2.89E+11	1.99E+11	1.85E+11	2.37E+11
360	1.06E+17	5.29E+14	2.53E+14	4.04E+13	1.11E+13	6.28E+12	3.47E+12	4.78E+11	2.42E+11	1.55E+11	1.38E+11	1.62E+11	2.22E+11
370	1.05E+17	5.21E+14	2.46E+14	3.53E+13	7.32E+12	3.95E+12	2.13E+12	2.08E+11	9.62E+10	8.29E+10	1.04E+11	1.46E+11	2.08E+11
380	1.04E+17	5.09E+14	2.38E+14	3.12E+13	4.49E+12	2.24E+12	1.20E+12	1.04E+11	5.06E+10	5.88E+10	8.90E+10	1.35E+11	1.94E+11
390	1.04E+17	5.07E+14	2.36E+14	2.85E+13	2.56E+12	1.09E+12	5.97E+11	7.75E+10	4.87E+10	5.64E+10	8.47E+10	1.27E+11	1.82E+11
400	1.02E+17	4.97E+14	2.30E+14	2.66E+13	1.38E+12	3.94E+11	2.31E+11	6.03E+10	4.64E+10	5.32E+10	7.95E+10	1.19E+11	1.70E+11
410	1.01E+17	4.90E+14	2.27E+14	2.56E+13	8.80E+11	1.05E+11	7.92E+10	5.36E+10	4.54E+10	5.11E+10	7.54E+10	1.12E+11	1.60E+11
420	9.99E+16	4.88E+14	2.26E+14	2.55E+13	8.07E+11	6.17E+10	5.59E+10	5.08E+10	4.35E+10	4.84E+10	7.10E+10	1.06E+11	1.50E+11
430	9.64E+16	4.71E+14	2.18E+14	2.46E+13	7.77E+11	5.88E+10	5.34E+10	4.87E+10	4.16E+10	4.58E+10	6.67E+10	9.89E+10	1.40E+11
440	9.69E+16	4.70E+14	2.18E+14	2.46E+13	7.76E+11	5.91E+10	5.38E+10	4.90E+10	4.13E+10	4.46E+10	6.39E+10	9.39E+10	1.31E+11
450	9.51E+16	4.62E+14	2.14E+14	2.42E+13	7.64E+11	5.70E+10	5.20E+10	4.73E+10	3.97E+10	4.23E+10	6.03E+10	8.83E+10	1.23E+11
460	9.45E+16	4.61E+14	2.14E+14	2.42E+13	7.61E+11	5.69E+10	5.19E+10	4.72E+10	3.93E+10	4.11E+10	5.77E+10	8.38E+10	1.16E+11
470	9.04E+16	4.46E+14	2.08E+14	2.35E+13	7.35E+11	5.29E+10	4.83E+10	4.39E+10	3.65E+10	3.81E+10	5.36E+10	7.79E+10	1.08E+11
480	9.15E+16	4.45E+14	2.06E+14	2.33E+13	7.33E+11	5.54E+10	5.06E+10	4.59E+10	3.77E+10	3.82E+10	5.24E+10	7.51E+10	1.02E+11
490	8.87E+16	4.39E+14	2.04E+14	2.31E+13	7.21E+11	5.09E+10	4.65E+10	4.23E+10	3.47E+10	3.53E+10	4.87E+10	6.99E+10	9.52E+10
500	8.62E+16	4.20E+14	1.95E+14	2.21E+13	6.92E+11	5.05E+10	4.62E+10	4.19E+10	3.42E+10	3.42E+10	4.64E+10	6.60E+10	8.91E+10

Table 12. Energy (eV) deposited per second per gram of moist air of 0.5-g/cm^3 density: 25 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.03E+17	2.23E+15	1.75E+15	1.16E+15	8.63E+14	5.82E+14	3.85E+14	1.60E+14	9.82E+13	4.81E+13	2.14E+13	6.81E+12	2.59E+12
20	9.48E+16	8.72E+14	6.40E+14	3.90E+14	2.85E+14	1.92E+14	1.26E+14	5.16E+13	3.15E+13	1.55E+13	6.89E+12	2.23E+12	8.97E+11
30	6.05E+16	4.79E+14	3.28E+14	1.81E+14	1.29E+14	8.62E+13	5.64E+13	2.26E+13	1.38E+13	6.76E+12	3.02E+12	9.95E+11	4.29E+11
40	4.39E+16	3.04E+14	1.93E+14	9.27E+13	6.36E+13	4.22E+13	2.74E+13	1.06E+13	6.47E+12	3.18E+12	1.43E+12	4.84E+11	2.29E+11
50	3.38E+16	2.08E+14	1.22E+14	4.80E+13	3.07E+13	2.02E+13	1.29E+13	4.76E+12	2.88E+12	1.42E+12	6.44E+11	2.32E+11	1.28E+11
60	2.77E+16	1.52E+14	8.15E+13	2.41E+13	1.33E+13	8.57E+12	5.37E+12	1.80E+12	1.08E+12	5.34E+11	2.51E+11	1.03E+11	7.27E+10
70	2.29E+16	1.17E+14	5.77E+13	1.14E+13	4.44E+12	2.71E+12	1.61E+12	4.19E+11	2.42E+11	1.24E+11	6.71E+10	4.17E+10	4.32E+10
80	1.96E+16	9.55E+13	4.48E+13	5.77E+12	7.63E+11	3.76E+11	2.07E+11	2.73E+10	1.47E+10	1.23E+10	1.47E+10	2.02E+10	2.76E+10
90	1.72E+16	8.25E+13	3.83E+13	4.33E+12	1.39E+11	1.14E+10	9.90E+09	8.42E+09	6.89E+09	6.97E+09	9.56E+09	1.37E+10	1.83E+10
100	1.51E+16	7.28E+13	3.38E+13	3.83E+12	1.20E+11	8.76E+09	8.01E+09	7.24E+09	5.77E+09	5.46E+09	7.08E+09	9.77E+09	1.25E+10
110	1.35E+16	6.50E+13	3.02E+13	3.42E+12	1.07E+11	7.71E+09	7.05E+09	6.36E+09	4.96E+09	4.42E+09	5.42E+09	7.21E+09	8.62E+09
120	1.21E+16	5.86E+13	2.73E+13	3.09E+12	9.66E+10	6.81E+09	6.23E+09	5.60E+09	4.30E+09	3.64E+09	4.23E+09	5.40E+09	5.98E+09
130	1.10E+16	5.34E+13	2.49E+13	2.82E+12	8.81E+10	6.09E+09	5.57E+09	5.00E+09	3.78E+09	3.08E+09	3.42E+09	4.20E+09	4.31E+09
140	9.93E+15	4.86E+13	2.27E+13	2.57E+12	7.99E+10	5.37E+09	4.91E+09	4.41E+09	3.31E+09	2.62E+09	2.82E+09	3.37E+09	3.21E+09
150	9.18E+15	4.49E+13	2.09E+13	2.38E+12	7.38E+10	4.93E+09	4.51E+09	4.04E+09	3.03E+09	2.37E+09	2.51E+09	2.93E+09	2.57E+09
160	8.48E+15	4.16E+13	1.94E+13	2.21E+12	6.83E+10	4.44E+09	4.06E+09	3.64E+09	2.72E+09	2.13E+09	2.24E+09	2.60E+09	2.16E+09
170	7.83E+15	3.83E+13	1.79E+13	2.04E+12	6.29E+10	4.03E+09	3.69E+09	3.31E+09	2.47E+09	1.93E+09	2.04E+09	2.37E+09	1.94E+09
180	7.25E+15	3.56E+13	1.67E+13	1.89E+12	5.85E+10	3.73E+09	3.41E+09	3.05E+09	2.28E+09	1.79E+09	1.89E+09	2.19E+09	1.80E+09
190	6.82E+15	3.34E+13	1.56E+13	1.77E+12	5.47E+10	3.50E+09	3.20E+09	2.87E+09	2.15E+09	1.68E+09	1.78E+09	2.06E+09	1.69E+09
200	6.36E+15	3.13E+13	1.47E+13	1.67E+12	5.12E+10	3.17E+09	2.90E+09	2.60E+09	1.95E+09	1.54E+09	1.63E+09	1.90E+09	1.57E+09
210	5.95E+15	2.94E+13	1.38E+13	1.57E+12	4.81E+10	2.91E+09	2.66E+09	2.38E+09	1.78E+09	1.41E+09	1.50E+09	1.76E+09	1.46E+09
220	5.56E+15	2.75E+13	1.29E+13	1.47E+12	4.50E+10	2.65E+09	2.42E+09	2.17E+09	1.63E+09	1.29E+09	1.39E+09	1.63E+09	1.36E+09
230	5.19E+15	2.59E+13	1.22E+13	1.39E+12	4.22E+10	2.43E+09	2.22E+09	1.99E+09	1.50E+09	1.19E+09	1.28E+09	1.51E+09	1.26E+09
240	4.95E+15	2.46E+13	1.16E+13	1.32E+12	4.02E+10	2.30E+09	2.11E+09	1.89E+09	1.42E+09	1.13E+09	1.21E+09	1.44E+09	1.20E+09
250	4.66E+15	2.32E+13	1.09E+13	1.24E+12	3.78E+10	2.16E+09	1.97E+09	1.77E+09	1.33E+09	1.06E+09	1.14E+09	1.35E+09	1.13E+09

Table 12. Energy (eV) deposited per second per gram of moist air of 0.5-g/cm^3 density: 25 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	4.40E+15	2.21E+13	1.04E+13	1.19E+12	3.59E+10	1.96E+09	1.80E+09	1.61E+09	1.21E+09	9.66E+08	1.05E+09	1.25E+09	1.06E+09
270	4.17E+15	2.09E+13	9.83E+12	1.12E+12	3.40E+10	1.83E+09	1.67E+09	1.50E+09	1.13E+09	9.03E+08	9.88E+08	1.18E+09	1.00E+09
280	3.94E+15	1.98E+13	9.35E+12	1.07E+12	3.22E+10	1.71E+09	1.56E+09	1.40E+09	1.05E+09	8.48E+08	9.29E+08	1.11E+09	9.46E+08
290	3.74E+15	1.89E+13	8.91E+12	1.02E+12	3.07E+10	1.57E+09	1.44E+09	1.29E+09	9.70E+08	7.82E+08	8.64E+08	1.04E+09	8.93E+08
300	3.59E+15	1.81E+13	8.55E+12	9.78E+11	2.94E+10	1.49E+09	1.36E+09	1.22E+09	9.19E+08	7.43E+08	8.23E+08	9.95E+08	8.55E+08
310	3.42E+15	1.73E+13	8.18E+12	9.36E+11	2.81E+10	1.40E+09	1.28E+09	1.15E+09	8.65E+08	7.01E+08	7.79E+08	9.43E+08	8.12E+08
320	3.22E+15	1.63E+13	7.73E+12	8.84E+11	2.65E+10	1.27E+09	1.16E+09	1.04E+09	7.87E+08	6.42E+08	7.20E+08	8.77E+08	7.60E+08
330	3.06E+15	1.56E+13	7.39E+12	8.47E+11	2.52E+10	1.15E+09	1.05E+09	9.43E+08	7.13E+08	5.88E+08	6.67E+08	8.20E+08	7.19E+08
340	2.98E+15	1.52E+13	7.19E+12	8.23E+11	2.46E+10	1.15E+09	1.06E+09	9.48E+08	7.15E+08	5.85E+08	6.59E+08	8.06E+08	7.03E+08
350	2.85E+15	1.46E+13	6.92E+12	7.92E+11	2.36E+10	1.10E+09	1.00E+09	9.00E+08	6.79E+08	5.57E+08	6.28E+08	7.70E+08	6.72E+08
360	2.70E+15	1.39E+13	6.59E+12	7.55E+11	2.24E+10	1.01E+09	9.21E+08	8.25E+08	6.24E+08	5.14E+08	5.84E+08	7.19E+08	6.31E+08
370	2.59E+15	1.33E+13	6.33E+12	7.26E+11	2.15E+10	9.22E+08	8.44E+08	7.56E+08	5.73E+08	4.76E+08	5.47E+08	6.80E+08	6.02E+08
380	2.49E+15	1.28E+13	6.10E+12	6.99E+11	2.07E+10	8.91E+08	8.16E+08	7.32E+08	5.54E+08	4.61E+08	5.29E+08	6.56E+08	5.80E+08
390	2.37E+15	1.23E+13	5.83E+12	6.69E+11	1.98E+10	8.19E+08	7.50E+08	6.72E+08	5.10E+08	4.26E+08	4.93E+08	6.16E+08	5.49E+08
400	2.28E+15	1.18E+13	5.59E+12	6.41E+11	1.90E+10	7.91E+08	7.25E+08	6.49E+08	4.93E+08	4.12E+08	4.76E+08	5.93E+08	5.27E+08
410	2.22E+15	1.14E+13	5.44E+12	6.24E+11	1.84E+10	7.49E+08	6.86E+08	6.15E+08	4.67E+08	3.93E+08	4.57E+08	5.72E+08	5.11E+08
420	2.13E+15	1.10E+13	5.22E+12	5.99E+11	1.77E+10	7.32E+08	6.70E+08	6.01E+08	4.56E+08	3.82E+08	4.42E+08	5.52E+08	4.91E+08
430	2.03E+15	1.06E+13	5.04E+12	5.78E+11	1.70E+10	6.66E+08	6.10E+08	5.47E+08	4.17E+08	3.52E+08	4.13E+08	5.19E+08	4.65E+08
440	1.94E+15	1.01E+13	4.83E+12	5.55E+11	1.63E+10	6.29E+08	5.76E+08	5.16E+08	3.93E+08	3.33E+08	3.91E+08	4.94E+08	4.44E+08
450	1.83E+15	9.67E+12	4.62E+12	5.31E+11	1.55E+10	5.48E+08	5.02E+08	4.50E+08	3.44E+08	2.96E+08	3.55E+08	4.54E+08	4.14E+08
460	1.77E+15	9.32E+12	4.45E+12	5.11E+11	1.49E+10	5.41E+08	4.95E+08	4.44E+08	3.40E+08	2.92E+08	3.48E+08	4.43E+08	4.01E+08
470	1.68E+15	8.82E+12	4.21E+12	4.84E+11	1.41E+10	4.85E+08	4.44E+08	3.98E+08	3.06E+08	2.66E+08	3.21E+08	4.12E+08	3.76E+08
480	1.59E+15	8.40E+12	4.02E+12	4.62E+11	1.34E+10	4.42E+08	4.05E+08	3.63E+08	2.80E+08	2.46E+08	3.00E+08	3.87E+08	3.56E+08
490	1.50E+15	7.98E+12	3.82E+12	4.39E+11	1.27E+10	4.14E+08	3.79E+08	3.40E+08	2.62E+08	2.30E+08	2.81E+08	3.63E+08	3.34E+08
500	1.38E+15	7.36E+12	3.53E+12	4.06E+11	1.17E+10	3.47E+08	3.18E+08	2.85E+08	2.21E+08	1.99E+08	2.49E+08	3.27E+08	3.04E+08

Table 13. Energy (eV) deposited per second per gram of water: 25 GWd/MTU average assembly burnup

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	2.03E+17	2.04E+15	1.54E+15	1.95E+15	1.44E+15	9.67E+14	6.38E+14	2.64E+14	1.62E+14	7.92E+13	3.52E+13	1.13E+13	4.40E+12
20	9.34E+16	6.91E+14	4.53E+14	4.61E+14	3.21E+14	2.14E+14	1.40E+14	5.52E+13	3.37E+13	1.65E+13	7.41E+12	2.47E+12	1.11E+12
30	5.89E+16	3.45E+14	1.92E+14	1.30E+14	7.79E+13	5.08E+13	3.22E+13	1.15E+13	6.96E+12	3.43E+12	1.58E+12	5.95E+11	3.60E+11
40	4.22E+16	2.14E+14	1.03E+14	3.32E+13	9.32E+12	5.48E+12	3.23E+12	7.86E+11	4.52E+11	2.42E+11	1.48E+11	1.15E+11	1.32E+11
50	3.23E+16	1.59E+14	7.40E+13	1.68E+13	5.23E+11	3.66E+10	3.34E+10	3.01E+10	2.44E+10	2.39E+10	3.20E+10	4.50E+10	5.87E+10
60	2.59E+16	1.28E+14	5.95E+13	1.35E+13	4.20E+11	2.85E+10	2.61E+10	2.35E+10	1.82E+10	1.58E+10	1.90E+10	2.47E+10	2.84E+10
70	2.15E+16	1.07E+14	5.00E+13	1.14E+13	3.51E+11	2.26E+10	2.07E+10	1.86E+10	1.40E+10	1.13E+10	1.25E+10	1.52E+10	1.50E+10
80	1.82E+16	9.14E+13	4.28E+13	9.74E+12	2.99E+11	1.84E+10	1.69E+10	1.51E+10	1.13E+10	8.94E+09	9.53E+09	1.12E+10	9.62E+09
90	1.56E+16	7.88E+13	3.70E+13	8.41E+12	2.58E+11	1.55E+10	1.41E+10	1.27E+10	9.49E+09	7.48E+09	7.95E+09	9.29E+09	7.68E+09
100	1.37E+16	6.94E+13	3.26E+13	7.44E+12	2.27E+11	1.31E+10	1.20E+10	1.07E+10	8.04E+09	6.36E+09	6.82E+09	8.02E+09	6.69E+09
110	1.20E+16	6.17E+13	2.91E+13	6.64E+12	2.01E+11	1.09E+10	9.98E+09	8.95E+09	6.72E+09	5.35E+09	5.81E+09	6.90E+09	5.82E+09
120	1.08E+16	5.54E+13	2.61E+13	5.96E+12	1.80E+11	9.66E+09	8.84E+09	7.92E+09	5.95E+09	4.76E+09	5.18E+09	6.16E+09	5.21E+09
130	9.58E+15	4.96E+13	2.34E+13	5.36E+12	1.61E+11	8.13E+09	7.44E+09	6.67E+09	5.01E+09	4.04E+09	4.45E+09	5.35E+09	4.58E+09
140	8.75E+15	4.53E+13	2.14E+13	4.90E+12	1.47E+11	7.29E+09	6.68E+09	5.98E+09	4.50E+09	3.64E+09	4.02E+09	4.85E+09	4.17E+09
150	7.95E+15	4.15E+13	1.96E+13	4.49E+12	1.34E+11	6.44E+09	5.89E+09	5.28E+09	3.98E+09	3.23E+09	3.60E+09	4.36E+09	3.76E+09
160	7.25E+15	3.81E+13	1.81E+13	4.14E+12	1.23E+11	5.57E+09	5.10E+09	4.57E+09	3.45E+09	2.82E+09	3.18E+09	3.90E+09	3.40E+09
170	6.57E+15	3.48E+13	1.65E+13	3.80E+12	1.12E+11	4.72E+09	4.32E+09	3.87E+09	2.93E+09	2.43E+09	2.78E+09	3.45E+09	3.05E+09
180	6.08E+15	3.24E+13	1.54E+13	3.54E+12	1.04E+11	4.29E+09	3.93E+09	3.52E+09	2.67E+09	2.22E+09	2.55E+09	3.17E+09	2.81E+09
190	5.66E+15	3.01E+13	1.43E+13	3.29E+12	9.70E+10	3.97E+09	3.64E+09	3.26E+09	2.47E+09	2.05E+09	2.37E+09	2.94E+09	2.61E+09
200	5.20E+15	2.79E+13	1.33E+13	3.05E+12	8.98E+10	3.56E+09	3.26E+09	2.92E+09	2.22E+09	1.85E+09	2.14E+09	2.68E+09	2.39E+09
210	4.08E+15	2.43E+13	1.16E+13	2.66E+12	7.80E+10	2.97E+09	2.72E+09	2.43E+09	1.81E+09	1.47E+09	1.66E+09	2.05E+09	1.79E+09
220	3.81E+15	2.27E+13	1.09E+13	2.50E+12	7.30E+10	2.66E+09	2.44E+09	2.18E+09	1.63E+09	1.33E+09	1.52E+09	1.89E+09	1.66E+09
230	3.57E+15	2.14E+13	1.03E+13	2.36E+12	6.88E+10	2.37E+09	2.17E+09	1.94E+09	1.45E+09	1.19E+09	1.38E+09	1.73E+09	1.54E+09
240	3.37E+15	2.03E+13	9.69E+12	2.23E+12	6.50E+10	2.26E+09	2.07E+09	1.85E+09	1.38E+09	1.14E+09	1.31E+09	1.64E+09	1.46E+09
250	3.15E+15	1.91E+13	9.13E+12	2.10E+12	6.10E+10	1.96E+09	1.79E+09	1.60E+09	1.20E+09	9.98E+08	1.17E+09	1.49E+09	1.35E+09

Table 13. Energy (eV) deposited per second per gram of water: 25 GWd/MTU average assembly burnup (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	2.96E+15	1.80E+13	8.65E+12	1.99E+12	5.76E+10	1.74E+09	1.59E+09	1.42E+09	1.07E+09	9.01E+08	1.07E+09	1.38E+09	1.25E+09
270	2.79E+15	1.70E+13	8.18E+12	1.88E+12	5.44E+10	1.62E+09	1.48E+09	1.32E+09	9.96E+08	8.42E+08	1.01E+09	1.29E+09	1.18E+09
280	2.64E+15	1.62E+13	7.79E+12	1.80E+12	5.18E+10	1.47E+09	1.35E+09	1.20E+09	9.05E+08	7.69E+08	9.31E+08	1.21E+09	1.11E+09
290	2.47E+15	1.53E+13	7.36E+12	1.70E+12	4.87E+10	1.25E+09	1.15E+09	1.02E+09	7.74E+08	6.72E+08	8.34E+08	1.10E+09	1.03E+09
300	2.32E+15	1.44E+13	6.93E+12	1.60E+12	4.57E+10	1.10E+09	1.01E+09	9.01E+08	6.85E+08	6.04E+08	7.61E+08	1.01E+09	9.51E+08
310	2.22E+15	1.38E+13	6.63E+12	1.53E+12	4.37E+10	1.04E+09	9.59E+08	8.55E+08	6.50E+08	5.75E+08	7.26E+08	9.65E+08	9.08E+08
320	2.11E+15	1.32E+13	6.34E+12	1.47E+12	4.18E+10	9.69E+08	8.89E+08	7.93E+08	6.03E+08	5.36E+08	6.82E+08	9.11E+08	8.61E+08
330	1.99E+15	1.25E+13	6.02E+12	1.39E+12	3.96E+10	8.63E+08	7.92E+08	7.06E+08	5.40E+08	4.88E+08	6.30E+08	8.48E+08	8.06E+08
340	1.90E+15	1.19E+13	5.77E+12	1.33E+12	3.78E+10	7.68E+08	7.05E+08	6.29E+08	4.84E+08	4.45E+08	5.84E+08	7.94E+08	7.60E+08
350	1.80E+15	1.14E+13	5.50E+12	1.27E+12	3.60E+10	7.02E+08	6.45E+08	5.75E+08	4.43E+08	4.12E+08	5.47E+08	7.48E+08	7.20E+08
360	1.71E+15	1.09E+13	5.26E+12	1.22E+12	3.43E+10	6.29E+08	5.78E+08	5.15E+08	3.99E+08	3.77E+08	5.08E+08	7.00E+08	6.78E+08
370	1.65E+15	1.05E+13	5.06E+12	1.17E+12	3.30E+10	5.89E+08	5.41E+08	4.82E+08	3.75E+08	3.57E+08	4.84E+08	6.70E+08	6.51E+08
380	1.57E+15	1.00E+13	4.84E+12	1.12E+12	3.16E+10	5.43E+08	4.99E+08	4.45E+08	3.47E+08	3.33E+08	4.55E+08	6.33E+08	6.17E+08
390	1.50E+15	9.53E+12	4.61E+12	1.07E+12	3.00E+10	5.00E+08	4.59E+08	4.09E+08	3.21E+08	3.12E+08	4.29E+08	5.99E+08	5.84E+08
400	1.43E+15	9.13E+12	4.42E+12	1.02E+12	2.87E+10	4.59E+08	4.21E+08	3.76E+08	2.96E+08	2.91E+08	4.05E+08	5.66E+08	5.54E+08
410	1.37E+15	8.77E+12	4.25E+12	9.82E+11	2.76E+10	4.24E+08	3.89E+08	3.47E+08	2.75E+08	2.74E+08	3.83E+08	5.38E+08	5.27E+08
420	1.30E+15	8.36E+12	4.05E+12	9.37E+11	2.63E+10	3.92E+08	3.59E+08	3.21E+08	2.55E+08	2.57E+08	3.61E+08	5.09E+08	5.00E+08
430	1.26E+15	8.07E+12	3.91E+12	9.04E+11	2.53E+10	3.74E+08	3.43E+08	3.06E+08	2.45E+08	2.47E+08	3.49E+08	4.91E+08	4.82E+08
440	1.20E+15	7.74E+12	3.75E+12	8.67E+11	2.43E+10	3.47E+08	3.18E+08	2.84E+08	2.27E+08	2.31E+08	3.29E+08	4.66E+08	4.58E+08
450	1.15E+15	7.40E+12	3.59E+12	8.30E+11	2.32E+10	3.12E+08	2.86E+08	2.56E+08	2.07E+08	2.15E+08	3.10E+08	4.41E+08	4.34E+08
460	1.09E+15	7.10E+12	3.44E+12	7.96E+11	2.22E+10	2.87E+08	2.63E+08	2.36E+08	1.92E+08	2.03E+08	2.94E+08	4.18E+08	4.12E+08
470	1.04E+15	6.72E+12	3.26E+12	7.52E+11	2.10E+10	2.71E+08	2.48E+08	2.23E+08	1.82E+08	1.92E+08	2.78E+08	3.96E+08	3.89E+08
480	9.82E+14	6.39E+12	3.10E+12	7.15E+11	1.99E+10	2.45E+08	2.23E+08	2.01E+08	1.67E+08	1.80E+08	2.62E+08	3.73E+08	3.65E+08
490	9.23E+14	6.01E+12	2.91E+12	6.73E+11	1.87E+10	2.28E+08	2.08E+08	1.87E+08	1.56E+08	1.69E+08	2.46E+08	3.49E+08	3.41E+08
500	8.45E+14	5.51E+12	2.67E+12	6.17E+11	1.71E+10	1.94E+08	1.77E+08	1.60E+08	1.36E+08	1.51E+08	2.22E+08	3.17E+08	3.10E+08

Table 14. Percentage relative difference between energy deposition values based on varying radial power and the energy deposition values based on uniform radial power for a 60 GWd/MTU average assembly burnup and 0.1 g/cm^3 moist air density

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
10	16.69	40.13	37.26	37.78	40.54	41.80	41.23	37.84	37.39	37.05	35.51	28.99	22.80
20	16.40	40.07	37.21	37.77	40.54	41.81	41.25	37.85	37.39	37.05	35.49	28.93	22.80
30	16.00	39.92	37.12	37.75	40.55	41.82	41.26	37.86	37.40	37.05	35.47	28.85	22.80
40	15.71	39.84	37.06	37.73	40.55	41.83	41.28	37.87	37.40	37.04	35.45	28.77	22.80
50	15.35	39.68	36.96	37.71	40.56	41.84	41.29	37.88	37.41	37.04	35.43	28.70	22.81
60	14.86	39.50	36.84	37.68	40.56	41.85	41.30	37.89	37.41	37.04	35.41	28.63	22.82
70	14.42	39.34	36.74	37.66	40.56	41.85	41.31	37.89	37.41	37.04	35.39	28.56	22.83
80	14.23	39.18	36.64	37.64	40.57	41.86	41.32	37.90	37.42	37.03	35.37	28.46	22.82
90	13.77	38.97	36.50	37.60	40.57	41.87	41.34	37.91	37.42	37.03	35.34	28.37	22.82
100	13.48	38.78	36.37	37.57	40.57	41.88	41.35	37.92	37.43	37.03	35.31	28.29	22.84
110	13.18	38.60	36.25	37.54	40.57	41.89	41.36	37.93	37.43	37.03	35.29	28.20	22.85
120	12.84	38.29	36.04	37.50	40.58	41.90	41.38	37.94	37.44	37.02	35.26	28.09	22.85
130	12.53	38.18	35.96	37.47	40.58	41.92	41.40	37.95	37.44	37.02	35.22	27.97	22.86
140	12.11	37.85	35.73	37.42	40.58	41.93	41.41	37.97	37.45	37.01	35.18	27.85	22.87
150	11.75	37.57	35.54	37.37	40.59	41.94	41.43	37.98	37.46	37.01	35.15	27.72	22.88
160	11.45	37.28	35.34	37.31	40.59	41.95	41.45	37.99	37.46	37.01	35.11	27.59	22.89
170	11.23	37.06	35.17	37.27	40.60	41.97	41.47	38.01	37.48	37.00	35.05	27.43	22.91
180	10.92	36.58	34.83	37.18	40.60	41.99	41.50	38.03	37.48	36.99	35.00	27.24	22.91
190	10.54	36.21	34.55	37.10	40.61	42.01	41.52	38.05	37.50	36.98	34.93	27.03	22.92
200	10.42	36.04	34.41	37.05	40.62	42.03	41.56	38.08	37.51	36.97	34.85	26.79	22.93
210	10.06	35.57	34.05	36.94	40.62	42.05	41.59	38.11	37.52	36.96	34.75	26.50	22.94
220	9.72	35.08	33.66	36.82	40.63	42.08	41.63	38.14	37.53	36.94	34.64	26.17	22.95
230	9.39	34.64	33.30	36.69	40.63	42.10	41.67	38.17	37.55	36.92	34.51	25.82	22.98
240	9.07	34.12	32.87	36.54	40.64	42.14	41.71	38.21	37.57	36.89	34.35	25.40	23.01
250	8.97	33.74	32.53	36.41	40.65	42.17	41.76	38.25	37.59	36.86	34.17	24.95	23.04

Table 14. Percentage relative difference between energy deposition values based on varying radial power and energy deposition values based on uniform radial power for a 60 GWd/MTU average assembly burnup and 0.1 g/cm^3 moist air density (continued)

Distance from fuel pellet (μm)/ Decay time (yr)	0	30	60	150	300	600	1×10^3	3×10^3	1×10^4	2.5×10^4	5×10^4	1×10^5	5×10^5
260	8.69	33.15	32.02	36.20	40.65	42.20	41.81	38.30	37.61	36.82	33.94	24.42	23.08
270	8.42	32.43	31.39	35.94	40.66	42.24	41.87	38.36	37.64	36.77	33.66	23.79	23.12
280	8.14	31.84	30.84	35.68	40.66	42.30	41.95	38.45	37.68	36.70	33.30	23.04	23.17
290	7.84	31.02	30.07	35.30	40.67	42.36	42.04	38.55	37.72	36.60	32.81	22.13	23.21
300	7.55	30.13	29.20	34.82	40.67	42.43	42.16	38.69	37.78	36.45	32.13	21.03	23.25
310	7.36	29.35	28.42	34.31	40.67	42.52	42.29	38.87	37.85	36.23	31.21	19.75	23.32
320	7.12	28.45	27.52	33.69	40.67	42.61	42.45	39.08	37.92	35.90	29.95	18.28	23.40
330	6.81	27.59	26.56	32.81	40.65	42.73	42.63	39.42	38.04	35.34	28.09	16.70	23.50
340	6.73	26.68	25.51	31.68	40.61	42.87	42.88	39.97	38.24	34.36	25.37	15.09	23.65
350	6.46	25.78	24.50	30.34	40.53	43.04	43.18	40.85	38.52	32.54	21.55	13.62	23.83
360	6.33	24.82	23.38	28.52	40.35	43.24	43.54	42.49	39.05	29.00	16.81	12.59	24.04
370	6.13	23.88	22.29	26.28	39.99	43.44	43.91	45.30	39.78	22.91	12.49	12.07	24.23
380	5.89	22.90	21.21	23.68	39.19	43.60	44.21	47.76	39.34	18.18	10.81	12.07	24.40
390	5.83	22.21	20.42	21.12	37.39	43.84	44.63	48.52	38.80	18.19	11.19	12.41	24.55
400	5.70	21.42	19.66	18.97	33.06	44.69	45.93	49.38	38.73	18.34	11.37	12.57	24.65
410	5.42	20.72	19.03	17.72	25.47	48.18	49.77	49.87	38.94	18.80	11.67	12.77	24.72
420	5.38	20.21	18.69	17.54	22.96	51.26	52.02	50.19	39.38	19.22	11.89	12.92	24.79
430	5.29	19.75	18.32	17.32	22.71	51.25	52.00	50.17	39.57	19.57	12.13	13.10	24.88
440	5.08	19.52	18.15	17.26	22.65	51.24	52.00	50.23	40.04	20.22	12.47	13.29	24.92
450	4.97	19.37	18.08	17.30	22.57	51.31	52.07	50.34	40.36	20.59	12.67	13.43	24.99
460	5.05	19.28	17.98	17.21	22.44	51.27	52.04	50.36	40.71	21.20	13.03	13.64	25.04
470	4.91	19.10	17.87	17.16	22.22	51.34	52.11	50.44	40.84	21.28	13.09	13.72	25.10
480	4.96	19.31	18.00	17.20	22.41	51.25	52.03	50.43	41.32	22.17	13.58	13.97	25.12
490	4.90	18.95	17.73	17.02	21.97	51.31	52.09	50.49	41.34	22.12	13.54	13.94	25.12
500	4.83	19.13	17.87	17.11	22.19	51.28	52.07	50.50	41.63	22.65	13.85	14.11	25.13

Nuclide concentrations in spent fuel vary with decay time. The discharge alpha source terms are dominated by the alpha decay of ^{242}Cm ($T_{1/2}$ = 162.8 d) and ^{244}Cm ($T_{1/2}$ = 18.1 yr). The mean energy values of the alpha particles emitted by the ^{242}Cm and ^{244}Cm nuclides are approximately 6.1 and 5.8 MeV, respectively. Significant contributions to the alpha source terms for relatively short decay times is made by ^{244}Cm ($T_{1/2}$ = 18.1 yr), ^{238}Pu ($T_{1/2}$ = 87.7 yr), and ^{241}Am ($T_{1/2}$ = 432.6 yr). Alpha decay of ^{239}Pu ($T_{1/2}$ = 24.11×10^3 yr), ^{240}Pu ($T_{1/2}$ = 6.561×10^3 yr), ^{242}Pu ($T_{1/2}$ = 3.75×10^5 yr), ^{237}Np ($T_{1/2}$ = 2.14×10^6 yr), and ^{243}Am ($T_{1/2}$ = 7.37×10^3 yr) dominates the source terms at longer decay times (up to approximately 1×10^5 years). The mean energy values of the alpha particles emitted by those nuclides vary from approximately 4.9 to 5.8 MeV. The alpha source term for the 5×10^5-year decay time includes contributions from many nuclides (e.g., ^{210}Po, ^{213}Po, ^{214}Po, ^{218}Po, ^{217}At, ^{222}Rn, ^{221}Fr, ^{226}Ra, ^{225}Ac, ^{229}Th, ^{230}Th, ^{233}U, ^{234}U, ^{236}U, ^{238}U, and ^{237}Np), the majority of which build up over time from the decay chains of uranium and transuranic radionuclides. The energy of the alpha particles emitted by those nuclides varies from approximately 4.5 to 8.4 MeV, as seen in Fig. 11.

Calculated nuclide concentrations in spent fuel also depend on the depletion modeling approach. The varying radial power profile generates larger quantities of transuranic radionuclides than the uniform radial power profile due to a higher thermal neutron flux in the outer pellet layer. Therefore, the calculated alpha source intensities and energy deposition values based on a varying radial power profile are greater than those based on a uniform power profile. The graph illustrated in Fig. 18 identifies the energies of alpha particles contributing to the energy deposited in the 10-µm thick moist air (0.1 g/cm^3) layer in contact with the fuel pellet for the 1×10^3- and 5×10^5-year cooling times as a function of depletion calculation modeling approach. As seen in the graph, the energy deposition for the 1×10^3-year cooling time is dominated by a relatively narrow energy range primarily from ^{239}Pu, ^{240}Pu, ^{240}Am, and ^{240}Am decay; the energy deposition for the 5×10^5-year cooling time has contributions from alpha particles with a broader energy spectrum.

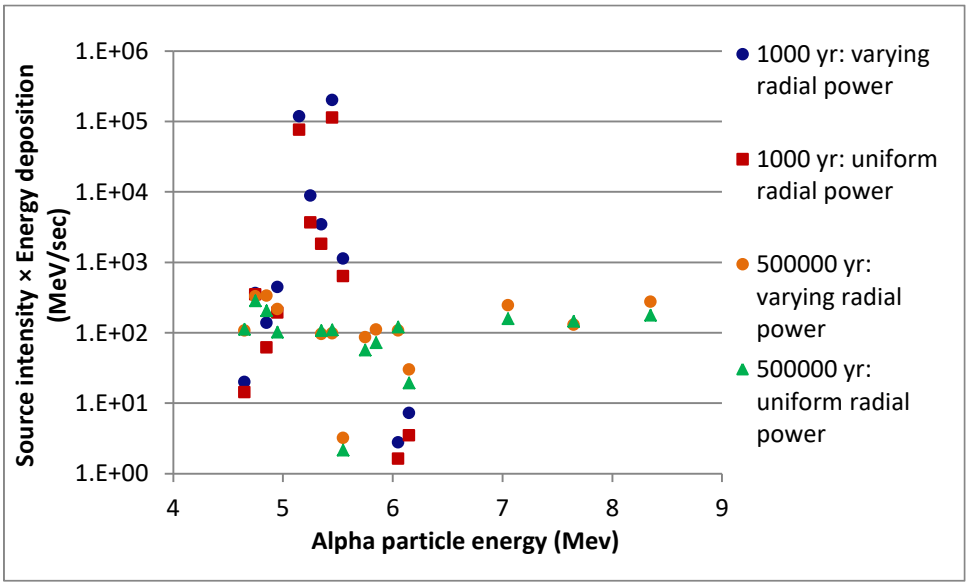


Fig. 18. Energy deposition as a function of decay time and depletion modeling approach.

4. CONCLUSIONS

This letter report describes the calculated values of (1) total dose rate on the outer surfaces of a representative spent nuclear fuel transportation/dry storage cask and on the outer surfaces of disposal canisters proposed for clay/shale and borehole repositories as well as the corresponding values of energy absorption rate for moist air and (2) energy deposited by alpha and beta particles in moist air surrounding a UO_2 fuel pellet. The values of dose rate on the outside surfaces of SNF storage/disposal packages were determined using Scale 6.1 for fuel assemblies of 5.0 wt% ^{235}U initial enrichment and 60 GWd/MTU burnup and for the following decay times: 0, 10, 20, 40, 100, 200, and 300 years. Energy deposition in moist air made by alpha and beta particles escaping from a fuel pellet were calculated as a function of moist air density (e.g., 0.1, 0.5, and 1 g/cm^3), assembly average burnup (e.g., 25, 40, and 60 GWd/MTU), and decay time (e.g., 0, 30, 60, 150, 300, 600, 1×10^3, 3×10^3, 1×10^4, 2.5×10^4, 5×10^4, 1×10^5, and 5×10^5 years) using MCNPX. The effects of depletion modeling approach on the energy deposition were analyzed for the 60-GWd/MTU burnup value. The values provided in this letter report may serve as reference data for determining the production rates of radiolysis products.

5. REFERENCES

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APPENDIX A

Appendix A presents the axial variation of energy absorption rate on the external SNF package surfaces for selected cases, which were determined using dose rate values available in MAVRIC 3dmap electronic files. Examples include energy absorption rate values for a transportation/dry storage cask (20-year cooling time, presented in Table A-1), the multi-purpose canister inside the cask (20-year cooling time, presented in Table A-2), a disposal canister for clay/shale disposal (60- and 1×10^{3}-year decay times presented in Tables A-3 and A-4, respectively), and a disposal canister for borehole disposal (30- and 5×10^{4}-year decay times presented in Tables A-5 and A-6, respectively). MAVRIC 3dmap electronic files, which contain dose rate values for a user-defined 3-D cartesian mesh superimposed over the geometry model, are available for all SNF storage/disposal packages analyzed in this letter report and may be used to obtain other dose rate values of interest.

Table A-1. Energy absorption rate per gram of moist air on the outer radial surface along the z axis and on the outer top and bottom surfaces along the y axis for a dry storage cask and for a 20-year decay time

Radial surface				Bottom surface		Top surface	
Coordinate (cm) [a]	eV/g/s [b]	Coordinate (cm)	eV/g/s	Coordinate (cm) [c]	eV/g/s	Coordinate (cm) [c]	eV/g/s
4.1	2.42E+09	268.5	1.30E+09	-106.5	1.48E+09	-106.5	3.06E+07
9.7	3.20E+09	274.1	1.25E+09	-101.5	2.61E+09	-101.5	2.68E+07
15.3	4.05E+09	279.8	1.25E+09	-96.6	4.34E+09	-96.6	3.74E+07
20.9	4.63E+09	285.4	1.25E+09	-91.6	6.90E+09	-91.6	4.88E+07
26.6	3.33E+09	291.0	1.24E+09	-86.7	1.09E+10	-86.7	5.50E+07
32.2	1.88E+09	296.7	1.23E+09	-81.7	1.26E+10	-81.7	7.04E+07
37.8	2.00E+09	302.3	1.23E+09	-76.8	1.47E+10	-76.8	7.49E+07
43.4	1.90E+09	307.9	1.19E+09	-71.8	2.02E+10	-71.8	8.36E+07
49.1	1.60E+09	313.5	1.19E+09	-66.9	3.19E+10	-66.9	8.88E+07
54.7	1.41E+09	319.2	1.15E+09	-61.9	3.47E+10	-61.9	9.39E+07
60.3	1.23E+09	324.8	1.15E+09	-57.0	3.35E+10	-57.0	9.94E+07
65.9	1.15E+09	330.4	1.09E+09	-52.0	3.71E+10	-52.0	1.16E+08
71.6	1.14E+09	336.0	1.05E+09	-47.1	3.77E+10	-47.1	1.09E+08
77.2	1.11E+09	341.7	1.00E+09	-42.1	3.88E+10	-42.1	1.16E+08
82.8	1.16E+09	347.3	9.95E+08	-37.1	4.00E+10	-37.1	1.17E+08
88.5	1.22E+09	352.9	9.81E+08	-32.2	4.52E+10	-32.2	1.28E+08
94.1	1.23E+09	358.6	9.04E+08	-27.2	3.92E+10	-27.2	1.20E+08
99.7	1.22E+09	364.2	8.91E+08	-22.3	4.74E+10	-22.3	1.26E+08
105.3	1.25E+09	369.8	8.78E+08	-17.3	4.04E+10	-17.3	1.24E+08
111.0	1.23E+09	375.4	9.27E+08	-12.4	3.79E+10	-12.4	1.28E+08
116.6	1.28E+09	381.1	1.04E+09	-7.4	3.81E+10	-7.4	1.22E+08
122.2	1.29E+09	386.7	1.19E+09	-2.5	3.83E+10	-2.5	1.29E+08
127.8	1.31E+09	392.3	1.37E+09	2.5	4.27E+10	2.5	1.21E+08
133.5	1.38E+09	397.9	1.79E+09	7.4	3.70E+10	7.4	1.31E+08
139.1	1.30E+09	403.6	2.07E+09	12.4	4.40E+10	12.4	1.23E+08
144.7	1.30E+09	409.2	2.42E+09	17.3	4.32E+10	17.3	1.23E+08
150.4	1.37E+09	414.8	2.70E+09	22.3	4.08E+10	22.3	1.22E+08
156.0	1.36E+09	420.5	2.91E+09	27.2	4.21E+10	27.2	1.21E+08
161.6	1.35E+09	426.1	3.01E+09	32.2	4.28E+10	32.2	1.18E+08
167.2	1.38E+09	431.7	3.08E+09	37.1	3.95E+10	37.1	1.20E+08
172.9	1.32E+09	437.3	2.99E+09	42.1	3.65E+10	42.1	1.16E+08
178.5	1.36E+09	443.0	2.71E+09	47.1	4.10E+10	47.1	1.03E+08
184.1	1.34E+09	448.6	2.55E+09	52.0	3.78E+10	52.0	1.04E+08
189.7	1.33E+09	454.2	2.23E+09	57.0	3.49E+10	57.0	9.49E+07
195.4	1.30E+09	459.8	2.04E+09	61.9	2.86E+10	61.9	1.04E+08
201.0	1.38E+09	465.5	2.06E+09	66.9	2.67E+10	66.9	9.41E+07
206.6	1.31E+09	471.1	3.86E+09	71.8	2.14E+10	71.8	8.87E+07
212.3	1.27E+09	476.7	5.22E+09	76.8	1.42E+10	76.8	7.76E+07
217.9	1.30E+09	482.3	5.08E+09	81.7	1.19E+10	81.7	6.69E+07
223.5	1.34E+09	488.0	4.26E+09	86.7	9.14E+09	86.7	5.77E+07
229.1	1.33E+09	493.6	2.98E+09	91.6	6.26E+09	91.6	4.97E+07
234.8	1.31E+09	499.2	2.11E+09	96.6	4.42E+09	96.6	3.74E+07
240.4	1.28E+09	504.9	1.56E+09	101.5	2.69E+09	101.5	2.88E+07
246.0	1.31E+09	510.5	1.11E+09	106.5	1.58E+09	106.5	5.20E+07
251.6	1.28E+09	516.1	7.07E+08				
257.3	1.30E+09	521.7	5.21E+08				
262.9	1.30E+09	527.4	3.68E+08				

[a] from the bottom of a cask; [b] absorbed energy (eV) per gram of moist air per second; [c] from the center of a cask.

Table A-2. Energy absorption rate for moist air on the outer radial surface along the z axis and on the outer top and bottom surfaces along the y axis for a multi-purpose canister and for a 20-year decay time

Radial surface				Bottom surface		Top surface	
Coordinate (cm) [a]	eV/g/s [b]	Coordinate (cm)	eV/g/s	Coordinate (cm) [c]	eV/g/s	Coordinate (cm) [c]	eV/g/s
3.7	4.96E+12	245.7	2.25E+13	-86.7	2.88E+12	-86.7	5.94E+09
9.3	9.17E+12	251.3	2.19E+13	-81.7	4.17E+12	-81.7	6.98E+09
15.0	1.05E+13	256.9	2.11E+13	-76.8	4.75E+12	-76.8	8.18E+09
20.6	1.15E+13	262.5	2.23E+13	-71.8	6.54E+12	-71.8	9.00E+09
26.2	1.31E+13	268.2	2.18E+13	-66.9	1.00E+13	-66.9	9.54E+09
31.8	1.55E+13	273.8	2.15E+13	-61.9	1.26E+13	-61.9	9.96E+09
37.5	1.50E+13	279.4	2.48E+13	-57.0	1.30E+13	-57.0	1.04E+10
43.1	1.65E+13	285.1	2.13E+13	-52.0	1.34E+13	-52.0	1.12E+10
48.7	1.84E+13	290.7	2.13E+13	-47.1	1.29E+13	-47.1	1.19E+10
54.3	1.92E+13	296.3	2.07E+13	-42.1	1.41E+13	-42.1	1.22E+10
60.0	1.99E+13	301.9	2.03E+13	-37.1	1.47E+13	-37.1	1.26E+10
65.6	2.04E+13	307.6	2.05E+13	-32.2	1.53E+13	-32.2	1.30E+10
71.2	2.21E+13	313.2	1.95E+13	-27.2	1.56E+13	-27.2	1.30E+10
76.9	2.16E+13	318.8	2.04E+13	-22.3	1.45E+13	-22.3	1.30E+10
82.5	2.20E+13	324.4	1.90E+13	-17.3	1.46E+13	-17.3	1.27E+10
88.1	2.21E+13	330.1	1.98E+13	-12.4	1.32E+13	-12.4	1.25E+10
93.7	2.30E+13	335.7	1.93E+13	-7.4	1.21E+13	-7.4	1.28E+10
99.4	2.32E+13	341.3	1.70E+13	-2.5	1.18E+13	-2.5	1.32E+10
105.0	2.24E+13	346.9	1.64E+13	2.5	1.11E+13	2.5	1.31E+10
110.6	2.23E+13	352.6	1.51E+13	7.4	1.28E+13	7.4	1.32E+10
116.2	2.35E+13	358.2	1.39E+13	12.4	1.40E+13	12.4	1.32E+10
121.9	2.26E+13	363.8	1.25E+13	17.3	1.51E+13	17.3	1.29E+10
127.5	2.29E+13	369.5	1.13E+13	22.3	1.55E+13	22.3	1.31E+10
133.1	2.37E+13	375.1	1.09E+13	27.2	1.56E+13	27.2	1.26E+10
138.7	2.23E+13	380.7	1.01E+13	32.2	1.55E+13	32.2	1.24E+10
144.4	2.22E+13	386.3	9.87E+12	37.1	1.46E+13	37.1	1.18E+10
150.0	2.34E+13	392.0	1.00E+13	42.1	1.30E+13	42.1	1.23E+10
155.6	2.30E+13	397.6	1.01E+13	47.1	1.24E+13	47.1	1.18E+10
161.3	2.24E+13	403.2	1.05E+13	52.0	1.24E+13	52.0	1.18E+10
166.9	2.28E+13	408.8	1.02E+13	57.0	1.30E+13	57.0	1.13E+10
172.5	2.27E+13	414.5	1.04E+13	61.9	1.23E+13	61.9	1.05E+10
178.1	2.26E+13	420.1	9.64E+12	66.9	9.95E+12	66.9	9.50E+09
183.8	2.36E+13	425.7	8.79E+12	71.8	6.56E+12	71.8	8.99E+09
189.4	2.31E+13	431.4	7.16E+12	76.8	4.93E+12	76.8	8.05E+09
195.0	2.33E+13	437.0	6.85E+12	81.7	4.45E+12	81.7	7.21E+09
200.6	2.17E+13	442.6	6.24E+12	86.7	2.82E+12	86.7	5.84E+09
206.3	2.24E+13	448.2	5.82E+12				
211.9	2.37E+13	453.9	5.78E+12				
217.5	2.21E+13	459.5	4.37E+12				
223.2	2.24E+13	465.1	1.18E+12				
228.8	2.21E+13	470.7	1.76E+11				
234.4	2.31E+13	476.4	2.97E+10				
240.0	2.21E+13						

[a] from the bottom of a canister; [b] absorbed energy (eV) per gram of moist air per second; [c] from the center of a canister.

Table A-3. Energy absorption rate for moist air on the outer radial surface along the z axis and on the outer top and bottom surfaces along the y axis for a clay/shale disposal canister and for a 60-year decay time

Radial surface				Bottom surface		Top surface	
Coordinate (cm) [a]	eV/g/s [b]	Coordinate (cm)	eV/g/s	Coordinate (cm) [c]	eV/g/s	Coordinate (cm) [c]	eV/g/s
4.8	4.63E+09	243.4	3.65E+11	-53.025	2.02E+09	-53.025	1.69E+09
14.3	1.07E+10	253.0	3.67E+11	-47.975	3.26E+09	-47.975	2.37E+09
23.9	6.44E+10	262.5	3.61E+11	-42.925	4.77E+09	-42.925	3.71E+09
33.4	2.35E+11	272.1	3.49E+11	-37.875	5.82E+09	-37.875	8.83E+09
43.0	3.41E+11	281.6	3.66E+11	-32.825	9.23E+09	-32.825	2.41E+10
52.5	4.01E+11	291.2	3.80E+11	-27.775	1.48E+10	-27.775	1.16E+10
62.0	3.58E+11	300.7	4.14E+11	-22.725	2.06E+10	-22.725	3.49E+10
71.6	3.74E+11	310.2	3.80E+11	-17.675	1.85E+10	-17.675	2.09E+10
81.1	3.91E+11	319.8	3.47E+11	-12.625	1.99E+10	-12.625	1.54E+10
90.7	3.80E+11	329.3	4.08E+11	-7.575	1.91E+10	-7.575	1.75E+10
100.2	3.86E+11	338.9	3.49E+11	-2.525	1.37E+10	-2.525	1.66E+10
109.8	3.80E+11	348.4	3.87E+11	2.525	1.74E+10	2.525	9.22E+09
119.3	3.57E+11	358.0	3.46E+11	7.575	1.81E+10	7.575	3.18E+10
128.9	4.02E+11	367.5	3.76E+11	12.625	1.83E+10	12.625	2.27E+10
138.4	3.83E+11	377.1	3.52E+11	17.675	1.88E+10	17.675	1.15E+10
148.0	3.84E+11	386.6	3.29E+11	22.725	1.37E+10	22.725	2.06E+10
157.5	4.00E+11	396.2	2.38E+11	27.775	1.46E+10	27.775	1.89E+10
167.1	3.88E+11	405.7	9.81E+10	32.825	1.14E+10	32.825	1.10E+10
176.6	3.85E+11	415.3	3.34E+10	37.875	7.92E+09	37.875	6.50E+09
186.1	3.65E+11	424.8	1.28E+10	42.925	4.72E+09	42.925	4.35E+09
195.7	3.89E+11	434.3	8.74E+09	47.975	3.42E+09	47.975	2.93E+09
205.2	3.66E+11	443.9	5.04E+09	53.025	2.20E+09	53.025	1.85E+09
214.8	3.75E+11	453.4	2.50E+09				
224.3	3.78E+11	463.0	2.10E+09				
233.9	3.94E+11						

[a] from the bottom of a canister; [b] absorbed energy (eV) per gram of moist air per second; [c] from the center of a canister.

Table A-4. Energy absorption rate for moist air on the outer radial surface along the z axis and on the outer top and bottom surfaces along the y axis for a clay/shale disposal canister and for a 1×10^3-year decay time

Radial surface				Bottom surface		Top surface	
Coordinate (cm) [a]	eV/g/s [b]	Coordinate (cm)	eV/g/s	Coordinate (cm) [c]	eV/g/s	Coordinate (cm) [c]	eV/g/s
4.8	3.71E+08	243.4	1.63E+09	-53.025	1.80E+08	-53.025	1.53E+08
14.3	6.39E+08	253.0	1.62E+09	-47.975	2.55E+08	-47.975	2.18E+08
23.9	9.17E+08	262.5	1.61E+09	-42.925	3.42E+08	-42.925	2.88E+08
33.4	1.14E+09	272.1	1.61E+09	-37.875	4.43E+08	-37.875	3.72E+08
43.0	1.33E+09	281.6	1.61E+09	-32.825	5.53E+08	-32.825	4.52E+08
52.5	1.47E+09	291.2	1.65E+09	-27.775	6.22E+08	-27.775	5.54E+08
62.0	1.52E+09	300.7	1.61E+09	-22.725	6.81E+08	-22.725	5.88E+08
71.6	1.62E+09	310.2	1.61E+09	-17.675	7.39E+08	-17.675	6.23E+08
81.1	1.62E+09	319.8	1.57E+09	-12.625	7.67E+08	-12.625	6.55E+08
90.7	1.64E+09	329.3	1.53E+09	-7.575	7.63E+08	-7.575	6.48E+08
100.2	1.70E+09	338.9	1.53E+09	-2.525	7.61E+08	-2.525	6.40E+08
109.8	1.64E+09	348.4	1.43E+09	2.525	7.88E+08	2.525	6.58E+08
119.3	1.72E+09	358.0	1.39E+09	7.575	7.79E+08	7.575	6.54E+08
128.9	1.68E+09	367.5	1.29E+09	12.625	7.62E+08	12.625	6.72E+08
138.4	1.67E+09	377.1	1.11E+09	17.675	7.38E+08	17.675	6.48E+08
148.0	1.68E+09	386.6	9.12E+08	22.725	6.96E+08	22.725	5.83E+08
157.5	1.66E+09	396.2	6.75E+08	27.775	6.29E+08	27.775	5.31E+08
167.1	1.64E+09	405.7	4.83E+08	32.825	5.58E+08	32.825	4.62E+08
176.6	1.70E+09	415.3	3.51E+08	37.875	4.54E+08	37.875	3.76E+08
186.1	1.68E+09	424.8	2.59E+08	42.925	3.45E+08	42.925	2.88E+08
195.7	1.68E+09	434.3	1.98E+08	47.975	2.49E+08	47.975	2.13E+08
205.2	1.67E+09	443.9	1.55E+08	53.025	1.75E+08	53.025	1.55E+08
214.8	1.75E+09	453.4	1.33E+08				
224.3	1.68E+09	463.0	1.33E+08				
233.9	1.65E+09						

[a] from the bottom of a canister; [b] absorbed energy (eV) per gram of moist air per second; [c] from the center of a canister.

Table A-5. Energy absorption rate for moist air on the outer radial surface along the z axis and on the outer top and bottom surfaces along the y axis for a borehole disposal canister and for a 30-year decay time

Radial surface				Bottom surface		Top surface	
Coordinate (cm) [a]	eV/g/s [b]	Coordinate (cm)	eV/g/s	Coordinate (cm) [c]	eV/g/s	Coordinate (cm) [c]	eV/g/s
-0.1	2.56E+13	255.1	1.15E+14	-24.4	4.61E+12	-24.4	1.45E+13
10.1	6.31E+13	265.3	1.13E+14	-20.0	8.24E+12	-20.0	2.64E+13
20.3	9.72E+13	275.5	1.16E+14	-15.6	1.04E+13	-15.6	5.24E+13
30.5	1.12E+14	285.7	1.16E+14	-11.1	1.19E+13	-11.1	6.83E+13
40.7	1.17E+14	295.9	1.15E+14	-6.7	1.26E+13	-6.7	9.04E+13
50.9	1.18E+14	306.1	1.12E+14	-2.2	1.43E+13	-2.2	9.91E+13
61.1	1.17E+14	316.4	1.12E+14	2.2	1.42E+13	2.2	9.96E+13
71.3	1.14E+14	326.6	1.14E+14	6.7	1.37E+13	6.7	8.52E+13
81.6	1.16E+14	336.8	1.10E+14	11.1	1.21E+13	11.1	6.39E+13
91.8	1.12E+14	347.0	1.12E+14	15.6	1.11E+13	15.6	5.08E+13
102.0	1.14E+14	357.2	1.08E+14	20.0	8.16E+12	20.0	2.62E+13
112.2	1.18E+14	367.4	9.73E+13	24.4	4.52E+12	24.4	1.42E+13
122.4	1.13E+14	377.6	6.04E+13				
132.6	1.15E+14	387.8	2.95E+13				
142.8	1.14E+14	398.0	1.55E+13				
153.0	1.14E+14	408.2	1.07E+13				
163.2	1.13E+14	418.4	8.21E+12				
173.4	1.13E+14	428.7	4.91E+12				
183.6	1.15E+14	438.9	2.47E+12				
193.9	1.18E+14	449.1	1.28E+12				
204.1	1.17E+14	459.3	7.77E+11				
214.3	1.18E+14	469.5	6.49E+11				
224.5	1.16E+14	479.7	8.50E+11				
234.7	1.12E+14	489.9	1.98E+12				
244.9	1.12E+14	500.1	8.32E+12				

[a] from the bottom of a canister; [b] absorbed energy (eV) per gram of moist air per second; [c] from the center of a canister.

Table A-6. Energy absorption rate for moist air on the outer radial surface along the z axis and on the outer top and bottom surfaces along the y axis for a borehole disposal canister and for a 5×10^4-year decay time

Radial surface				Bottom surface		Top surface	
Coordinate (cm) [a]	eV/g/s [b]	Coordinate (cm)	eV/g/s	Coordinate (cm) [c]	eV/g/s	Coordinate (cm) [c]	eV/g/s
-0.1	1.52E+08	255.1	1.01E+10	-24.4	3.84E+08	-24.4	3.84E+08
10.1	4.90E+08	265.3	1.06E+10	-20.0	5.92E+08	-20.0	5.92E+08
20.3	1.34E+09	275.5	1.06E+10	-15.6	7.27E+08	-15.6	7.27E+08
30.5	2.52E+09	285.7	1.02E+10	-11.1	7.18E+08	-11.1	7.18E+08
40.7	4.04E+09	295.9	1.06E+10	-6.7	7.48E+08	-6.7	7.48E+08
50.9	4.78E+09	306.1	1.06E+10	-2.2	7.83E+08	-2.2	7.83E+08
61.1	5.28E+09	316.4	1.07E+10	2.2	7.45E+08	2.2	7.45E+08
71.3	6.03E+09	326.6	1.05E+10	6.7	7.43E+08	6.7	7.43E+08
81.6	7.21E+09	336.8	1.06E+10	11.1	7.91E+08	11.1	7.91E+08
91.8	7.77E+09	347.0	1.02E+10	15.6	7.18E+08	15.6	7.18E+08
102.0	7.75E+09	357.2	9.86E+09	20.0	5.82E+08	20.0	5.82E+08
112.2	7.78E+09	367.4	8.77E+09	24.4	3.89E+08	24.4	3.89E+08
122.4	8.13E+09	377.6	5.26E+09				
132.6	8.23E+09	387.8	2.49E+09				
142.8	9.02E+09	398.0	1.02E+09				
153.0	9.41E+09	408.2	4.80E+08				
163.2	9.81E+09	418.4	2.34E+08				
173.4	9.84E+09	428.7	1.23E+08				
183.6	1.18E+10	438.9	5.79E+07				
193.9	9.53E+09	449.1	3.82E+07				
204.1	9.82E+09	459.3	3.55E+07				
214.3	9.67E+09	469.5	4.49E+07				
224.5	9.68E+09	479.7	6.98E+07				
234.7	1.00E+10	489.9	1.87E+08				
244.9	1.01E+10	500.1	6.92E+08				

[a] from the bottom of a canister; [b] absorbed energy (eV) per gram of moist air per second; [c] from the center of a canister.