

Table 1. Zircaloy-4 material constituent and impurity concentrations.

Constituent or Impurity	Impurity (ppm)	Constituent or Impurity	Impurity (ppm)
H	25	Ag	
Li		Cd	0.5
B	0.5	Sn	16000
C	270	Sb	
N	80	Cs	
O	950	Ba	
Na		La	
Al	75	Ce	
Si	120	Sm	10
P	100	Gd	5
S	35	Eu	
Cl		Tb	
K		Dy	
Ca		Ho	
Sc		Yb	
Ti	50	Lu	
V	50	Hf	35
Cr	1250	Ta	200
Mn	50	W	100
Fe	2250	Pb	100
Co	20	Th	7
Ni	70	U	3.5
Cu	50		
Zn	100		
Ga			
As			
Se			
Br			
Rb			
Sr			
Y			
Zr	979069		
Nb	70		
Mo	50		

Table 2. Aluminum-6061T material constituent and impurity concentrations.

Constituent or Impurity	Weight Fraction (wt%)
H	
Li	0.0005
B	0.022
C	0.02
N	0.0005
O	0.05
Na	0.00002
Mg	0.9
Al	97.39387
Si	0.65
P	0.001
S	0.002
Ti	0.02
V	0.02
Cr	0.05
Mn	0.03
Fe	0.2
Co	0.05
Ni	0.04
Cu	0.25
Zn	0.02
Ga	0.05
Sr	0.00001
Zr	0.02
Nb	0.01
Mo	0.0001
Cd	0.05
Sn	0.02
Sb	0.01
Hf	0.05
Ta	0.05
Pb	0.02

Table 3. Assumed burnup or power history for a single hypothetical fuel element.

Condition	Time (years)	Decay Time (days)	Cumulative Duration (days)	Time-Averaged Power (MW _{th})
Irradiation	1	—	365.25	0.0137
Decay	5	1825.00	2191.50	0.0
Decay	10	3652.50	4017.75	0.0
Decay	15	5478.75	5844.00	0.0
Decay	20	7305.00	7670.25	0.0
Decay	25	9131.25	9496.50	0.0
Decay	35	12783.75	13149.00	0.0
Decay	50	18262.50	18627.75	0.0
Decay	65	23741.25	24106.50	0.0
Decay	80	29220.00	29585.25	0.0
Decay	100	36525.00	36890.25	0.0

The entries with zero associated power represent the ten different cooling or decay dates after exposure. These ten dates are specifically the 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling times designated for the template methodology.

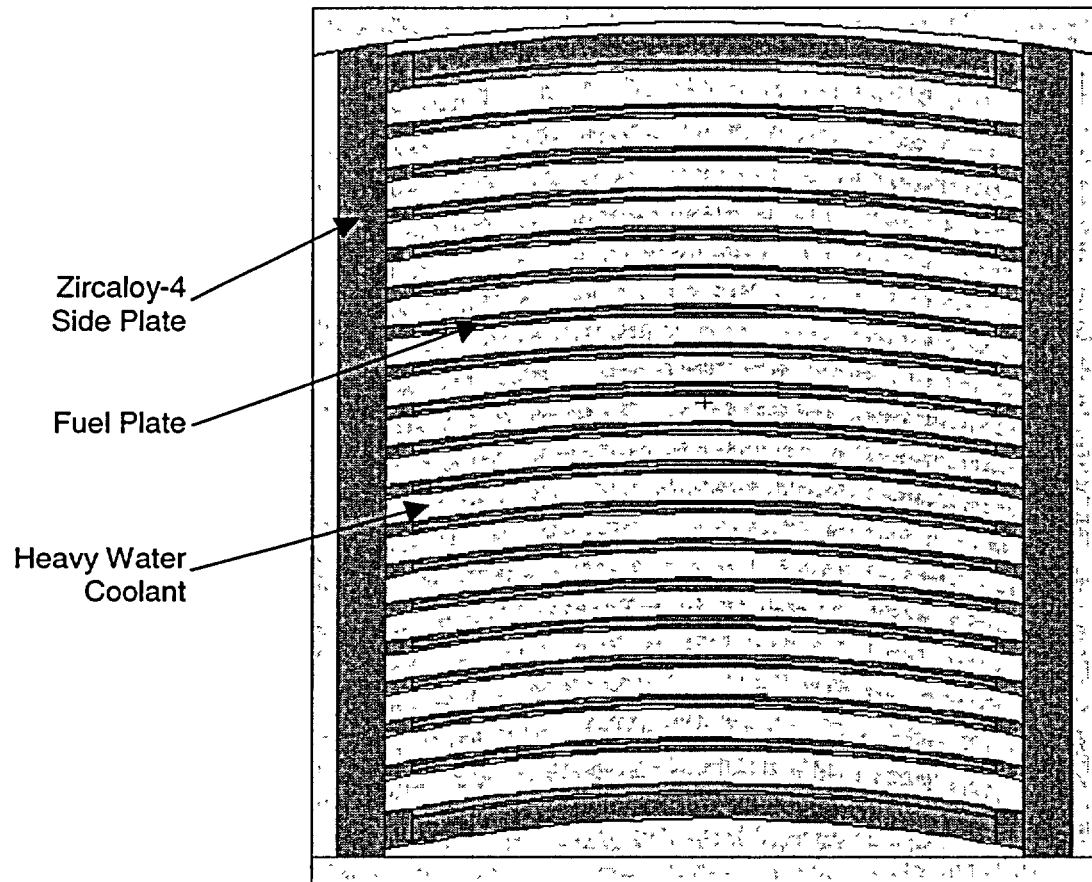


Figure 1. Curved-plate fuel element used in the analysis.

Template 11

Zircaloy-4 Cladding, 0 to 5% Enriched U-235 Fuel

Reactor Moderator/Coolant: Heavy Water
Fuel Meat: U-Al-Si (30% U, 68% Al, 2%Si) in Aluminum
Clad: Zircaloy-4
Burnup: 5.4 g U-235 depleted
Burnup: 5 MWd/single element
Burnup: 31.5% U-235 depletion (fissioned and transmuted)
Basis of Calculation: Single fuel element
BOL U-235: 17.13 g U-235 per element
BOL U-238: 322.12 g U-238 per element
BOL U-234: 2.06 g U-234 per element
BOL U-236: 1.20 g U-236 per element
BOL Total U per element: 342.51 g U per element
BOL Fuel Enrichment: 5 wt% U-235

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
H 3	6.411E-01	4.843E-01	3.657E-01	2.763E-01	2.087E-01	1.190E-01	5.128E-02	2.209E-02	9.520E-03	3.098E-03
BE 10	8.087E-10	8.087E-10	8.087E-10	8.087E-10	8.087E-10	8.087E-10	8.087E-10	8.087E-10	8.087E-10	8.087E-10
C 14	5.652E-03	5.649E-03	5.645E-03	5.642E-03	5.639E-03	5.632E-03	5.622E-03	5.611E-03	5.601E-03	5.588E-03
CL 36	4.189E-10	4.189E-10	4.188E-10	4.188E-10	4.188E-10	4.188E-10	4.188E-10	4.188E-10	4.188E-10	4.188E-10
CR 51	6.221E-19	8.975E-39	1.295E-58	1.868E-78	2.695E-98	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MN 54	6.789E-04	1.182E-05	2.058E-07	3.582E-09	6.236E-11	1.890E-14	9.973E-20	5.262E-25	2.776E-30	2.550E-37
FE 55	8.548E-01	2.254E-01	5.944E-02	1.567E-02	4.133E-03	2.874E-04	5.269E-06	9.661E-08	1.771E-09	8.564E-12
FE 59	2.225E-13	1.351E-25	8.200E-38	4.978E-50	3.021E-62	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO 60	1.666E+01	8.632E+00	4.472E+00	2.317E+00	1.200E+00	3.221E-01	4.478E-02	6.227E-03	8.658E-04	6.236E-05
NI 59	1.163E-04	1.163E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04	1.162E-04
NI 63	1.619E-02	1.559E-02	1.502E-02	1.446E-02	1.393E-02	1.292E-02	1.154E-02	1.030E-02	9.203E-03	7.916E-03
ZN 65	6.459E-03	3.596E-05	2.002E-07	1.115E-09	6.205E-12	1.923E-16	3.319E-23	5.728E-30	9.886E-37	9.499E-46
SE 79	6.264E-05	6.263E-05	6.263E-05	6.263E-05	6.262E-05	6.262E-05	6.261E-05	6.260E-05	6.259E-05	6.257E-05
KR 85	1.330E+00	9.623E-01	6.965E-01	5.041E-01	3.648E-01	1.911E-01	7.246E-02	2.747E-02	1.041E-02	2.858E-03
RB 87	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09	4.100E-09
SR 89	6.372E-09	8.270E-20	1.073E-30	1.393E-41	1.808E-52	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 90	1.291E+01	1.146E+01	1.017E+01	9.031E+00	8.018E+00	6.319E+00	4.422E+00	3.094E+00	2.165E+00	1.345E+00
Y 90	1.291E+01	1.146E+01	1.017E+01	9.033E+00	8.020E+00	6.321E+00	4.423E+00	3.095E+00	2.166E+00	1.345E+00
Y 91	2.435E-07	9.771E-17	3.922E-26	1.574E-35	6.320E-45	1.018E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 93	1.371E-03	1.371E-03	1.371E-03	1.371E-03	1.371E-03	1.371E-03	1.371E-03	1.371E-03	1.371E-03	1.371E-03
ZR 95	3.233E-06	8.263E-15	2.112E-23	5.399E-32	1.380E-40	9.017E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 93M	3.180E-04	5.395E-04	7.111E-04	8.442E-04	9.473E-04	1.089E-03	1.203E-03	1.256E-03	1.281E-03	1.295E-03
NB 94	1.879E-04	1.879E-04	1.878E-04	1.878E-04	1.878E-04	1.877E-04	1.876E-04	1.875E-04	1.874E-04	1.873E-04

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
NB 95	7.178E-06	1.835E-14	4.689E-23	1.199E-31	3.063E-40	2.002E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 95M	2.398E-08	6.130E-17	1.567E-25	4.005E-34	1.024E-42	6.689E-60	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO 93	2.900E-06	2.897E-06	2.894E-06	2.891E-06	2.888E-06	2.883E-06	2.874E-06	2.865E-06	2.857E-06	2.846E-06
TC 99	2.207E-03	2.207E-03	2.207E-03	2.207E-03	2.207E-03	2.207E-03	2.206E-03	2.206E-03	2.206E-03	2.206E-03
RU103	4.294E-12	4.344E-26	4.395E-40	4.446E-54	4.498E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU106	1.483E+00	4.764E-02	1.530E-03	4.916E-05	1.579E-06	1.629E-09	5.399E-14	1.789E-18	5.930E-23	6.313E-29
RH103M	3.871E-12	3.916E-26	3.962E-40	4.008E-54	4.055E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH106	1.483E+00	4.764E-02	1.530E-03	4.916E-05	1.579E-06	1.629E-09	5.399E-14	1.789E-18	5.930E-23	6.313E-29
PD107	5.642E-06	5.642E-06	5.642E-06	5.642E-06	5.642E-06	5.642E-06	5.642E-06	5.642E-06	5.642E-06	5.642E-06
AG110	2.289E-06	1.444E-08	9.110E-11	5.748E-13	3.626E-15	1.443E-19	3.624E-26	9.101E-33	2.285E-39	3.621E-48
AG110M	1.721E-04	1.086E-06	6.850E-09	4.321E-11	2.726E-13	1.085E-17	2.725E-24	6.843E-31	1.718E-37	2.722E-46
AG111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD113M	1.775E-03	1.400E-03	1.104E-03	8.705E-04	6.865E-04	4.269E-04	2.093E-04	1.026E-04	5.032E-05	1.946E-05
CD113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD115M	1.185E-13	5.572E-26	2.620E-38	1.232E-50	5.790E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114	1.672E-13	1.318E-24	1.039E-35	8.201E-47	6.468E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114M	1.747E-13	1.377E-24	1.086E-35	8.570E-47	6.759E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN115M	5.964E-18	2.804E-30	1.318E-42	6.197E-55	2.913E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN119M	1.213E-01	6.919E-04	3.947E-06	2.253E-08	1.285E-10	4.183E-15	7.771E-22	1.443E-28	2.681E-35	2.841E-44
SN121M	2.137E-03	1.994E-03	1.861E-03	1.736E-03	1.619E-03	1.410E-03	1.145E-03	9.298E-04	7.552E-04	5.722E-04
SN123	3.057E-04	1.695E-08	9.396E-13	5.210E-17	2.888E-21	8.877E-30	1.513E-42	2.578E-55	4.393E-68	4.149E-85
SN125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN126	6.028E-05	6.027E-05	6.027E-05	6.027E-05	6.027E-05	6.026E-05	6.026E-05	6.025E-05	6.024E-05	6.024E-05
SB124	1.015E-09	7.477E-19	5.508E-28	4.059E-37	2.991E-46	1.624E-64	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB125	1.725E+00	4.935E-01	1.412E-01	4.041E-02	1.156E-02	9.468E-04	2.218E-05	5.198E-07	1.218E-08	8.166E-11
SB126	8.439E-06	8.438E-06	8.438E-06	8.438E-06	8.437E-06	8.437E-06	8.436E-06	8.435E-06	8.434E-06	8.433E-06
SB126M	6.028E-05	6.027E-05	6.027E-05	6.027E-05	6.027E-05	6.026E-05	6.026E-05	6.025E-05	6.024E-05	6.024E-05
TE123M	7.104E-08	1.811E-12	4.614E-17	1.175E-21	2.997E-26	1.946E-35	3.222E-49	5.334E-63	8.829E-77	3.725E-95
TE125M	4.208E-01	1.204E-01	3.446E-02	9.859E-03	2.821E-03	2.310E-04	5.413E-06	1.268E-07	2.972E-09	1.993E-11
TE127	2.436E-05	2.204E-10	1.995E-15	1.805E-20	1.633E-25	1.337E-35	9.907E-51	7.339E-66	5.438E-81	0.000E+00
TE127M	2.487E-05	2.250E-10	2.036E-15	1.843E-20	1.667E-25	1.365E-35	1.011E-50	7.493E-66	5.551E-81	0.000E+00
TE129	3.746E-16	1.628E-32	7.072E-49	3.073E-65	1.335E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE129M	5.755E-16	2.500E-32	1.086E-48	4.720E-65	2.051E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I129	3.751E-06	3.751E-06	3.751E-06	3.751E-06	3.751E-06	3.751E-06	3.751E-06	3.751E-06	3.751E-06	3.751E-06
I131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS134	9.499E-01	1.769E-01	3.294E-02	6.135E-03	1.142E-03	3.962E-05	2.559E-07	1.652E-09	1.067E-11	1.283E-14
CS135	3.957E-05	3.957E-05	3.957E-05	3.957E-05	3.957E-05	3.957E-05	3.957E-05	3.957E-05	3.957E-05	3.957E-05
CS136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
CS137	1.432E+01	1.275E+01	1.136E+01	1.012E+01	9.019E+00	7.158E+00	5.061E+00	3.579E+00	2.531E+00	1.594E+00
BA136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA137M	1.354E+01	1.207E+01	1.075E+01	9.576E+00	8.532E+00	6.771E+00	4.788E+00	3.386E+00	2.394E+00	1.508E+00
BA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE141	8.101E-15	9.977E-32	1.229E-48	1.513E-65	1.864E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE142	4.409E-09	4.409E-09	4.409E-09	4.409E-09	4.409E-09	4.409E-09	4.409E-09	4.409E-09	4.409E-09	4.409E-09
CE144	4.119E+00	4.795E-02	5.582E-04	6.498E-06	7.564E-08	1.025E-11	1.617E-17	2.552E-23	4.026E-29	7.393E-37
PR143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR144	4.119E+00	4.795E-02	5.582E-04	6.498E-06	7.565E-08	1.025E-11	1.617E-17	2.552E-23	4.026E-29	7.394E-37
PR144M	4.942E-02	5.754E-04	6.698E-06	7.797E-08	9.077E-10	1.230E-13	1.941E-19	3.062E-25	4.831E-31	8.872E-39
ND144	2.305E-13	2.320E-13	2.320E-13	2.320E-13	2.320E-13	2.320E-13	2.320E-13	2.320E-13	2.320E-13	2.320E-13
ND147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM145	1.084E-04	9.104E-05	7.489E-05	6.158E-05	5.063E-05	3.422E-05	1.902E-05	1.057E-05	5.875E-06	2.685E-06
PM147	1.378E+01	3.676E+00	9.810E-01	2.618E-01	6.986E-02	4.975E-03	9.453E-05	1.796E-06	3.414E-08	1.731E-10
PM148M	2.329E-13	1.134E-26	5.524E-40	2.690E-53	1.310E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM148	1.312E-14	6.389E-28	3.111E-41	1.515E-54	7.379E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM145	4.249E-05	1.027E-06	2.482E-08	6.000E-10	1.450E-11	8.472E-15	1.196E-19	1.689E-24	2.386E-29	8.143E-36
SM147	1.328E-09	1.575E-09	1.642E-09	1.659E-09	1.664E-09	1.665E-09	1.666E-09	1.666E-09	1.666E-09	1.666E-09
SM151	3.907E-02	3.760E-02	3.617E-02	3.481E-02	3.349E-02	3.101E-02	2.763E-02	2.461E-02	2.193E-02	1.880E-02
EU152	5.019E-04	3.890E-04	3.015E-04	2.337E-04	1.811E-04	1.088E-04	5.065E-05	2.358E-05	1.097E-05	3.962E-06
EU154	3.810E-01	2.546E-01	1.702E-01	1.137E-01	7.600E-02	3.395E-02	1.013E-02	3.025E-03	9.029E-04	1.802E-04
EU155	2.080E-01	1.034E-01	5.142E-02	2.556E-02	1.271E-02	3.140E-03	3.859E-04	4.743E-05	5.827E-06	3.560E-07
EU156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD153	4.445E-04	2.378E-06	1.273E-08	6.809E-11	3.643E-13	1.043E-17	1.598E-24	2.448E-31	3.750E-38	3.074E-47
TB160	4.354E-10	1.085E-17	2.703E-25	6.736E-33	1.679E-40	1.042E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL206	4.308E-16	4.308E-16	4.308E-16	4.308E-16	4.308E-16	4.308E-16	4.308E-16	4.308E-16	4.308E-16	4.308E-16
TL207	2.179E-09	4.306E-09	6.515E-09	8.793E-09	1.113E-08	1.594E-08	2.342E-08	3.111E-08	3.893E-08	4.946E-08
TL208	2.494E-07	2.806E-07	2.766E-07	2.659E-07	2.541E-07	2.310E-07	2.003E-07	1.737E-07	1.506E-07	1.247E-07
PB210	4.912E-11	2.904E-10	8.600E-10	1.874E-09	3.432E-09	8.502E-09	2.192E-08	4.336E-08	7.356E-08	1.282E-07
PB211	2.185E-09	4.318E-09	6.533E-09	8.818E-09	1.116E-08	1.599E-08	2.349E-08	3.120E-08	3.904E-08	4.960E-08
PB212	6.940E-07	7.809E-07	7.698E-07	7.399E-07	7.071E-07	6.430E-07	5.574E-07	4.833E-07	4.191E-07	3.471E-07
BI211	2.185E-09	4.318E-09	6.533E-09	8.818E-09	1.116E-08	1.599E-08	2.349E-08	3.120E-08	3.904E-08	4.960E-08
BI212	6.940E-07	7.809E-07	7.698E-07	7.399E-07	7.071E-07	6.430E-07	5.574E-07	4.833E-07	4.191E-07	3.471E-07
PO212	4.447E-07	5.003E-07	4.932E-07	4.741E-07	4.530E-07	4.120E-07	3.572E-07	3.097E-07	2.685E-07	2.224E-07
PO215	2.185E-09	4.318E-09	6.533E-09	8.818E-09	1.116E-08	1.599E-08	2.349E-08	3.120E-08	3.904E-08	4.960E-08
PO216	6.940E-07	7.809E-07	7.698E-07	7.399E-07	7.071E-07	6.430E-07	5.574E-07	4.833E-07	4.191E-07	3.471E-07
RN219	2.185E-09	4.318E-09	6.533E-09	8.818E-09	1.116E-08	1.599E-08	2.349E-08	3.120E-08	3.904E-08	4.960E-08
RN220	6.940E-07	7.809E-07	7.698E-07	7.399E-07	7.071E-07	6.430E-07	5.574E-07	4.833E-07	4.191E-07	3.471E-07
FR223	3.015E-11	5.953E-11	9.004E-11	1.215E-10	1.538E-10	2.203E-10	3.238E-10	4.301E-10	5.381E-10	6.838E-10

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
RA223	2.185E-09	4.318E-09	6.533E-09	8.818E-09	1.116E-08	1.599E-08	2.349E-08	3.120E-08	3.904E-08	4.960E-08
RA224	6.940E-07	7.809E-07	7.698E-07	7.399E-07	7.071E-07	6.430E-07	5.574E-07	4.833E-07	4.191E-07	3.471E-07
RA226	8.271E-10	2.770E-09	5.849E-09	1.006E-08	1.541E-08	2.948E-08	5.902E-08	9.861E-08	1.482E-07	2.297E-07
RA228	2.755E-09	4.050E-09	4.823E-09	5.283E-09	5.557E-09	5.819E-09	5.932E-09	5.956E-09	5.961E-09	5.963E-09
AC227	2.185E-09	4.314E-09	6.525E-09	8.805E-09	1.114E-08	1.597E-08	2.346E-08	3.116E-08	3.899E-08	4.955E-08
TH227	2.155E-09	4.259E-09	6.443E-09	8.696E-09	1.101E-08	1.577E-08	2.316E-08	3.077E-08	3.850E-08	4.891E-08
TH228	6.939E-07	7.803E-07	7.691E-07	7.393E-07	7.065E-07	6.429E-07	5.574E-07	4.833E-07	4.191E-07	3.471E-07
TH229	2.333E-09	4.492E-09	6.651E-09	8.809E-09	1.097E-08	1.528E-08	2.174E-08	2.820E-08	3.464E-08	4.323E-08
TH230	6.348E-07	1.162E-06	1.689E-06	2.217E-06	2.744E-06	3.798E-06	5.380E-06	6.961E-06	8.542E-06	1.065E-05
TH231	2.536E-05	2.536E-05	2.536E-05	2.536E-05	2.536E-05	2.536E-05	2.537E-05	2.537E-05	2.537E-05	2.537E-05
TH232	5.962E-09	5.962E-09	5.962E-09	5.963E-09	5.963E-09	5.963E-09	5.963E-09	5.963E-09	5.963E-09	5.963E-09
TH234	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04
PA231	1.528E-08	1.796E-08	2.064E-08	2.332E-08	2.601E-08	3.137E-08	3.941E-08	4.745E-08	5.548E-08	6.619E-08
PA233	2.661E-05	2.667E-05	2.677E-05	2.689E-05	2.703E-05	2.735E-05	2.789E-05	2.845E-05	2.902E-05	2.978E-05
PA234M	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04
PA234	1.399E-07	1.399E-07	1.399E-07	1.399E-07	1.399E-07	1.399E-07	1.399E-07	1.399E-07	1.399E-07	1.399E-07
U232	8.088E-07	7.834E-07	7.503E-07	7.161E-07	6.828E-07	6.203E-07	5.369E-07	4.647E-07	4.022E-07	3.317E-07
U233	4.576E-06	4.577E-06	4.577E-06	4.578E-06	4.578E-06	4.579E-06	4.581E-06	4.582E-06	4.584E-06	4.586E-06
U234	1.171E-02	1.172E-02	1.172E-02	1.172E-02	1.172E-02	1.172E-02	1.172E-02	1.172E-02	1.172E-02	1.172E-02
U235	2.536E-05	2.536E-05	2.536E-05	2.536E-05	2.536E-05	2.536E-05	2.537E-05	2.537E-05	2.537E-05	2.537E-05
U236	1.331E-04	1.331E-04	1.331E-04	1.331E-04	1.331E-04	1.331E-04	1.331E-04	1.331E-04	1.331E-04	1.332E-04
U237	7.593E-07	5.969E-07	4.692E-07	3.688E-07	2.899E-07	1.792E-07	8.703E-08	4.227E-08	2.053E-08	7.840E-09
U238	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04	1.076E-04
NP237	2.661E-05	2.667E-05	2.677E-05	2.689E-05	2.703E-05	2.735E-05	2.789E-05	2.845E-05	2.902E-05	2.978E-05
PU236	4.654E-07	1.380E-07	4.092E-08	1.214E-08	3.600E-09	3.190E-10	1.095E-11	2.914E-12	2.704E-12	2.698E-12
PU237	3.435E-18	3.019E-30	2.653E-42	2.332E-54	2.050E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU238	4.071E-02	3.913E-02	3.762E-02	3.616E-02	3.476E-02	3.212E-02	2.854E-02	2.535E-02	2.252E-02	1.923E-02
PU239	9.380E-02	9.379E-02	9.377E-02	9.376E-02	9.374E-02	9.372E-02	9.368E-02	9.364E-02	9.360E-02	9.354E-02
PU240	4.191E-02	4.188E-02	4.186E-02	4.184E-02	4.182E-02	4.177E-02	4.171E-02	4.164E-02	4.157E-02	4.149E-02
PU241	3.095E+00	2.433E+00	1.913E+00	1.504E+00	1.182E+00	7.303E-01	3.548E-01	1.723E-01	8.370E-02	3.196E-02
PU242	1.020E-05	1.020E-05	1.020E-05	1.020E-05	1.020E-05	1.020E-05	1.020E-05	1.019E-05	1.019E-05	1.019E-05
PU244	1.453E-13	1.453E-13	1.453E-13	1.453E-13	1.453E-13	1.453E-13	1.453E-13	1.453E-13	1.453E-13	1.453E-13
AM241	2.945E-02	5.118E-02	6.804E-02	8.107E-02	9.109E-02	1.046E-01	1.144E-01	1.177E-01	1.178E-01	1.158E-01
AM242M	2.030E-05	1.984E-05	1.939E-05	1.895E-05	1.853E-05	1.770E-05	1.653E-05	1.544E-05	1.442E-05	1.316E-05
AM242	2.019E-05	1.974E-05	1.929E-05	1.886E-05	1.843E-05	1.761E-05	1.645E-05	1.536E-05	1.434E-05	1.309E-05
AM243	1.032E-05	1.031E-05	1.031E-05	1.030E-05	1.030E-05	1.029E-05	1.028E-05	1.026E-05	1.025E-05	1.023E-05
CM242	6.346E-05	1.635E-05	1.596E-05	1.560E-05	1.525E-05	1.457E-05	1.360E-05	1.270E-05	1.186E-05	1.083E-05
CM243	5.221E-06	4.623E-06	4.094E-06	3.625E-06	3.210E-06	2.517E-06	1.748E-06	1.213E-06	8.425E-07	5.180E-07

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
CM244	1.647E-04	1.360E-04	1.123E-04	9.277E-05	7.661E-05	5.225E-05	2.943E-05	1.657E-05	9.334E-06	4.341E-06
CM245	2.442E-09	2.441E-09	2.440E-09	2.439E-09	2.438E-09	2.436E-09	2.433E-09	2.430E-09	2.427E-09	2.423E-09
CM246	1.230E-10	1.229E-10	1.228E-10	1.227E-10	1.226E-10	1.225E-10	1.222E-10	1.219E-10	1.217E-10	1.213E-10
CM247	4.224E-17	4.224E-17	4.224E-17	4.224E-17	4.224E-17	4.224E-17	4.224E-17	4.224E-17	4.224E-17	4.224E-17
<i>SUBTOTAL**</i>	1.054E+02	6.580E+01	5.169E+01	4.316E+01	3.706E+01	2.832E+01	1.957E+01	1.372E+01	9.692E+00	6.151E+00
<i>TOTAL***</i>	1.054E+02	6.580E+01	5.170E+01	4.317E+01	3.706E+01	2.832E+01	1.957E+01	1.372E+01	9.692E+00	6.152E+00

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 12

Fuel-Specific Source Term Calculations Advanced Test Reactor Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a generic source term for the Advanced Test Reactor spent nuclear fuel elements currently stored at the INEEL. The data sources for the analysis are documented in Reference 1 and the INEEL calculational methodology is described in detail in Reference 2.

Advanced Test Reactor Data

The Advanced Test Reactor (ATR) is a 250-MW_{th} rated light-water reactor designed specifically to study the effects of intense radiation on reactor fuels and materials. The core contains nine individual test irradiation flux traps in a 3 × 3 array within a four-leaf clover or serpentine driver core configuration as shown in Figure 1. The serpentine driver core is composed of 40 high-enriched, 48-in. active length U-Al_x plate-type fuel elements. The core driver elements are light water-cooled and beryllium-reflected. Hafnium absorber drums located in the beryllium reflector coupled with hafnium shim rods control the local power levels in each quadrant of the core. The beryllium reflector is contained within an aluminum tank, and the entire reactor core is enclosed in a stainless steel reactor pressure vessel.

Each driver fuel element contains 19 curved aluminum-clad fuel plates. Figure 2 shows the geometrical configuration of a fuel element along with pertinent dimensions. The fuel meat is an intermetallic uranium/aluminum compound with each successive plate (wider arc plate) containing proportionally more uranium (Table 1).

In a fresh ATR element, the uranium enrichment is nominally 93.15 wt% U-235. However, for the source term calculations here, in order to maximize the production of higher order actinides, the maximum U-234 and U-236 impurity concentrations have been used that results in an effective enrichment of approximately 92 wt%. This assumption is not conservative with regard to criticality safety.

There are two different types of aluminum used in the ATR elements. One is a high purity Aluminum-1100 and is used exclusively in the fuel meat. The other is a lower purity Aluminum-6061T and is used everywhere else in the fuel element (clad, end boxes, side plates). For the source term calculations, all aluminum in the ATR element is assumed to be Aluminum-6061T. This results in slightly higher impurity concentrations, which in turn produces slightly higher activation or a slightly more conservative source term. Table 2 lists the impurities and their concentrations (Reference 3).

The data below give specific dimensions, materials, loadings, densities, enrichment, etc. for the ATR driver element used in the burnup calculation for the source term generation.

Fuel Element:

Fuel Meat: U-Al_x
Enriched uranium in Aluminum-1100
Average Density = ~4.00 g/cc

Clad: Aluminum-6061T
Density = 2.70 g/cc

Loading: 1075.0 g/element U-235 BOL (nominal)
69.93 g/element U-238 BOL (nominal)
13.87 g/element U-234 BOL (nominal)
8.09 g/element U-236 BOL (nominal)
92.13% effective enrichment U-235 BOL (calculated)
93.15% nominal enrichment U-235 BOL (ATR)

Active Fuel Length: 48.0 in.
Fuel Element Length: 66.0 in. (5.5 ft end-to-end of the end boxes)

Structural Materials: 2,797.36 g/element aluminum side plates
1,174.32 g/element aluminum in the fuel meat
3,766.74 g/element aluminum clad
1,200.00 g/element upper/lower aluminum end boxes
8,938.42 g/element total aluminum

Core Coolant Water Temperature:

Inlet: <125°F
Outlet: 160°F (average)

Core Coolant Water Pressure:

Inlet: 355 psi (guage)
Outlet: 255 psi

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for all the material components in a single ATR driver fuel element. In addition, for the ORIGEN2 (Reference 4) depletion calculation, conservative and detailed impurity concentrations were added for aluminum (Al-1100 and Al-6061T) based on the estimated aluminum masses including the cladding, fuel meat, side plates, and end boxes.

Burnup

The burnup chosen for this template is based on a 35.95% burnup of the initial U-235. This burnup is equivalent to 367.2 MWd, 314,683 MWd/MTU, and 463.3 g U-235 depleted per element and represents the upper end of typical ATR fuel element burnups. The assumption of maximum burnup is conservative for the buildup of fission products, activation products, and minor actinides in the source term and nonconservative with regard to criticality safety.

Aluminum Cladding, 60 to 100% Enriched U-235 Fuel

Reactor Moderator/Coolant:	Light Water
Fuel Meat:	U-Al _x
Clad:	Aluminum
Burnup:	367.2 MWd/element (maximum element burnup)
Burnup:	35.95 % U-235 burnup (fissioned)
Burnup:	43.10% U-235 depletion (fissioned and transmuted)
Basis of Calculation:	Single element
BOL U-235:	1075.00 g U-235 per element
BOL U-238:	69.93 g U-238 per element
BOL U-234:	13.87 g U-234 per element
BOL U-236:	8.09 g U-236 per element
BOL Total U per element:	1166.89 g U per element
BOL Fuel Enrichment:	92.13 wt%

DECAY TIMES (years out of core)
(Activities* in Ci/element)

[illegible]

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
ZR-95	2.534E-04	6.565E-13	1.701E-21	4.407E-30	1.142E-38	7.665E-56	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-93M	5.422E-03	9.424E-03	1.253E-02	1.493E-02	1.680E-02	1.936E-02	2.142E-02	2.239E-02	2.283E-02	2.308E-02
NB-94	2.626E-07	2.626E-07	2.626E-07	2.625E-07	2.625E-07	2.624E-07	2.622E-07	2.621E-07	2.620E-07	2.618E-07
NB-95	5.625E-04	1.458E-12	3.776E-21	9.784E-30	2.535E-38	1.702E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-95M	1.880E-06	4.870E-15	1.262E-23	3.269E-32	8.471E-41	5.686E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO-93	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TC-99	1.551E-01	1.551E-01	1.551E-01	1.551E-01	1.551E-01	1.551E-01	1.551E-01	1.551E-01	1.551E-01	1.551E-01
RU-103	5.452E-10	5.639E-24	5.832E-38	6.031E-52	6.237E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU-106	6.997E+01	2.253E+00	7.253E-02	2.335E-03	7.519E-05	7.794E-08	2.601E-12	8.683E-17	2.898E-21	3.114E-27
RH-103M	4.915E-10	5.083E-24	5.257E-38	5.437E-52	5.623E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH-106	6.997E+01	2.253E+00	7.253E-02	2.335E-03	7.519E-05	7.794E-08	2.601E-12	8.683E-17	2.898E-21	3.114E-27
PD-107	1.830E-04	1.830E-04	1.830E-04	1.830E-04	1.830E-04	1.830E-04	1.830E-04	1.830E-04	1.830E-04	1.830E-04
AG-110	3.393E-04	2.148E-06	1.360E-08	8.609E-11	5.450E-13	2.184E-17	5.542E-24	1.406E-30	3.568E-37	5.732E-46
AG-110M	2.551E-02	1.615E-04	1.022E-06	6.473E-09	4.098E-11	1.642E-15	4.167E-22	1.057E-28	2.683E-35	4.310E-44
AG-111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-113M	1.215E-01	9.579E-02	7.555E-02	5.959E-02	4.699E-02	2.923E-02	1.434E-02	7.035E-03	3.451E-03	1.335E-03
CD-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-115M	1.133E-11	5.431E-24	2.604E-36	1.248E-48	5.983E-61	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114	1.089E-13	8.740E-25	7.015E-36	5.631E-47	4.520E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114M	1.138E-13	9.132E-25	7.330E-36	5.883E-47	4.723E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-115M	7.963E-16	3.817E-28	1.830E-40	8.771E-53	4.205E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-119M	2.773E-02	1.588E-04	9.092E-07	5.207E-09	2.981E-11	9.773E-16	1.835E-22	3.444E-29	6.466E-36	6.950E-45
SN-121M	1.096E-03	1.022E-03	9.539E-04	8.901E-04	8.305E-04	7.229E-04	5.873E-04	4.770E-04	3.875E-04	2.937E-04
SN-123	3.516E-03	1.962E-07	1.095E-11	6.112E-16	3.411E-20	1.063E-28	1.848E-41	3.212E-54	5.585E-67	5.419E-84
SN-125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-126	4.250E-03	4.250E-03	4.250E-03	4.250E-03	4.250E-03	4.249E-03	4.249E-03	4.248E-03	4.248E-03	4.247E-03
SB-124	8.220E-09	6.144E-18	4.593E-27	3.432E-36	2.566E-45	1.433E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB-125	2.311E+01	6.618E+00	1.896E+00	5.428E-01	1.555E-01	1.275E-02	2.995E-04	7.038E-06	1.654E-07	1.112E-09
SB-126	5.950E-04	5.950E-04	5.950E-04	5.950E-04	5.949E-04	5.949E-04	5.948E-04	5.948E-04	5.947E-04	5.946E-04
SB-126M	4.250E-03	4.250E-03	4.250E-03	4.250E-03	4.250E-03	4.249E-03	4.249E-03	4.248E-03	4.248E-03	4.247E-03
TE-123M	4.118E-07	1.057E-11	2.714E-16	6.966E-21	1.788E-25	1.178E-34	1.994E-48	3.372E-62	5.705E-76	2.477E-94
TE-125M	5.639E+00	1.614E+00	4.625E-01	1.325E-01	3.794E-02	3.112E-03	7.309E-05	1.717E-06	4.033E-08	2.714E-10
TE-127	2.511E-03	2.290E-08	2.089E-13	1.905E-18	1.738E-23	1.445E-33	1.097E-48	8.322E-64	6.314E-79	4.369E-99
TE-127M	2.563E-03	2.338E-08	2.132E-13	1.945E-18	1.774E-23	1.476E-33	1.120E-48	8.496E-64	6.446E-79	4.461E-99
TE-129	5.027E-14	2.241E-30	9.993E-47	4.455E-63	1.986E-79	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

DECAY TIMES (years out of core)

(Activities* in Ci/element)

[illegible]

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
TL-207	1.776E-08	5.329E-08	1.042E-07	1.681E-07	2.432E-07	4.202E-07	7.354E-07	1.090E-06	1.469E-06	1.995E-06
TL-208	1.178E-05	1.618E-05	1.715E-05	1.690E-05	1.628E-05	1.484E-05	1.285E-05	1.112E-05	9.627E-06	7.949E-06
PB-210	1.994E-10	1.381E-09	4.347E-09	9.779E-09	1.826E-08	4.631E-08	1.216E-07	2.430E-07	4.150E-07	7.277E-07
PB-211	1.781E-08	5.344E-08	1.045E-07	1.686E-07	2.439E-07	4.214E-07	7.375E-07	1.093E-06	1.473E-06	2.001E-06
PB-212	3.280E-05	4.502E-05	4.772E-05	4.703E-05	4.530E-05	4.129E-05	3.576E-05	3.095E-05	2.679E-05	2.212E-05
BI-211	1.781E-08	5.344E-08	1.045E-07	1.686E-07	2.439E-07	4.214E-07	7.375E-07	1.093E-06	1.473E-06	2.001E-06
BI-212	3.280E-05	4.502E-05	4.772E-05	4.703E-05	4.530E-05	4.129E-05	3.576E-05	3.095E-05	2.679E-05	2.212E-05
PO-212	2.101E-05	2.885E-05	3.058E-05	3.013E-05	2.902E-05	2.646E-05	2.291E-05	1.983E-05	1.717E-05	1.417E-05
PO-215	1.781E-08	5.344E-08	1.045E-07	1.686E-07	2.439E-07	4.214E-07	7.375E-07	1.093E-06	1.473E-06	2.001E-06
PO-216	3.280E-05	4.502E-05	4.772E-05	4.703E-05	4.530E-05	4.129E-05	3.576E-05	3.095E-05	2.679E-05	2.212E-05
RN-219	1.781E-08	5.344E-08	1.045E-07	1.686E-07	2.439E-07	4.214E-07	7.375E-07	1.093E-06	1.473E-06	2.001E-06
RN-220	3.280E-05	4.502E-05	4.772E-05	4.703E-05	4.530E-05	4.129E-05	3.576E-05	3.095E-05	2.679E-05	2.212E-05
FR-223	2.457E-10	7.370E-10	1.440E-09	2.323E-09	3.361E-09	5.810E-09	1.017E-08	1.507E-08	2.030E-08	2.759E-08
RA-223	1.781E-08	5.344E-08	1.045E-07	1.686E-07	2.439E-07	4.214E-07	7.375E-07	1.093E-06	1.473E-06	2.001E-06
RA-224	3.280E-05	4.502E-05	4.772E-05	4.703E-05	4.530E-05	4.129E-05	3.576E-05	3.095E-05	2.679E-05	2.212E-05
RA-226	3.720E-09	1.397E-08	3.075E-08	5.407E-08	8.392E-08	1.632E-07	3.309E-07	5.570E-07	8.413E-07	1.311E-06
RA-228	3.338E-13	1.098E-12	2.120E-12	3.296E-12	4.563E-12	7.239E-12	1.139E-11	1.558E-11	1.979E-11	2.540E-11
AC-227	1.781E-08	5.341E-08	1.043E-07	1.684E-07	2.435E-07	4.210E-07	7.369E-07	1.092E-06	1.471E-06	1.999E-06
TH-227	1.756E-08	5.271E-08	1.030E-07	1.662E-07	2.405E-07	4.156E-07	7.273E-07	1.078E-06	1.452E-06	1.973E-06
TH-228	3.280E-05	4.500E-05	4.768E-05	4.699E-05	4.526E-05	4.129E-05	3.576E-05	3.095E-05	2.679E-05	2.212E-05
TH-229	3.710E-10	6.921E-10	1.049E-09	1.442E-09	1.871E-09	2.837E-09	4.556E-09	6.598E-09	8.963E-09	1.262E-08
TH-230	3.227E-06	6.258E-06	9.294E-06	1.233E-05	1.538E-05	2.148E-05	3.066E-05	3.986E-05	4.909E-05	6.144E-05
TH-231	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03
TH-232	1.467E-12	2.869E-12	4.271E-12	5.674E-12	7.076E-12	9.880E-12	1.409E-11	1.829E-11	2.250E-11	2.811E-11
TH-234	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05
PA-231	1.880E-07	3.279E-07	4.678E-07	6.077E-07	7.476E-07	1.027E-06	1.446E-06	1.865E-06	2.284E-06	2.843E-06
PA-233	3.506E-03	3.506E-03	3.507E-03	3.508E-03	3.509E-03	3.511E-03	3.516E-03	3.520E-03	3.525E-03	3.531E-03
PA-234M	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05
PA-234	2.851E-08	2.851E-08	2.851E-08	2.851E-08	2.851E-08	2.851E-08	2.851E-08	2.851E-08	2.851E-08	2.851E-08
U-232	4.405E-05	4.829E-05	4.790E-05	4.620E-05	4.420E-05	4.020E-05	3.481E-05	3.013E-05	2.608E-05	2.152E-05
U-233	6.419E-07	7.184E-07	7.950E-07	8.717E-07	9.483E-07	1.102E-06	1.332E-06	1.562E-06	1.793E-06	2.101E-06
U-234	6.735E-02	6.746E-02	6.756E-02	6.765E-02	6.775E-02	6.792E-02	6.816E-02	6.836E-02	6.855E-02	6.877E-02
U-235	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03	1.323E-03
U-236	5.689E-03	5.689E-03	5.689E-03	5.689E-03	5.689E-03	5.689E-03	5.689E-03	5.689E-03	5.689E-03	5.689E-03
U-237	6.195E-06	4.871E-06	3.829E-06	3.011E-06	2.367E-06	1.463E-06	7.110E-07	3.456E-07	1.679E-07	6.417E-08

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
U-238	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05	2.193E-05
NP-237	3.506E-03	3.506E-03	3.507E-03	3.508E-03	3.509E-03	3.511E-03	3.516E-03	3.520E-03	3.525E-03	3.531E-03
PU-236	2.331E-04	6.917E-05	2.053E-05	6.095E-06	1.811E-06	1.619E-07	6.794E-09	2.741E-09	2.634E-09	2.631E-09
PU-237	8.648E-15	7.746E-27	6.939E-39	6.216E-51	5.568E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU-238	7.546E+00	7.254E+00	6.973E+00	6.703E+00	6.444E+00	5.955E+00	5.290E+00	4.699E+00	4.174E+00	3.565E+00
PU-239	1.573E-01	1.573E-01	1.573E-01	1.572E-01	1.572E-01	1.572E-01	1.571E-01	1.570E-01	1.570E-01	1.569E-01
PU-240	8.960E-02	8.956E-02	8.952E-02	8.948E-02	8.944E-02	8.935E-02	8.922E-02	8.908E-02	8.894E-02	8.875E-02
PU-241	2.525E+01	1.985E+01	1.561E+01	1.227E+01	9.649E+00	5.964E+00	2.899E+00	1.409E+00	6.846E-01	2.616E-01
PU-242	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04	1.334E-04
PU-244	2.396E-11	2.396E-11	2.396E-11	2.396E-11	2.396E-11	2.396E-11	2.396E-11	2.396E-11	2.396E-11	2.396E-11
AM-241	2.337E-01	4.109E-01	5.484E-01	6.548E-01	7.366E-01	8.466E-01	9.272E-01	9.542E-01	9.553E-01	9.390E-01
AM-242M	1.668E-04	1.630E-04	1.594E-04	1.558E-04	1.523E-04	1.455E-04	1.359E-04	1.269E-04	1.185E-04	1.082E-04
AM-242	1.660E-04	1.622E-04	1.586E-04	1.550E-04	1.515E-04	1.448E-04	1.352E-04	1.263E-04	1.179E-04	1.076E-04
AM-243	5.479E-04	5.476E-04	5.474E-04	5.471E-04	5.469E-04	5.464E-04	5.456E-04	5.448E-04	5.441E-04	5.430E-04
CM-242	5.028E-04	1.344E-04	1.312E-04	1.282E-04	1.253E-04	1.197E-04	1.118E-04	1.044E-04	9.752E-05	8.902E-05
CM-243	8.694E-05	7.699E-05	6.818E-05	6.038E-05	5.347E-05	4.193E-05	2.912E-05	2.023E-05	1.405E-05	8.639E-06
CM-244	1.911E-02	1.579E-02	1.304E-02	1.077E-02	8.894E-03	6.067E-03	3.418E-03	1.926E-03	1.085E-03	5.049E-04
CM-245	1.124E-06	1.124E-06	1.123E-06	1.123E-06	1.123E-06	1.122E-06	1.120E-06	1.119E-06	1.118E-06	1.116E-06
CM-246	7.669E-08	7.663E-08	7.657E-08	7.652E-08	7.646E-08	7.635E-08	7.618E-08	7.602E-08	7.585E-08	7.563E-08
CM-247	8.015E-14	8.015E-14	8.015E-14	8.015E-14	8.015E-14	8.015E-14	8.015E-14	8.015E-14	8.015E-14	8.015E-14
SUBTOTAL**	6.336E+03	4.066E+03	3.399E+03	2.961E+03	2.612E+03	2.052E+03	1.438E+03	1.011E+03	7.122E+02	4.473E+02
TOTAL***	6.336E+03	4.066E+03	3.399E+03	2.961E+03	2.612E+03	2.052E+03	1.438E+03	1.011E+03	7.122E+02	4.473E+02

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 15

Fuel-Specific Source Term Calculations

Pathfinder Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a source term template for a single Pathfinder superheater spent nuclear fuel element. The data sources for the analysis are documented in References 1 through 5, and the INEEL calculational methodology is described in detail in Reference 6.

Pathfinder Data

The Pathfinder core consisted of a superheater region of elements surrounded by an annular boiler region of elements. See Figure 1 for a detailed sketch of the superheater fuel element materials and geometry. The geometric detail of the superheater fuel element was fully incorporated into the MCNP geometry model as was the boiler fuel element geometry. Although the boiler fuel element is not considered in the source term calculation, it is part of the partial core model used in the MCNP neutron transport calculation. Figures 2 through 5 show cross-sectional views of the 3-D MCNP geometry model. Figure 2 shows the superheater element. Figure 3 shows the superheater lattice. Figure 4 shows a partial core cross section with superheater elements in the center of the core surrounded by boiler region elements and an outer water reflector region. Figure 5 shows an axial cross-sectional view of the core.

The data below and resulting source term calculation are for an average burnup superheater fuel element.

Superheater Fuel Element:

Fuel Meat:	UO ₂ + 316L Stainless Steel Cermet Density = 8.1799 g/cc
Clad:	316L Stainless Steel Density = 8.03 g/cc
Loading:	120.4 g/element U-235 BOL 0.05 g/element U-236 BOL 8.37 g/element U-238 BOL Enrichment 93.5% U-235 BOL Inner fuel tube: 51.2 g/element U-235 BOL Outer fuel tube: 69.2 g/element U-235 BOL
Active Fuel Length:	72.0 in.
Fuel Element Length:	74.5 in.
Boron-Al ₂ O ₃ Poison:	Length = 72.5 in. Pellet Radius: 0.511 cm Natural boron Loading = 1.4808 g boron/rod Density of Al ₂ O ₃ = 2.59 g/cc (70% TD)

Boiler Fuel Element:

UO₂ fuel meat
2.2 and 3.2 wt% U-235 enrichment
Upper core half pellet radius = 0.448 cm
Upper core half clad thickness = 0.028 in.
Lower core half pellet radius = 0.400 cm
Lower core half clad thickness = 0.026 in.
UO₂ Density = 10.41 g/cc

Superheater Core Power Fraction: 15% (conservative)
No. of Superheater Elements in the Core: 409 total

Water Temperature:

Boiler Inlet 486°F
Steam Region 626°F

Water Pressure:

Boiler Inlet 642 psia
Steam Region 0.01665 g/cc

Aluminum-6061 per Element: 205.501 g
Stainless Steel-316L per Element: 3228.5 g
Stainless Steel 304 per Element: 456.03 g

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for all the material components in a single Pathfinder fuel element. In addition, for the ORIGEN2 (Reference 7) depletion calculation, conservative and detailed impurity concentrations were added for the UO₂, stainless steel 316L, stainless steel 304, and aluminum (Al-6061). Table 1 lists the impurities and their concentrations (References 8 through 12).

Burnup

The burnup chosen for this template is 6.46% U-235 depletion, 6.01 MWd/element, or approximately 7.78 g of U-235 depleted for a single Pathfinder fuel element. This burnup is reasonable for an average superheater element and the depletion accounts for buildup of fission products, activation products, and minor actinides in the source term, but non-conservative with regard to criticality safety, in particular U-235 and U-238 end-of-life concentrations.

Cross-Section Development

The MCNP model was used to develop neutron cross sections specifically for the Pathfinder superheater elements. These cross sections are in turn used in the superheater fuel element ORIGEN2 depletion calculation.

The neutron cross sections used in the burnup or depletion calculation for the source term generation of a single Pathfinder fuel element are based on the methodology described in Reference 6. Cross sections from a standard ORIGEN2 light water reactor library were updated once using the specially developed beginning-of-life (BOL) cross sections for the Pathfinder. The updated cross sections take into account the unique Pathfinder neutron flux spatial and spectral characteristics to ensure accurate calculation of the fission product and actinide production as a function of burnup.

Pathfinder Exposure History

Table 2 summarizes the detailed power or exposure history used in the burnup or source term calculations for a single Pathfinder superheater fuel element. Following the burnup or exposure period, the radionuclide activities are decayed for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100 years.

Burnup Calculation

The ORIGEN2 computer code (Reference 7) was used to perform the depletion or burnup calculation for the Pathfinder fuel element. The radionuclide inventory or source term template is for a single Pathfinder superheater fuel element or assembly. The fuel element masses and impurities, neutron cross sections, burnup, power history, and power level as discussed above are input data for the ORIGEN2 calculation. The radionuclide concentrations are given as a function of time in the template table.

The 145 radionuclides listed in the template represent greater than 99.99% of the total curie inventory had all 684 activation products, 880 fission products, and 127 actinide/daughter isotopes from the ORIGEN2 output been included in the template.

References

1. Lockheed Martin Idaho Technologies Company, *Pathfinder Fuel Summary Report*, INEL/INT-97-00127, February 1997.
2. Northern States Power Company Pathfinder Atomic Power Plant, *Six Month Report No. 4—November 19, 1967 to May 19, 1968*, NSP-6801, June 17, 1968.
3. Northern States Power Company Pathfinder Atomic Power Plant, *Six Month Report No. 3—May 19, 1967 to November 19, 1967*, NSP-6603, June 27, 1967.
4. Northern States Power Company Pathfinder Atomic Power Plant, *Six Month Report No. 2—November 19, 1966 to May 19, 1967—Pathfinder Testing Results 40% to 85%*, NSP-6701, June 15, 1967.
5. Northern States Power Company Pathfinder Atomic Power Plant, *Six Month Report No. 1—May 19, 1966 to November 19, 1966*, TID-23646, January 9, 1967.
6. J. W. Sterbentz and C. A. Wemple, *Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels*, INEL-96/0304, September 1996.
7. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.
8. A. G. Croft, M. A. Bjerke, G. W. Morrison, and L. M. Petrie, *Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code*, ORNL/TM-6051, Oak Ridge National Laboratory.
9. J. C. Evans et al., *Long-Lived Activation Products in Reactor Materials*, NUREG/CR-3474, August 1984.

10. E. A. Avallone and T. Baumeister III, *MARK'S Standard Handbook for Mechanical Engineers*, Ninth Edition.
11. F. W. Walker et al., "Nuclides and Isotopes: Chart of the Nuclides," General Electric Company, 1989.
12. ASTM B-209, Table 1, "Chemical Composition Limits," 1990.

Table 1. Pathfinder fuel assembly material impurity concentrations.

Constituent or Impurity	UO ₂ Concentration (ppm)	Stainless Steel-316L Concentration (ppm)	Stainless Steel-304 Concentration (wt%)	Aluminum-6061 Concentration (wt%)
H				0.02143
Li	1	0.18	0.13	
Be				
B	1			
C	89.4	0.03 wt%	0.08 wt%	0.02143
N	25	357	525	
O	134454			0.02143
F	10.7			
Na	15	6	37	
Mg	2			1
Al	16.7	50	200	97.15499
Si	12.1	1 wt%	1 wt%	0.6
P	35	0.045 wt%		
S		0.03 wt%		
Cl	5.3		130	
K		3	3	
Ca	2	14	19	
Sc			0.03	
Ti	1	200	600	0.075
V	3	630	690	
Cr	4	17.3 wt%	18.4 wt%	0.195
Mn	1.7	2 wt%	1.53 wt%	0.075
Fe	18	64.24 wt%	68.99 wt%	0.35
Co	1	1630	2570	
Ni	24	13.2 wt%	10 wt%	0.02143
Cu	1	2900	8150	0.275
Zn	40.3	71	2230	0.125
Ga		60	450	
As		95	1010	
Se		9	70	
Br		2	8	
Rb			10	
Sr		0.23	0.2	
Y		5	5	
Zr		6	20	0.02143
Nb		64	300	
Mo	10	2.16 wt%	5500	

Constituent or Impurity	UO ₂ Concentration (ppm)	Stainless Steel-316L Concentration (ppm)	Stainless Steel-304 Concentration (wt%)	Aluminum-6061 Concentration (wt%)
Ag	0.1	5	2	
Cd	25			
In	2			
Sn	4			0.02143
Sb		13	17	
Cs			0.3	
Ba			500	
La		0.2	2.1	
Ce			550	
Pr				
Nd				
Sm		0.2	0.15	
Eu		0.07	0.02	
Gd				
Tb		9	0.71	
Dy			1	
Ho		1	1	
Er				
Tm				
Yb		2	2	
Lu		0.8	0.8	
Hf			2	
Ta				
W	2	218	520	
Tl				
Pb	1	30	139	0.02143
Bi	0.4			
Th			1	
U		5	2	

Table 2. Assumed power or exposure history for a single Pathfinder fuel element.

Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MW _{th})	Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MW _{th})
226	226	1.14E-05	1	975	0.00E+00
184	410	0.00E+00	3	978	4.46E-02
65	475	1.14E-05	2	980	0.00E+00
74	549	2.32E-05	4	984	2.17E-02
42	591	1.28E-03	3	987	0.00E+00
31	622	9.62E-04	1	988	5.01E-02
30	652	1.22E-02	3	991	3.69E-02
31	683	0.00E+00	2	993	4.43E-02
31	714	9.46E-03	3	996	3.33E-02
8	722	3.07E-03	4	1000	5.91E-02
20	742	0.00E+00	1	1001	0.00E+00
2	744	1.06E-02	1	1002	2.96E-02
31	775	2.82E-02	4	1006	4.25E-02
24	799	1.77E-02	1	1007	0.00E+00
10	809	0.00E+00	7	1014	5.38E-02
26	835	2.06E-02	1	1015	0.00E+00
31	866	1.70E-03	3	1018	4.62E-02
30	896	8.03E-03	2	1020	0.00E+00
18	914	8.48E-03	3	1023	3.41E-02
25	939	0.00E+00	4	1027	5.30E-02
1	940	1.20E-02	3	1030	0.00E+00
1	941	0.00E+00	4	1034	5.30E-02
9	950	3.34E-02	1825	2859	0.00E+00
2	952	0.00E+00	1825	4684	0.00E+00
5	957	3.31E-02	1825	6509	0.00E+00
3	960	0.00E+00	1825	8334	0.00E+00
1	961	4.85E-02	1825	10159	0.00E+00
1	962	0.00E+00	3650	13809	0.00E+00
1	963	6.77E-02	5475	19284	0.00E+00
1	964	0.00E+00	5475	24759	0.00E+00
7	971	4.34E-02	5475	30234	0.00E+00
3	974	2.67E-02	7300	37534	0.00E+00

The bottom ten dates with zero associated power represent the ten different cooling or decay dates after exposure. These ten dates are specifically the 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling times designated for the template methodology.

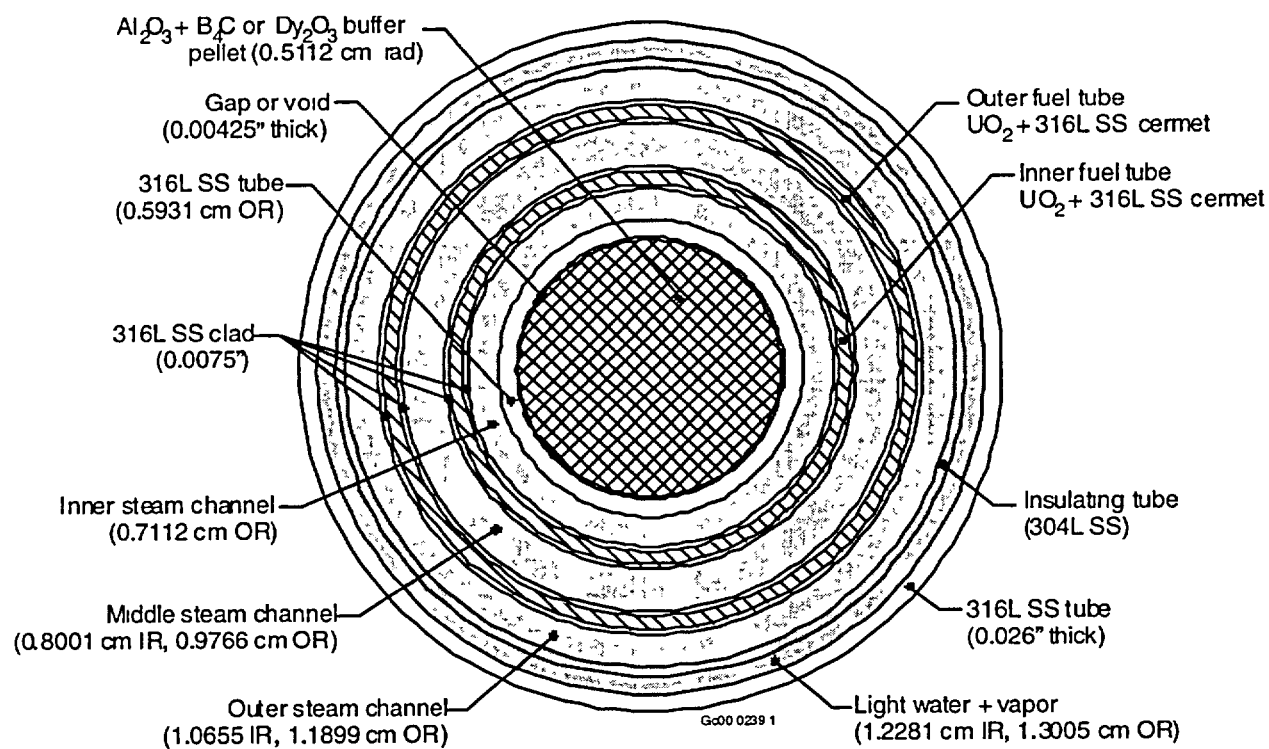
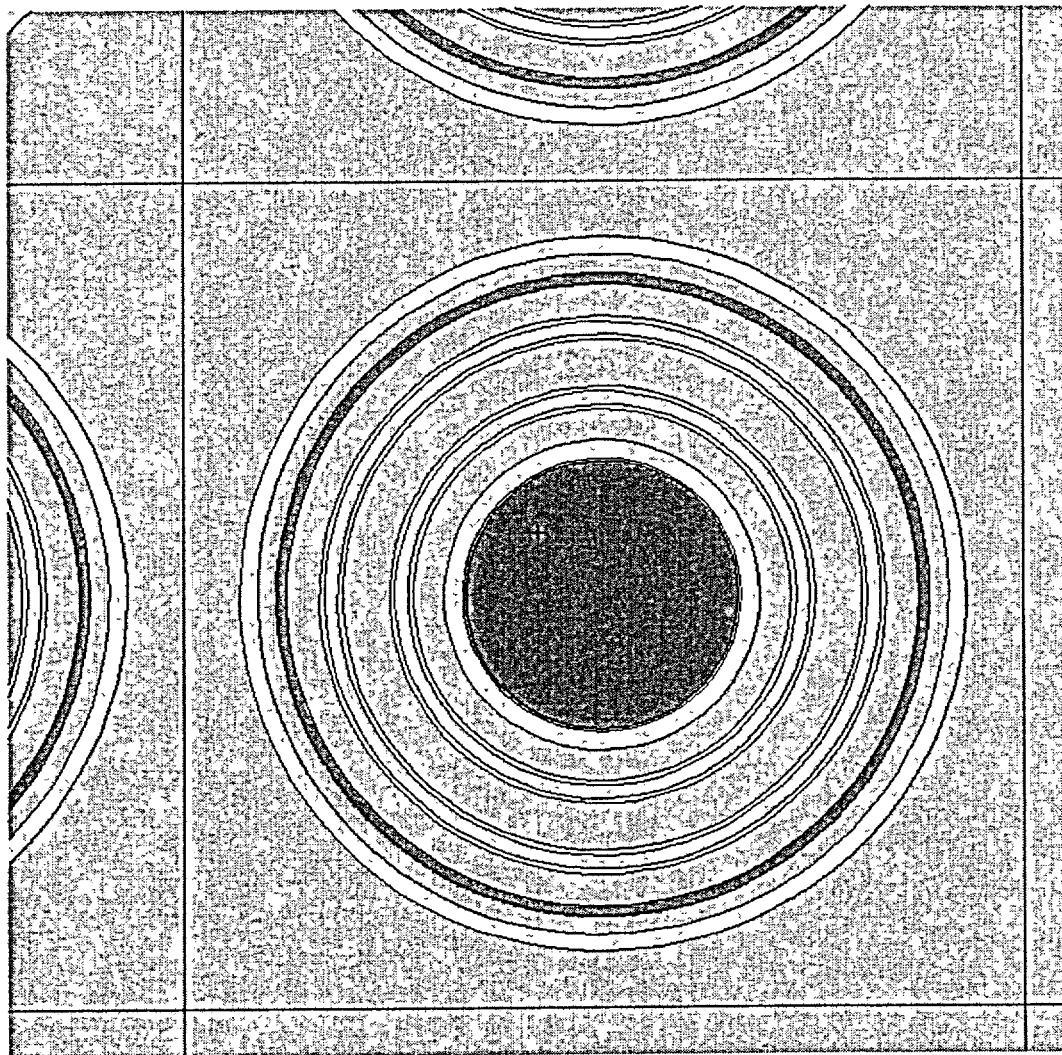


Figure 1. Cross sectional view of an actual Pathfinder superheater element.



Gc00 0239 3

Figure 2. MCNP model representation of a Pathfinder superheater element.

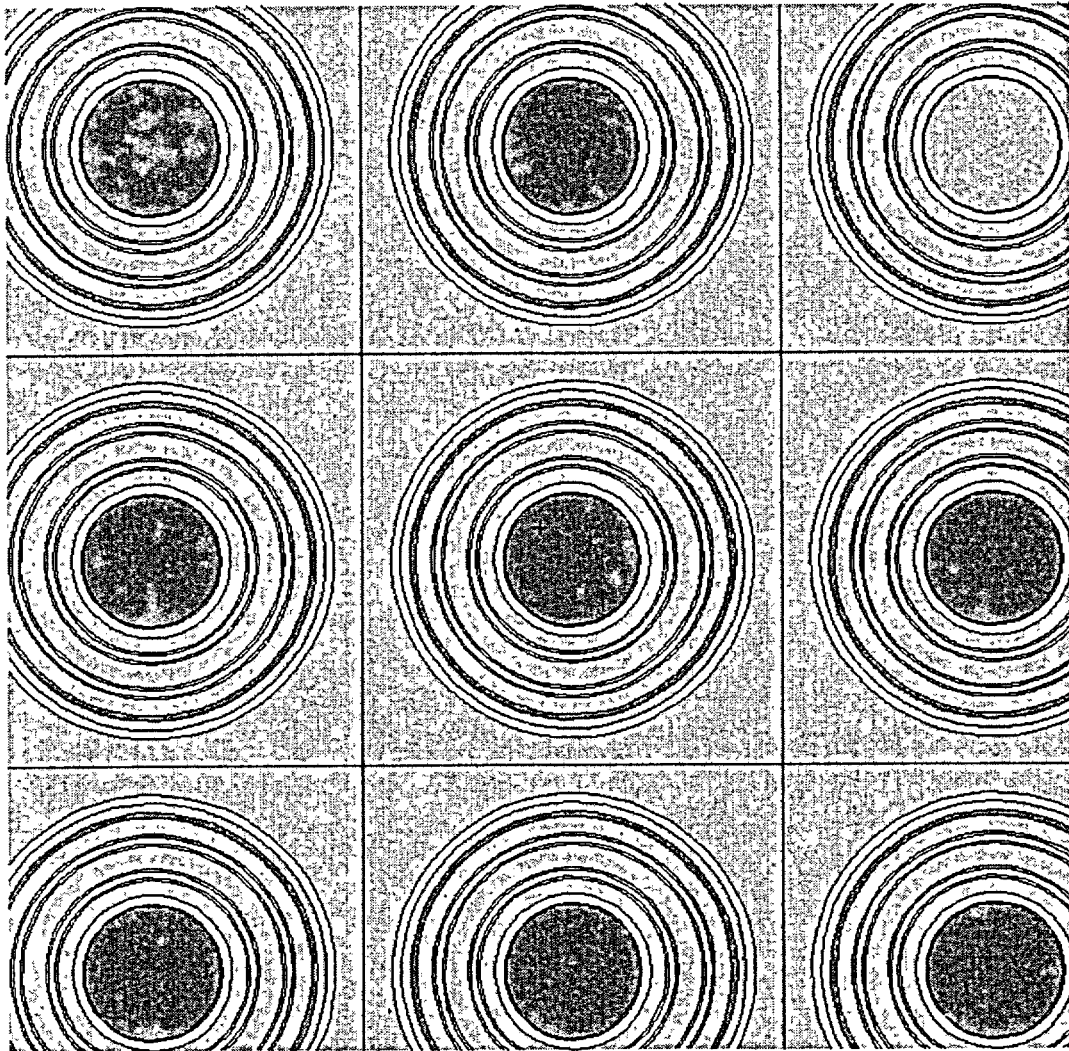


Figure 3. MCNP model representation of a Pathfinder superheater lattice.

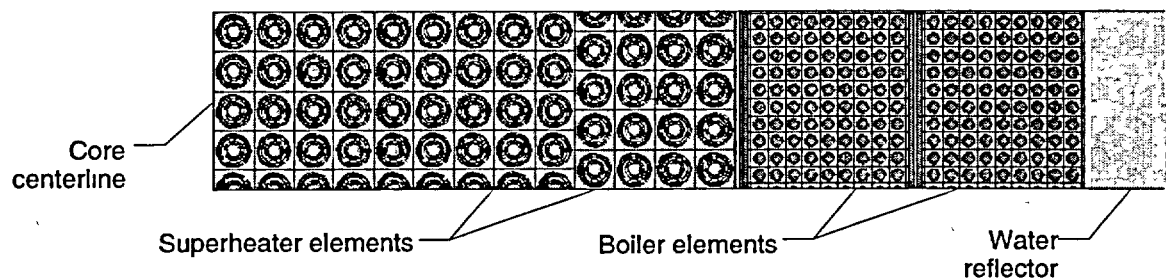
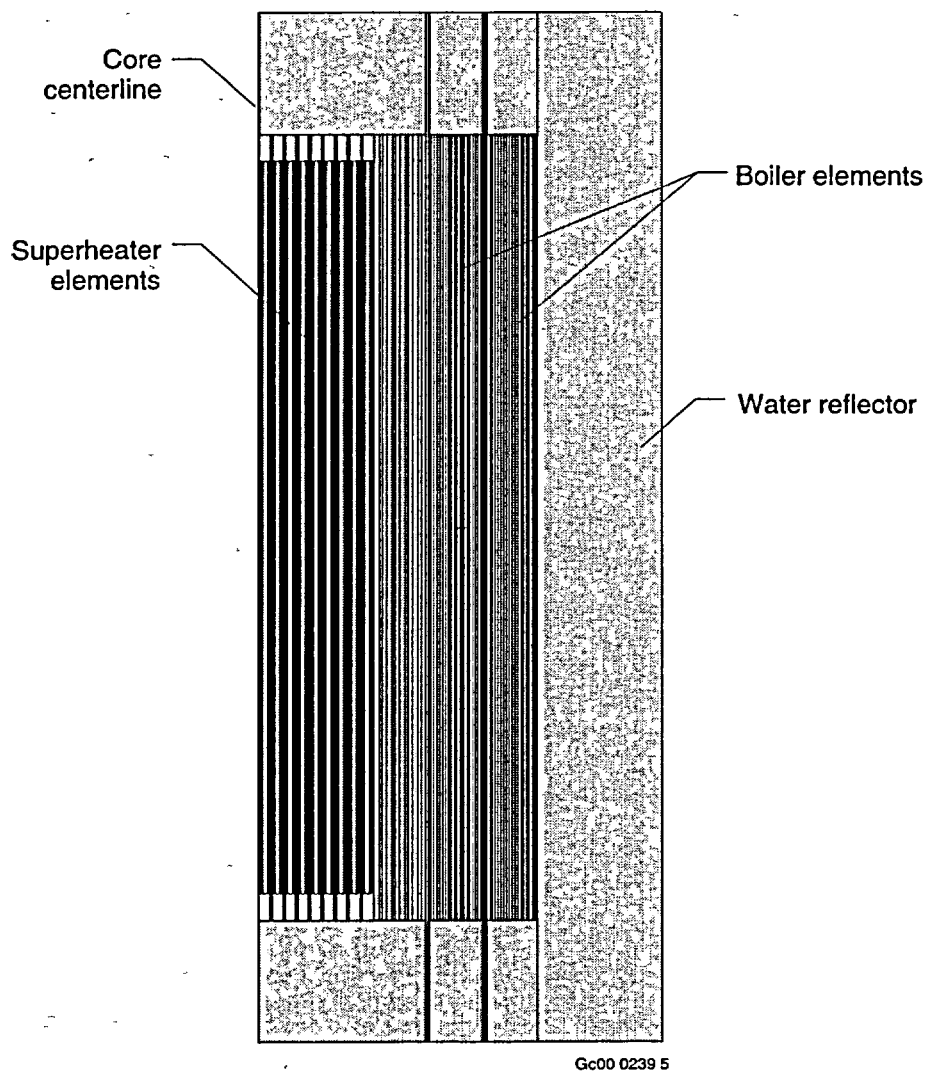


Figure 4. MCNP model representation of a section of the Pathfinder core.



Gc00 0239 5

Figure 5. MCNP model axial view of the Pathfinder core.

Pathfinder Superheater Element

Stainless Steel Cladding, 60 to 100% Enriched U-235 Fuel

Reactor Moderator/Coolant:	Light Water
Fuel Meat:	UO ₂ -316L Stainless Steel (cermet)
Clad:	316L Stainless Steel
Burnup:	6.01 MWd/element (average element burnup)
Burnup:	5.25% U-235 burnup (amount fissioned)
Burnup:	6.46% U-235 depletion (amount fissioned and transmuted)
Core Power Fraction:	15.00% Superheater core power fraction (max assumed)
Basis of Calculation	Single superheater element with double annuli
BOL U-235:	120.40 grams U-235 per element (design basis)
BOL U-238:	8.37 grams U-238 per element
BOL U-234:	0.00 grams U-234 per element
BOL U-236:	0.05 grams U-236 per element
BOL Total U per element:	128.82 grams U per element
BOL Fuel Enrichment:	93.5 wt%

DECAY TIMES (years) (Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
H 3	8.128E-02	6.140E-02	4.638E-02	3.504E-02	2.647E-02	1.511E-02	6.512E-03	2.808E-03	1.210E-03	3.942E-04
BE 10	7.557E-10	7.557E-10	7.557E-10	7.557E-10	7.557E-10	7.557E-10	7.557E-10	7.557E-10	7.557E-10	7.557E-10
C 14	1.388E-03	1.387E-03	1.387E-03	1.386E-03	1.385E-03	1.383E-03	1.381E-03	1.378E-03	1.376E-03	1.372E-03
CL 36	7.369E-06	7.369E-06	7.369E-06	7.369E-06	7.369E-06	7.369E-06	7.369E-06	7.368E-06	7.368E-06	7.368E-06
CR 51	1.481E-17	2.204E-37	3.281E-57	4.884E-77	7.270E-97	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MN 54	2.539E-01	4.432E-03	7.738E-05	1.351E-06	2.358E-08	7.187E-12	3.824E-17	2.035E-22	1.083E-27	1.005E-34
FE 55	2.190E+01	5.780E+00	1.526E+00	4.026E-01	1.063E-01	7.403E-03	1.361E-04	2.502E-06	4.601E-08	2.233E-10
FE 59	9.776E-12	6.049E-24	3.744E-36	2.317E-48	1.434E-60	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO 60	2.197E+01	1.138E+01	5.900E+00	3.058E+00	1.585E+00	4.258E-01	5.928E-02	8.253E-03	1.149E-03	8.291E-05
NI 59	1.302E-02	1.302E-02	1.302E-02	1.302E-02	1.302E-02	1.302E-02	1.302E-02	1.301E-02	1.301E-02	1.301E-02
NI 63	1.762E+00	1.697E+00	1.634E+00	1.574E+00	1.516E+00	1.406E+00	1.256E+00	1.121E+00	1.002E+00	8.617E-01
ZN 65	2.803E-03	1.566E-05	8.751E-08	4.889E-10	2.732E-12	8.528E-17	1.488E-23	2.595E-30	4.526E-37	4.411E-46
SE 79	7.950E-05	7.950E-05	7.949E-05	7.949E-05	7.948E-05	7.947E-05	7.946E-05	7.945E-05	7.944E-05	7.942E-05
KR 85	1.724E+00	1.248E+00	9.033E-01	6.539E-01	4.734E-01	2.481E-01	9.412E-02	3.571E-02	1.355E-02	3.721E-03
RB 87	5.427E-09	5.427E-09	5.427E-09	5.427E-09	5.427E-09	5.427E-09	5.427E-09	5.427E-09	5.427E-09	5.427E-09
SR 89	1.391E-08	1.837E-19	2.425E-30	3.202E-41	4.228E-52	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 90	1.674E+01	1.487E+01	1.320E+01	1.172E+01	1.041E+01	8.203E+00	5.742E+00	4.019E+00	2.813E+00	1.748E+00
Y 90	1.675E+01	1.487E+01	1.320E+01	1.172E+01	1.041E+01	8.205E+00	5.743E+00	4.020E+00	2.813E+00	1.748E+00

DECAY TIMES (years)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
Y 91	4.983E-07	2.030E-16	8.270E-26	3.369E-35	1.372E-44	2.278E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 93	4.090E-04	4.090E-04	4.090E-04	4.090E-04	4.090E-04	4.090E-04	4.090E-04	4.090E-04	4.090E-04	4.090E-04
ZR 95	3.324E-06	8.612E-15	2.231E-23	5.781E-32	1.498E-40	1.006E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 93M	9.386E-05	1.601E-04	2.115E-04	2.513E-04	2.822E-04	3.246E-04	3.588E-04	3.747E-04	3.821E-04	3.862E-04
NB 94	3.416E-05	3.415E-05	3.414E-05	3.414E-05	3.413E-05	3.412E-05	3.410E-05	3.409E-05	3.407E-05	3.405E-05
NB 95	7.379E-06	1.912E-14	4.954E-23	1.283E-31	3.325E-40	2.232E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 95M	2.466E-08	6.389E-17	1.655E-25	4.289E-34	1.111E-42	7.459E-60	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO 93	2.431E-04	2.428E-04	2.426E-04	2.424E-04	2.421E-04	2.416E-04	2.409E-04	2.402E-04	2.395E-04	2.386E-04
TC 99	2.804E-03	2.804E-03	2.804E-03	2.804E-03	2.804E-03	2.804E-03	2.804E-03	2.803E-03	2.803E-03	2.803E-03
RU103	7.847E-12	8.116E-26	8.393E-40	8.681E-54	8.978E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU106	9.935E-01	3.199E-02	1.030E-03	3.316E-05	1.068E-06	1.107E-09	3.694E-14	1.233E-18	4.115E-23	4.422E-29
RH103M	7.074E-12	7.316E-26	7.567E-40	7.826E-54	8.093E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH106	9.935E-01	3.199E-02	1.030E-03	3.316E-05	1.068E-06	1.107E-09	3.694E-14	1.233E-18	4.115E-23	4.422E-29
PD107	2.885E-06	2.885E-06	2.885E-06	2.885E-06	2.885E-06	2.885E-06	2.885E-06	2.885E-06	2.885E-06	2.885E-06
AG110	6.377E-06	4.037E-08	2.556E-10	1.618E-12	1.024E-14	4.105E-19	1.042E-25	2.643E-32	6.706E-39	1.077E-47
AG110M	4.795E-04	3.035E-06	1.922E-08	1.216E-10	7.701E-13	3.087E-17	7.832E-24	1.987E-30	5.042E-37	8.100E-46
AG111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD113M	1.828E-03	1.441E-03	1.137E-03	8.966E-04	7.072E-04	4.399E-04	2.158E-04	1.059E-04	5.193E-05	2.009E-05
CD113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD115M	1.519E-13	7.283E-26	3.492E-38	1.674E-50	8.023E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114	4.047E-15	3.249E-26	2.608E-37	2.093E-48	1.680E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114M	4.229E-15	3.395E-26	2.725E-37	2.187E-48	1.756E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN115M	1.066E-17	5.108E-30	2.448E-42	1.174E-54	5.626E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN119M	1.774E-04	1.015E-06	5.815E-09	3.329E-11	1.906E-13	6.250E-18	1.173E-24	2.202E-31	4.135E-38	4.445E-47
SN121M	1.547E-05	1.444E-05	1.346E-05	1.256E-05	1.173E-05	1.021E-05	8.291E-06	6.735E-06	5.471E-06	4.146E-06
SN123	4.457E-05	2.488E-09	1.388E-13	7.749E-18	4.325E-22	1.347E-30	2.342E-43	4.072E-56	7.080E-69	6.871E-86
SN125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN126	6.908E-05	6.908E-05	6.908E-05	6.907E-05	6.907E-05	6.907E-05	6.906E-05	6.905E-05	6.904E-05	6.903E-05
SB124	4.254E-10	3.179E-19	2.377E-28	1.777E-37	1.328E-46	7.420E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB125	3.523E-01	1.009E-01	2.889E-02	8.276E-03	2.370E-03	1.944E-04	4.567E-06	1.073E-07	2.520E-09	1.696E-11
SB126	9.671E-06	9.671E-06	9.671E-06	9.670E-06	9.670E-06	9.669E-06	9.668E-06	9.667E-06	9.666E-06	9.665E-06
SB126M	6.908E-05	6.908E-05	6.908E-05	6.907E-05	6.907E-05	6.907E-05	6.906E-05	6.905E-05	6.904E-05	6.903E-05
TE123M	1.573E-08	4.038E-13	1.037E-17	2.662E-22	6.832E-27	4.502E-36	7.616E-50	1.288E-63	2.180E-77	9.464E-96
TE125M	8.595E-02	2.462E-02	7.049E-03	2.019E-03	5.782E-04	4.743E-05	1.114E-06	2.618E-08	6.148E-10	4.136E-12
TE127	3.223E-05	2.940E-10	2.681E-15	2.446E-20	2.231E-25	1.856E-35	1.408E-50	1.068E-65	8.106E-81	5.609E-101
TE127M	3.291E-05	3.001E-10	2.738E-15	2.497E-20	2.277E-25	1.894E-35	1.437E-50	1.091E-65	8.275E-81	5.727E-101

Radionuclide	DECAY TIMES (years)									
	(Activities* in Ci/element)									
	5	10	15	20	25	35	50	65	80	100
TE129	7.493E-16	3.341E-32	1.490E-48	6.641E-65	2.961E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE129M	1.151E-15	5.132E-32	2.288E-48	1.020E-64	4.549E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I129	4.399E-06	4.399E-06	4.399E-06	4.399E-06	4.399E-06	4.399E-06	4.399E-06	4.399E-06	4.399E-06	4.399E-06
I131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS134	4.331E-01	8.075E-02	1.505E-02	2.807E-03	5.233E-04	1.819E-05	1.179E-07	7.638E-10	4.950E-12	5.981E-15
CS135	1.822E-04	1.822E-04	1.822E-04	1.822E-04	1.822E-04	1.822E-04	1.822E-04	1.822E-04	1.822E-04	1.822E-04
CS136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS137	1.743E+01	1.553E+01	1.384E+01	1.233E+01	1.099E+01	8.721E+00	6.168E+00	4.362E+00	3.085E+00	1.944E+00
BA136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA137M	1.649E+01	1.469E+01	1.309E+01	1.166E+01	1.039E+01	8.250E+00	5.835E+00	4.127E+00	2.919E+00	1.839E+00
BA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE141	1.915E-14	2.422E-31	3.064E-48	3.875E-65	4.901E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE142	6.111E-09	6.111E-09	6.111E-09	6.111E-09	6.111E-09	6.111E-09	6.111E-09	6.111E-09	6.111E-09	6.111E-09
CE144	5.635E+00	6.580E-02	7.683E-04	8.971E-06	1.048E-07	1.428E-11	2.274E-17	3.621E-23	5.765E-29	1.072E-36
PR143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR144	5.635E+00	6.580E-02	7.683E-04	8.972E-06	1.048E-07	1.428E-11	2.274E-17	3.621E-23	5.765E-29	1.072E-36
PR144M	6.762E-02	7.896E-04	9.220E-06	1.077E-07	1.257E-09	1.714E-13	2.729E-19	4.345E-25	6.918E-31	1.286E-38
ND144	2.524E-13	2.544E-13	2.545E-13	2.545E-13	2.545E-13	2.545E-13	2.545E-13	2.545E-13	2.545E-13	2.545E-13
ND147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM145	1.981E-07	1.666E-07	1.371E-07	1.127E-07	9.268E-08	6.267E-08	3.484E-08	1.937E-08	1.077E-08	4.925E-09
PM147	1.929E+01	5.151E+00	1.376E+00	3.675E-01	9.815E-02	7.002E-03	1.334E-04	2.542E-06	4.844E-08	2.465E-10
PM148M	4.160E-13	2.069E-26	1.029E-39	5.116E-53	2.544E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM148	2.343E-14	1.165E-27	5.795E-41	2.882E-54	1.433E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.0

	DECAY TIMES (years)									
	(Activities* in Ci/element)									
Radionuclide	5	10	15	20	25	35	50	65	80	100
TL207	4.620E-09	1.180E-08	2.170E-08	3.394E-08	4.815E-08	8.136E-08	1.400E-07	2.056E-07	2.756E-07	3.727E-07
TL208	1.456E-07	1.606E-07	1.569E-07	1.503E-07	1.434E-07	1.302E-07	1.127E-07	9.753E-08	8.442E-08	6.971E-08
PB210	1.174E-14	4.855E-14	1.414E-13	3.119E-13	5.790E-13	1.467E-12	3.875E-12	7.804E-12	1.344E-11	2.383E-11
PB211	4.633E-09	1.183E-08	2.177E-08	3.403E-08	4.829E-08	8.159E-08	1.404E-07	2.062E-07	2.764E-07	3.738E-07
PB212	4.052E-07	4.469E-07	4.367E-07	4.183E-07	3.990E-07	3.623E-07	3.136E-07	2.714E-07	2.350E-07	1.940E-07
BI211	4.633E-09	1.183E-08	2.177E-08	3.403E-08	4.829E-08	8.159E-08	1.404E-07	2.062E-07	2.764E-07	3.738E-07
BI212	4.052E-07	4.469E-07	4.367E-07	4.183E-07	3.990E-07	3.623E-07	3.136E-07	2.714E-07	2.350E-07	1.940E-07
PO212	2.596E-07	2.863E-07	2.798E-07	2.680E-07	2.557E-07	2.321E-07	2.009E-07	1.739E-07	1.505E-07	1.243E-07
PO215	4.633E-09	1.183E-08	2.177E-08	3.403E-08	4.829E-08	8.159E-08	1.404E-07	2.062E-07	2.764E-07	3.738E-07
PO216	4.052E-07	4.469E-07	4.367E-07	4.183E-07	3.990E-07	3.623E-07	3.136E-07	2.714E-07	2.350E-07	1.940E-07
RN219	4.633E-09	1.183E-08	2.177E-08	3.403E-08	4.829E-08	8.159E-08	1.404E-07	2.062E-07	2.764E-07	3.738E-07
RN220	4.052E-07	4.469E-07	4.367E-07	4.183E-07	3.990E-07	3.623E-07	3.136E-07	2.714E-07	2.350E-07	1.940E-07
FR223	6.392E-11	1.631E-10	3.000E-10	4.690E-10	6.654E-10	1.125E-09	1.936E-09	2.843E-09	3.810E-09	5.153E-09
RA223	4.633E-09	1.183E-08	2.177E-08	3.403E-08	4.829E-08	8.159E-08	1.404E-07	2.062E-07	2.764E-07	3.738E-07
RA224	4.052E-07	4.469E-07	4.367E-07	4.183E-07	3.990E-07	3.623E-07	3.136E-07	2.714E-07	2.350E-07	1.940E-07
RA226	1.202E-13	4.419E-13	9.691E-13	1.704E-12	2.650E-12	5.180E-12	1.061E-11	1.803E-11	2.749E-11	4.335E-11
RA228	2.767E-11	3.664E-11	4.200E-11	4.521E-11	4.713E-11	4.898E-11	4.984E-11	5.008E-11	5.019E-11	5.029E-11
AC227	4.632E-09	1.182E-08	2.174E-08	3.399E-08	4.822E-08	8.151E-08	1.403E-07	2.060E-07	2.761E-07	3.734E-07
TH227	4.570E-09	1.167E-08	2.147E-08	3.356E-08	4.762E-08	8.046E-08	1.385E-07	2.034E-07	2.726E-07	3.686E-07
TH228	4.052E-07	4.465E-07	4.363E-07	4.179E-07	3.987E-07	3.622E-07	3.136E-07	2.714E-07	2.350E-07	1.940E-07
TH229	9.227E-12	1.765E-11	2.614E-11	3.469E-11	4.332E-11	6.076E-11	8.743E-11	1.147E-10	1.426E-10	1.807E-10
TH230	1.017E-10	1.963E-10	2.923E-10	3.897E-10	4.883E-10	6.891E-10	9.987E-10	1.317E-09	1.644E-09	2.090E-09
TH231	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04
TH232	4.988E-11	4.991E-11	4.993E-11	4.995E-11	4.998E-11	5.003E-11	5.010E-11	5.017E-11	5.024E-11	5.034E-11
TH234	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06
PA231	4.030E-08	6.605E-08	9.179E-08	1.175E-07	1.433E-07	1.947E-07	2.719E-07	3.490E-07	4.261E-07	5.289E-07
PA233	6.898E-06	6.898E-06	6.898E-06	6.899E-06	6.900E-06	6.902E-06	6.905E-06	6.908E-06	6.911E-06	6.916E-06
PA234M	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06
PA234	3.635E-09	3.635E-09	3.635E-09	3.635E-09	3.635E-09	3.635E-09	3.635E-09	3.635E-09	3.635E-09	3.635E-09
U232	4.671E-07	4.474E-07	4.271E-07	4.072E-07	3.881E-07	3.526E-07	3.052E-07	2.642E-07	2.287E-07	1.886E-07
U233	1.778E-08	1.793E-08	1.808E-08	1.823E-08	1.838E-08	1.868E-08	1.914E-08	1.959E-08	2.004E-08	2.064E-08
U234	2.089E-06	2.120E-06	2.150E-06	2.179E-06	2.207E-06	2.259E-06	2.330E-06	2.393E-06	2.449E-06	2.515E-06
U235	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04	2.435E-04
U236	9.730E-05	9.730E-05	9.730E-05	9.730E-05	9.730E-05	9.730E-05	9.730E-05	9.730E-05	9.730E-05	9.730E-05
U237	4.464E-07	3.509E-07	2.759E-07	2.169E-07	1.706E-07	1.054E-07	5.123E-08	2.490E-08	1.210E-08	4.623E-09
U238	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06	2.796E-06

DECAY TIMES (years)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
NP237	6.898E-06	6.898E-06	6.898E-06	6.899E-06	6.900E-06	6.902E-06	6.905E-06	6.908E-06	6.911E-06	6.916E-06
PU236	8.420E-08	2.499E-08	7.416E-09	2.201E-09	6.535E-10	5.796E-11	1.950E-12	4.857E-13	4.474E-13	4.463E-13
PU237	6.292E-19	5.636E-31	5.048E-43	4.522E-55	4.051E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU238	2.248E-03	2.161E-03	2.078E-03	1.997E-03	1.920E-03	1.774E-03	1.576E-03	1.400E-03	1.244E-03	1.062E-03
PU239	4.017E-03	4.016E-03	4.015E-03	4.015E-03	4.014E-03	4.013E-03	4.011E-03	4.010E-03	4.008E-03	4.006E-03
PU240	5.236E-04	5.233E-04	5.230E-04	5.227E-04	5.224E-04	5.219E-04	5.211E-04	5.202E-04	5.194E-04	5.183E-04
PU241	1.820E-02	1.431E-02	1.125E-02	8.843E-03	6.952E-03	4.298E-03	2.089E-03	1.015E-03	4.933E-04	1.885E-04
PU242	1.185E-08	1.185E-08	1.185E-08	1.185E-08	1.185E-08	1.185E-08	1.185E-08	1.185E-08	1.185E-08	1.185E-08
PU244	3.988E-17	3.988E-17	3.988E-17	3.988E-17	3.988E-17	3.988E-17	3.988E-17	3.988E-17	3.988E-17	3.988E-17
AM241	1.696E-04	2.973E-04	3.964E-04	4.730E-04	5.319E-04	6.111E-04	6.692E-04	6.886E-04	6.894E-04	6.776E-04
AM242M	5.862E-08	5.730E-08	5.601E-08	5.475E-08	5.352E-08	5.113E-08	4.776E-08	4.460E-08	4.165E-08	3.803E-08
AM242	5.833E-08	5.702E-08	5.573E-08	5.448E-08	5.325E-08	5.088E-08	4.752E-08	4.438E-08	4.145E-08	3.784E-08
AM243	5.938E-09	5.935E-09	5.932E-09	5.929E-09	5.926E-09	5.921E-09	5.913E-09	5.904E-09	5.896E-09	5.885E-09
CM242	1.147E-07	4.720E-08	4.611E-08	4.507E-08	4.406E-08	4.208E-08	3.930E-08	3.670E-08	3.428E-08	3.129E-08
CM243	3.100E-09	2.745E-09	2.431E-09	2.153E-09	1.907E-09	1.495E-09	1.038E-09	7.212E-10	5.009E-10	3.081E-10
CM244	4.388E-08	3.624E-08	2.993E-08	2.472E-08	2.042E-08	1.393E-08	7.848E-09	4.422E-09	2.491E-09	1.159E-09
CM245	3.390E-13	3.388E-13	3.387E-13	3.386E-13	3.384E-13	3.381E-13	3.377E-13	3.373E-13	3.369E-13	3.364E-13
CM246	2.485E-15	2.483E-15	2.481E-15	2.480E-15	2.478E-15	2.474E-15	2.469E-15	2.463E-15	2.458E-15	2.451E-15
CM247	4.323E-22	4.323E-22	4.323E-22	4.323E-22	4.323E-22	4.323E-22	4.323E-22	4.323E-22	4.323E-22	4.323E-22
Subtotal**	1.493E+02	8.620E+01	6.519E+01	5.390E+01	4.634E+01	3.578E+01	2.516E+01	1.792E+01	1.285E+01	8.322E+00
TOTAL***	1.493E+02	8.621E+01	6.520E+01	5.391E+01	4.634E+01	3.578E+01	2.516E+01	1.792E+01	1.285E+01	8.323E+00

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 21

Fuel-Specific Source Term Calculations LWBR Seed Module

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a source term template for a single Light Water Breeder Reactor (LWBR) spent nuclear fuel seed module. The data sources for the analysis are documented here, and the INEEL calculational methodology is described in detail in Reference 1.

Light Water Breeder Reactor History

The LWBR was a full-scale power production reactor with a core design power rating of 236 MW_{th}. The LWBR core operated over a time period extending from August 26, 1977, to December 2, 1982 (5+ years). The reactor design was conceived by the Westinghouse Atomic Power Development Laboratory (WAPD) and stationed at the Shippingport Atomic Power Station (APS).

The LWBR was a pressurized, light water moderated and cooled thermal reactor with zirconium-clad UO₂-ThO₂ fuel rods (Reference 6). The beginning-of-life (BOL) UO₂ was fully enriched in U-233 (>98%) and provided a total core fissile inventory of approximately 501 kg. In addition, to the UO₂-ThO₂ fuel rods, the entire fueled active core region was reflected radially or circumferentially around the core, and both above and below with ThO₂ fuel rods. The ThO₂ rods in the outer reflector regions and the very large ThO₂ loading in the active core were designed to reduce neutron leakage and breed U-233.

The LWBR core consisted of 39 modules (12 seed, 3 standard blanket Type I, 3 standard/power flattening blanket Type II, 6 standard/power flattening blanket Type III, 9 reflector Type IV, and 6 reflector Type V). These modules were in the core for the full operating period (5+ years). Over its lifetime, the core generated 29,047 EFPD (full power = 236 MW).

The reactor core design was complex; the primary design goal was to maximize the U-233 breeding ratio. The seed modules were moveable; operated on pneumatic pistons for reactivity control, supplanting the need for neutron absorbing control rods. The different fueled module types had different numbers of rods, rod diameters, and lattice pitch. In addition, each module type had complex radial and axial uranium/thoria loadings. Reference 6 provides a good description of the different module loadings and geometries. In addition, Reference 6 contains an extensive listing of additional references from which data were obtained and used in the depletion calculations here.

Light Water Breeder Reactor Seed and Reactor Data

The LWBR reactor core and fuel elements are described in some detail in Reference 6. Data from this reference have been used to develop reactor physics models needed to develop neutron cross sections for the fuel depletion and radionuclide inventory analysis.

The LWBR seed modules consisted of 619 fuel rods arranged in 15 hexagonal rings in a Zircaloy-4 hexagonal can. The 9.59-in. flat-to-flat can had a 0.08 in. thickness. The fuel rod meat or fuel pellet material was either a uranium-thoria (UO₂-ThO₂) binary composition or a pure thoria (ThO₂) composition. In the seed module, there were two binary compositions with different uranium loadings.

The fuel rod clad was Zircaloy-4. The fuel pellet and pin diameters were 0.262 in. and 0.306 in., respectively. The uranium metal was high enriched at 98.23 wt% U-233 at BOL. For modeling purposes, the thoria properties listed below for the binary pellet are also used for the pure thoria pellet.

The following data provide specific seed module dimensions, materials, densities, enrichment, etc., which are typical for an LWBR seed module (Reference 6). The BOL data below were used in the fuel depletion calculations for the LWBR seed module source term generation.

Seed Module:	15 concentric hexagonal rings of fuel rods	
No. of rods:	619 fuel rods per seed module (631 lattice positions)	
Types of rods:	4 (1 high zone and 3 low zones)	
High Zone rods:	331 per module	
Low Zone rods:	288 per module	
Fuel Pellet Diameter:	0.262 in.	
Fuel Rod Meat Length:	84 in.	
Fuel Rod Pitch:	0.370 in. (hot)	
Uranium Enrichment:	98.23 wt % U-233 1.29 wt % U-234 0.09 wt % U-235 0.02 wt % U-236 0.37 wt % U-238	
Binary Fuel Rod Meat:	Urania-thoria (UO ₂ -ThO ₂)	
UO ₂ Density:	10.96 g/cc (100% Theoretical Density [TD])	
ThO ₂ Density:	10.03 g/cc (100% TD)	
UO ₂ Density:	10.52 g/cc (96% TD)	
ThO ₂ Density:	9.93 g/cc (99% TD)	
UO ₂ Fraction:	4.337 wt% (Low Zone)	
UO ₂ Fraction:	5.202 wt% (High Zone)	
U-233 Mass:	16,877.36 g	per seed module
U-234 Mass:	221.64 g	per seed module
U-235 Mass:	15.46 g	per seed module
U-236 Mass:	3.44 g	per seed module
U-238 Mass:	63.57 g	per seed module
Th-232 Mass:	442,731.04 g	per seed module
Clad:	Zircaloy-4	
Clad Pin Outer Diameter:	0.306 in.	
Clad Thickness:	0.022 in.	
Clad Pin Length:	118 in.	
Clad Density:	6.44 g/cc	
Total Zircaloy Mass:	154,237.0 g per module (based conservatively on 631 fuel rods)	

Can Geometry:	Hexagonal
Can Dimensions:	9.59 in. flat-to-flat 0.08 in. wall thickness
Can Length:	118 in.
Can Material:	Zircaloy-4
Can Density:	6.44 g/cc
Can Mass:	33,114.6 g per module
Total Zircaloy-4 Mass:	187,351.6 g per module
Coolant:	Light water
Coolant Temperature:	531°F
Coolant Pressure:	2000 psig
Coolant Density:	0.6583 g/cc

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for the material components in a single LWBR seed module. In addition, for the ORIGEN2 (Reference 2) depletion calculation, conservative and detailed impurity concentrations were added for the zircaloy clad (Reference 3) and the urania-thoria fuel pellets (Reference 4). Table 1 lists the impurities and corresponding concentrations used in the calculations. Note: The impurities in the thoria pellets were assumed to be the same as in the urania-thoria pellets.

Burnup

The LWBR module burnup or depletion analysis was performed using the ORIGEN2 computer code (Reference 2). Three basic inputs are required to perform this analysis, which include: (1) neutron cross sections specific to the LWBR seed module, (2) power history or average burnup for a single LWBR seed module over its operating lifetime, and (3) BOL seed module fissile and fertile masses. The neutron cross sections are discussed below and were incorporated as an update into a standard ORIGEN2 pressurized water reactor (PWR) cross-section library.

The complete LWBR power history is given in References 4 and 8. These data have been used to derive a simplified power history and burnup for an average seed module. The derived data used in the ORIGEN2 code as input are given in Table 2 in terms of seed module power (MW_{th}) and cumulative or total seed module burnup (MWD).

The fissile and fertile BOL isotopic masses by module are derived from data found in Reference 6 and are given in the "LWBR Seed and Reactor Data" section above. Module masses are based on the following information: (1) total number of fuel rods for that particular module, (2) fuel rod radius and length, (3) number of fuel rods in a given radial loading zone, (4) axial loading step lengths, and (5) radial and axial step percent mass loadings of UO_2 in UO_2 - ThO_2 . From these data, the BOL uranium isotopic masses and Thorium-232 mass can be determined for each module type. In addition, the oxide fuel impurity masses are also included in the calculations. The impurity levels were obtained from LWBR UO_2 - ThO_2 fuel fabrication specifications.

Cross-Section Development

The primary goal of the reactor physics analysis was to develop BOL neutron cross sections specifically for the LWBR seed module. This required that MCNP4B (Reference 5) computer models be developed to represent the module geometry and the complex radial and axial fuel loadings in both the seed and standard blanket modules. The cross sections were required as input data for the ORIGEN2

depletion or burnup calculations. (Note: No standard ORIGEN2 neutron cross-section libraries were available for this unique reactor type). The MCNP neutron cross-section generation methodology is documented in Reference 1, and validation work to support the physics and depletion methodology and its predictive capability is given Reference 7 specifically for the LWBR.

A fully explicit, three-dimensional MCNP4B computer model of the seed, standard blanket, and top and bottom thorium reflectors was developed specifically to generate three BOL cross-section library updates. The model was essentially an infinite lattice model of seed and standard reflector blankets with exact numbers of fuel rods, rod diameters, clad thicknesses, lattice pitch, fuel and clad materials, and the complex radial and axial uranium-thorium loadings.

Figure 1 shows an x-y cross-sectional view of the infinite lattice model as drawn by the MCNP4B computer code. The complex geometry and radial binary fuel loading patterns of the UO_2 - ThO_2 pellets are fully visible from the color scheme as are the variable rod diameters and pitches between the seed rods and the standard blanket rods. The axially stepped binary and thorium fuel loading patterns for the seed and standard blanket modules are given Reference 6, and although not shown in Figure 1, are appropriately modeled in the MCNP model.

It should be noted that only BOL neutron cross sections were generated and used in the burnup calculations, i.e., burnup-dependent cross sections were not calculated at various time steps throughout the burnup calculations as was done in the validation work. Based on the validation work, good radionuclide inventories could be obtained with BOL cross sections only. Part of the reason for this is because during reactor operation, the seed modules burned their U-233 fissile inventory while the thorium bred new U-233. Therefore, since both the thorium and U-233 inventories remained relatively constant over the LWBR lifetime, the neutron cross sections would be weakly dependent on burnup, and here it is assumed that the BOL cross sections are reasonable estimates over the entire LWBR lifetime.

Light Water Breeder Reactor Seed Module Exposure History

Table 2 summarizes the LWBR single seed module power or exposure history used in the depletion calculations. The power history is based on data in References 4 and 8. Following the burnup or exposure period, the radionuclide activities are decayed for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100 years.

Burnup Calculation

The ORIGEN2 computer code was used to perform the depletion or burnup calculation for a single LWBR seed module. The seed module masses and impurities, neutron cross sections, burnup, power history, and power level as discussed above are input data for the ORIGEN2 calculation. The ORIGEN2 output or radionuclide concentrations are given as a function of time in the attached template table representing a single average-burnup LWBR seed module.

The 145 radionuclides listed in the template represent greater than 99.99% of the total curie inventory had all 684 activation products, 880 fission products, and 127 actinide/daughter isotopes from the ORIGEN2 output been included in the template.

References

1. J. W. Sterbentz and C. A. Wemple, *Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels*, INEL-96/0304, September 1996.

2. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.
3. Oak Ridge National Laboratory, *Characteristics of Potential Repository Wastes*, DOE/RW-0184-V1-R1, Volume 1, July 1992, Oak Ridge, Tennessee.
4. Bettis Atomic Power Laboratory, *Summary of the Nuclear Design and Performance of the Light water Breeder Reactor (LWBR)*, WAPD-TM-1326, June 1979.
5. "MCNP4B: Monte Carlo N-Particle Transport Code System," contributed by the Transport Methods Group, Los Alamos National Laboratory and distributed by the Radiation and Safety Information Computational Center as code package CCC-660, April 1997.
6. G. L. Olson, R. K. McCardell, and D. Illum, *Fuel Summary Report: Shippingport Light Water Breeder Reactor*, INEEL/EXT-98-00799, August 1998.
7. J. W. Sterbentz, *Validation Work to Support the Idaho National Engineering and Environmental Laboratory Calculational Burnup Methodology Using Shippingport Light Water Breeder Reactor (LWBR) Spent Fuel Assay Data*, INEEL/EXT-99-00581, August 1999.
8. Bettis Atomic Power Laboratory, "Shippingport Operations with the LWBR," WAPD-TM-1542, March 1986.

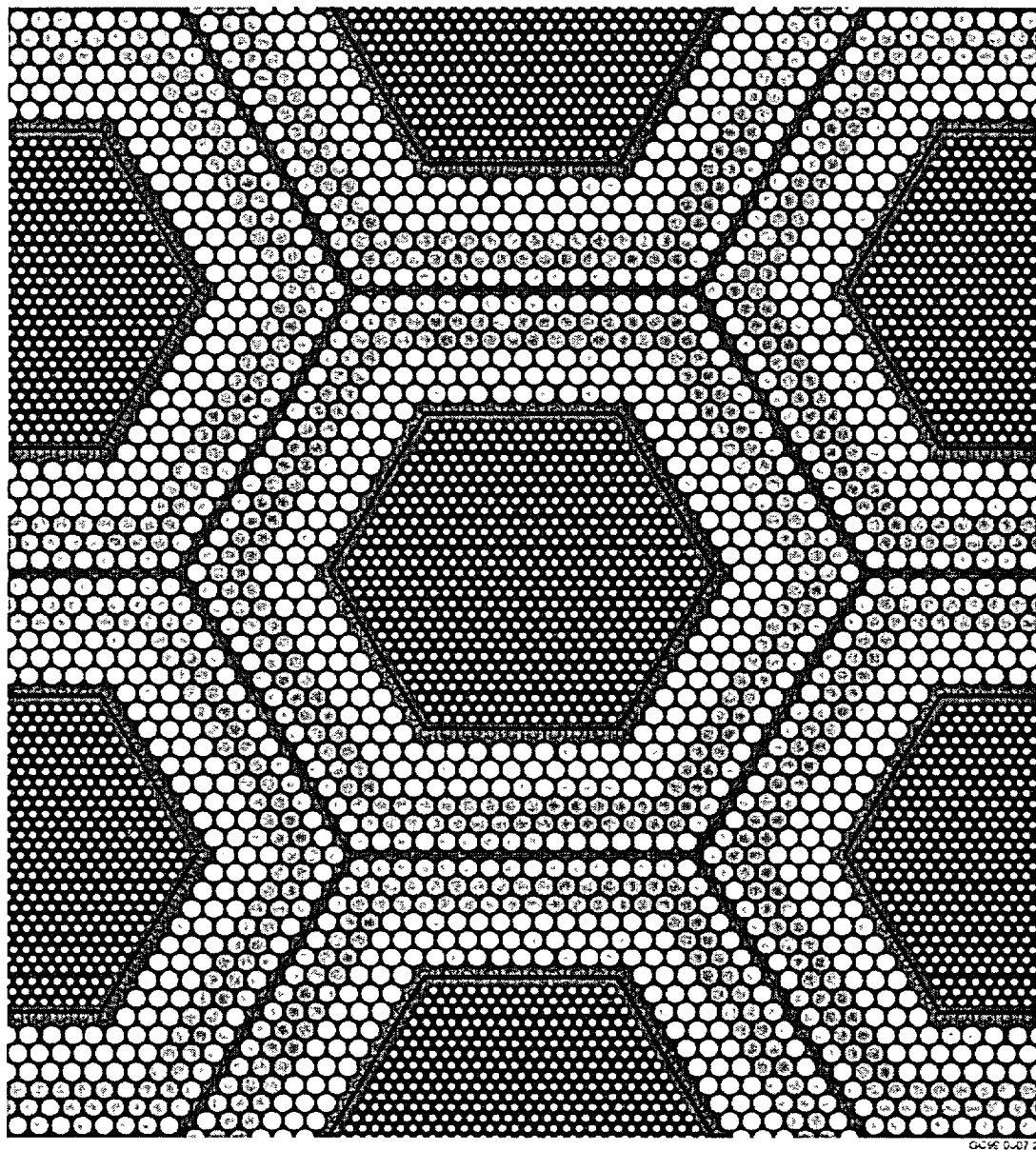


Figure 1. Infinite lattice model representation (MCNP) of the LWBR seed/standard blanket modules.

Table 1. Zircaloy-4 and UO₂-ThO₂ material constituent and impurity concentrations.

Constituent or Impurity	Zircaloy-4 Concentration (wt%)	UO ₂ -ThO ₂ Concentration (ppm)
H	0.002497	
B	0.00005	1
C	0.026968	200
N	0.00799	50
O	0.094887	134454
Mg		100
Al	0.007491	500
Si	0.011986	300
P	0.009988	
S	0.003496	
Cl		15
Ca		20
Ti	0.004994	20
V	0.004994	25
Cr	0.124851	100
Mn	0.004994	10
Fe	0.224731	300
Co	0.001998	10
Ni	0.006992	200
Cu	0.004994	40
Zn	0.009988	
Zr	97.789992	
Nb	0.006992	
Mo	0.004994	100
Cd	0.000050	
Sn	1.598089	
Sm	0.000999	
Gd	0.000499	
Hf	0.003496	
Ta	0.019976	
W	0.009988	
Hg		1
Pb	0.009988	
Th	0.000699	
U	0.000350	

Table 2. Light Water Breeder Reactor seed module power history.

Operating Start Date	Operating End Date	Operational (days)	Cumulative Operating (days)	Seed Module Power (MW _{th})	Cumulative Burnup (MWD)
26-Aug-77	30-Sep-77	35	35	2.731274	95.59
30-Sep-77	31-Dec-77	92	127	5.971203	644.95
31-Dec-77	31-Mar-78	90	217	7.897081	1355.68
31-Mar-78	30-Jun-78	91	308	5.969611	1898.92
30-Jun-78	30-Sep-78	92	400	6.767031	2521.48
30-Sep-78	31-Dec-78	92	492	7.217013	3185.45
31-Dec-78	31-Mar-79	90	582	7.549443	3864.90
31-Mar-79	30-Jun-79	91	673	0.000000	3864.90
30-Jun-79	30-Sep-79	92	765	5.202659	4343.54
30-Sep-79	31-Dec-79	92	857	6.666736	4956.88
31-Dec-79	31-Mar-80	91	948	5.068303	5418.10
31-Mar-80	30-Jun-80	91	1039	5.999137	5964.02
30-Jun-80	30-Sep-80	92	1131	6.289765	6542.68
30-Sep-80	31-Dec-80	92	1223	2.911629	6810.55
31-Dec-80	31-Mar-81	90	1313	6.354118	7382.42
31-Mar-81	30-Jun-81	91	1404	3.731881	7722.02
30-Jun-81	30-Sep-81	92	1496	6.338568	8305.17
30-Sep-81	31-Dec-81	92	1588	5.039344	8768.79
31-Dec-81	31-Mar-82	90	1678	5.325345	9248.07
31-Mar-82	30-Jun-82	91	1769	5.670859	9764.12
30-Jun-82	30-Sep-82	92	1861	5.467423	10267.12
30-Sep-82	2-Dec-82	63	1924	0.031986	10269.14
2-Dec-82	2-Dec-87	1826.25	3750.25	0	10269.14
2-Dec-87	2-Dec-92	1826.25	5576.50	0	10269.14
2-Dec-92	2-Dec-97	1826.25	7402.75	0	10269.14
2-Dec-97	2-Dec-02	1826.25	9229.00	0	10269.14
2-Dec-02	2-Dec-07	1826.25	11055.25	0	10269.14
2-Dec-07	2-Dec-17	3652.50	14707.75	0	10269.14
2-Dec-17	2-Dec-32	5478.75	20186.50	0	10269.14
2-Dec-32	2-Dec-47	5478.75	25665.25	0	10269.14
2-Dec-47	2-Dec-62	5478.75	31144.00	0	10269.14
2-Dec-62	2-Dec-82	7305.00	38449.00	0	10269.14

The ten dates with zero associated power represent the ten different cooling or decay dates after exposure or post-December 1982. These ten dates are specifically the 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling times designated for the template methodology.

Zircaloy Cladding, 60 to 100% Enriched U-233 Fuel

Reactor Moderator/Coolant:	Light Water
Fuel Meat:	UO ₂ -ThO ₂ (Urania-Thoria)
Clad:	Zircaloy-4
Burnup:	10,269.14 MWD
Burnup:	27, 749.70 MWD/MTHM
Basis of Calculation:	Single seed module
BOL U-233	16,877.36 g U-233 per seed module
BOL U-234	221.64 g U-234 per seed module
BOL U-235:	15.46 g U-235 per seed module
BOL U-236	3.44 g U-236 per seed module
BOL U-238:	63.57 g U-238 per seed module
BOL Th-232:	442,731.04 g Th-232 per seed module
BOL Fuel Enrichment:	98.23 wt% U-233

(Activities* in Ci/seed module)

[illegible]

DECAY TIMES (years out of core)
(Activities* in Ci/seed module)

Radionuclide	5	10	15	20	25	35	50	65	80	100
SR 89	1.585E-06	2.057E-17	2.670E-28	3.466E-39	4.498E-50	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 90	3.131E+04	2.779E+04	2.468E+04	2.191E+04	1.945E+04	1.533E+04	1.073E+04	7.506E+03	5.252E+03	3.263E+03
Y 90	3.131E+04	2.780E+04	2.468E+04	2.191E+04	1.945E+04	1.533E+04	1.073E+04	7.508E+03	5.254E+03	3.264E+03
Y 91	5.778E-05	2.319E-14	9.310E-24	3.737E-33	1.500E-42	2.417E-61	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 93	8.719E-01	8.719E-01	8.719E-01	8.719E-01	8.719E-01	8.719E-01	8.718E-01	8.718E-01	8.718E-01	8.718E-01
ZR 95	4.013E-04	1.026E-12	2.621E-21	6.701E-30	1.713E-38	1.119E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 93M	2.721E-01	3.972E-01	4.942E-01	5.693E-01	6.275E-01	7.077E-01	7.721E-01	8.021E-01	8.161E-01	8.239E-01
NB 94	2.796E-02	2.795E-02	2.795E-02	2.795E-02	2.794E-02	2.793E-02	2.792E-02	2.790E-02	2.789E-02	2.787E-02
NB 95	8.908E-04	2.277E-12	5.821E-21	1.487E-29	3.803E-38	2.485E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 95M	2.976E-06	7.608E-15	1.945E-23	4.970E-32	1.271E-40	8.302E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO 93	4.334E-03	4.330E-03	4.325E-03	4.321E-03	4.317E-03	4.308E-03	4.295E-03	4.283E-03	4.270E-03	4.253E-03
TC 99	3.341E+00	3.341E+00	3.341E+00	3.341E+00	3.341E+00	3.340E+00	3.340E+00	3.340E+00	3.340E+00	3.340E+00
RU103	2.716E-10	2.748E-24	2.780E-38	2.812E-52	2.845E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU106	3.759E+02	1.207E+01	3.879E-01	1.246E-02	4.002E-04	4.129E-07	1.368E-11	4.535E-16	1.503E-20	1.600E-26
RH103M	2.449E-10	2.477E-24	2.506E-38	2.535E-52	2.565E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH106	3.759E+02	1.207E+01	3.879E-01	1.246E-02	4.002E-04	4.129E-07	1.368E-11	4.535E-16	1.503E-20	1.600E-26
PD107	3.543E-03	3.543E-03	3.543E-03	3.543E-03	3.543E-03	3.543E-03	3.543E-03	3.543E-03	3.543E-03	3.543E-03
AG110	7.814E-03	4.930E-05	3.110E-07	1.962E-09	1.238E-11	4.927E-16	1.237E-22	3.107E-29	7.802E-36	1.236E-44
AG110M	5.875E-01	3.707E-03	2.338E-05	1.475E-07	9.308E-10	3.705E-14	9.303E-21	2.336E-27	5.866E-34	9.294E-43
AG111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD113M	3.574E+00	2.818E+00	2.222E+00	1.752E+00	1.382E+00	8.592E-01	4.213E-01	2.066E-01	1.013E-01	3.917E-02
CD113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD115M	1.621E-11	7.620E-24	3.582E-36	1.684E-48	7.918E-61	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114	7.035E-11	5.548E-22	4.377E-33	3.452E-44	2.723E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114M	7.351E-11	5.798E-22	4.573E-33	3.607E-44	2.845E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN115M	1.138E-15	5.352E-28	2.516E-40	1.183E-52	5.562E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN119M	1.551E+01	8.850E-02	5.048E-04	2.881E-06	1.643E-08	5.351E-13	9.939E-20	1.846E-26	3.429E-33	3.634E-42
SN121M	6.553E-01	6.114E-01	5.704E-01	5.322E-01	4.966E-01	4.322E-01	3.511E-01	2.851E-01	2.316E-01	1.755E-01
SN123	2.416E-02	1.339E-06	7.425E-11	4.117E-15	2.282E-19	7.015E-28	1.195E-40	2.036E-53	3.471E-66	3.279E-83
SN125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN126	4.093E-01	4.092E-01	4.092E-01	4.092E-01	4.092E-01	4.092E-01	4.091E-01	4.091E-01	4.090E-01	4.090E-01
SB124	7.506E-08	5.531E-17	4.075E-26	3.002E-35	2.212E-44	1.201E-62	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB125	1.521E+03	4.351E+02	1.245E+02	3.562E+01	1.019E+01	8.347E-01	1.956E-02	4.583E-04	1.074E-05	7.200E-08

DECAY TIMES (years out of core)

(Activities* in Ci/seed module)

Radionuclide	5	10	15	20	25	35	50	65	80	100
SB126	5.730E-02	5.729E-02	5.729E-02	5.729E-02	5.729E-02	5.728E-02	5.728E-02	5.727E-02	5.727E-02	5.726E-02
SB126M	4.093E-01	4.092E-01	4.092E-01	4.092E-01	4.092E-01	4.092E-01	4.091E-01	4.091E-01	4.090E-01	4.090E-01
TE123M	7.010E-05	1.786E-09	4.553E-14	1.160E-18	2.958E-23	1.921E-32	3.180E-46	5.263E-60	8.712E-74	3.676E-92
TE125M	3.710E+02	1.062E+02	3.038E+01	8.692E+00	2.487E+00	2.036E-01	4.772E-03	1.118E-04	2.619E-06	1.756E-08
TE127	2.778E-02	2.514E-07	2.275E-12	2.058E-17	1.862E-22	1.525E-32	1.130E-47	8.370E-63	6.201E-78	4.157E-98
TE127M	2.836E-02	2.566E-07	2.322E-12	2.101E-17	1.901E-22	1.557E-32	1.153E-47	8.545E-63	6.331E-78	4.244E-98
TE129	1.088E-13	4.728E-30	2.054E-46	8.927E-63	3.879E-79	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE129M	1.672E-13	7.264E-30	3.156E-46	1.371E-62	5.958E-79	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I129	1.628E-02	1.628E-02	1.628E-02	1.628E-02	1.628E-02	1.628E-02	1.628E-02	1.628E-02	1.628E-02	1.628E-02
I131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS134	6.303E+03	1.174E+03	2.186E+02	4.071E+01	7.581E+00	2.629E-01	1.698E-03	1.096E-05	7.081E-08	8.516E-11
CS135	2.941E-01	2.941E-01	2.941E-01	2.941E-01	2.941E-01	2.941E-01	2.941E-01	2.941E-01	2.941E-01	2.941E-01
CS136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS137	3.034E+04	2.703E+04	2.408E+04	2.146E+04	1.911E+04	1.517E+04	1.073E+04	7.586E+03	5.364E+03	3.379E+03
BA136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA137M	2.870E+04	2.557E+04	2.278E+04	2.030E+04	1.808E+04	1.435E+04	1.015E+04	7.176E+03	5.074E+03	3.196E+03
BA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE141	1.005E-12	1.238E-29	1.525E-46	1.878E-63	2.313E-80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE142	1.019E-05	1.019E-05	1.019E-05	1.019E-05	1.019E-05	1.019E-05	1.019E-05	1.019E-05	1.019E-05	1.019E-05
CE144	2.107E+03	2.453E+01	2.855E-01	3.324E-03	3.870E-05	5.244E-09	8.274E-15	1.305E-20	2.059E-26	3.782E-34
PR143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR144	2.107E+03	2.453E+01	2.855E-01	3.324E-03	3.870E-05	5.244E-09	8.274E-15	1.305E-20	2.059E-26	3.782E-34
PR144M	2.528E+01	2.943E-01	3.427E-03	3.989E-05	4.644E-07	6.293E-11	9.929E-17	1.566E-22	2.471E-28	4.539E-36
ND144	4.212E-10	4.220E-10	4.220E-10	4.220E-10	4.220E-10	4.220E-10	4.220E-10	4.220E-10	4.220E-10	4.220E-10
ND147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM145	1.075E-02	8.903E-03	7.322E-03	6.020E-03	4.949E-03	3.346E-03	1.859E-03	1.033E-03	5.744E-04	2.625E-04
PM147	7.457E+03	1.990E+03	5.310E+02	1.417E+02	3.781E+01	2.693E+00	5.117E-02	9.724E-04	1.848E-05	9.370E-08
PM148M	2.200E-10	1.071E-23	5.217E-37	2.541E-50	1.237E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM148	1.239E-11	6.034E-25	2.939E-38	1.431E-51	6.969E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM145	1.466E-03	3.543E-05	8.563E-07	2.070E-08	5.003E-10	2.923E-13	4.127E-18	5.828E-23	8.230E-28	2.809E-34

(Activities* in Ci/seed module)

Radionuclide	5	10	15	20	25	35	50	65	80	100
SM147	1.120E-06	1.254E-06	1.290E-06	1.300E-06	1.302E-06	1.303E-06	1.303E-06	1.303E-06	1.303E-06	1.303E-06
SM151	1.402E+02	1.349E+02	1.298E+02	1.249E+02	1.202E+02	1.113E+02	9.918E+01	8.836E+01	7.872E+01	6.748E+01
EU152	2.065E+00	1.600E+00	1.240E+00	9.612E-01	7.450E-01	4.475E-01	2.084E-01	9.700E-02	4.516E-02	1.630E-02
EU154	9.913E+02	6.625E+02	4.428E+02	2.960E+02	1.978E+02	8.834E+01	2.637E+01	7.872E+00	2.350E+00	4.688E-01
EU155	4.493E+02	2.234E+02	1.111E+02	5.520E+01	2.744E+01	6.784E+00	8.336E-01	1.024E-01	1.258E-02	7.689E-04
EU156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD153	2.054E-01	1.099E-03	5.879E-06	3.146E-08	1.683E-10	4.818E-15	7.382E-22	1.131E-28	1.732E-35	1.419E-44
TB160	3.487E-07	8.690E-15	2.166E-22	5.396E-30	1.345E-37	8.349E-53	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL206	1.518E-12	1.518E-12	1.518E-12	1.518E-12	1.518E-12	1.518E-12	1.518E-12	1.518E-12	1.518E-12	1.518E-12
TL207	2.525E-01	3.969E-01	5.200E-01	6.249E-01	7.144E-01	8.555E-01	9.982E-01	1.087E+00	1.142E+00	1.183E+00
TL208	1.723E+02	1.794E+02	1.734E+02	1.657E+02	1.580E+02	1.434E+02	1.241E+02	1.074E+02	9.297E+01	7.675E+01
PB210	1.657E-04	1.471E-04	1.338E-04	1.252E-04	1.208E-04	1.226E-04	1.463E-04	1.892E-04	2.466E-04	3.410E-04
PB211	2.532E-01	3.980E-01	5.214E-01	6.267E-01	7.164E-01	8.579E-01	1.001E+00	1.090E+00	1.145E+00	1.187E+00
PB212	4.795E+02	4.993E+02	4.827E+02	4.612E+02	4.397E+02	3.991E+02	3.454E+02	2.989E+02	2.587E+02	2.136E+02
BI211	2.532E-01	3.980E-01	5.214E-01	6.267E-01	7.164E-01	8.579E-01	1.001E+00	1.090E+00	1.145E+00	1.187E+00
BI212	4.795E+02	4.993E+02	4.827E+02	4.612E+02	4.397E+02	3.991E+02	3.454E+02	2.989E+02	2.587E+02	2.136E+02
PO212	3.072E+02	3.199E+02	3.093E+02	2.955E+02	2.817E+02	2.557E+02	2.213E+02	1.915E+02	1.658E+02	1.369E+02
PO215	2.532E-01	3.980E-01	5.214E-01	6.267E-01	7.164E-01	8.579E-01	1.001E+00	1.090E+00	1.145E+00	1.187E+00
PO216	4.795E+02	4.993E+02	4.827E+02	4.612E+02	4.397E+02	3.991E+02	3.454E+02	2.989E+02	2.587E+02	2.136E+02
RN219	2.532E-01	3.980E-01	5.214E-01	6.267E-01	7.164E-01	8.579E-01	1.001E+00	1.090E+00	1.145E+00	1.187E+00
RN220	4.795E+02	4.993E+02	4.827E+02	4.612E+02	4.397E+02	3.991E+02	3.454E+02	2.989E+02	2.587E+02	2.136E+02
FR223	3.492E-03	5.485E-03	7.185E-03	8.634E-03	9.870E-03	1.182E-02	1.380E-02	1.502E-02	1.578E-02	1.636E-02
RA223	2.532E-01	3.980E-01	5.214E-01	6.267E-01	7.164E-01	8.579E-01	1.001E+00	1.090E+00	1.145E+00	1.187E+00
RA224	4.795E+02	4.993E+02	4.827E+02	4.612E+02	4.397E+02	3.991E+02	3.454E+02	2.989E+02	2.587E+02	2.136E+02
RA226	2.659E-05	4.499E-05	6.416E-05	8.411E-05	1.048E-04	1.486E-04	2.200E-04	2.982E-04	3.833E-04	5.073E-04
RA228	3.075E-02	3.757E-02	4.163E-02	4.406E-02	4.550E-02	4.688E-02	4.748E-02	4.760E-02	4.763E-02	4.764E-02
AC227	2.530E-01	3.975E-01	5.206E-01	6.257E-01	7.152E-01	8.567E-01	9.998E-01	1.088E+00	1.143E+00	1.185E+00
TH227	2.497E-01	3.925E-01	5.142E-01	6.181E-01	7.066E-01	8.460E-01	9.872E-01	1.075E+00	1.129E+00	1.170E+00
TH228	4.793E+02	4.989E+02	4.823E+02	4.608E+02	4.393E+02	3.990E+02	3.454E+02	2.989E+02	2.587E+02	2.136E+02
TH229	1.158E-01	1.768E-01	2.377E-01	2.986E-01	3.594E-01	4.810E-01	6.632E-01	8.452E-01	1.027E+00	1.269E+00
TH230	8.339E-03	8.716E-03	9.094E-03	9.471E-03	9.849E-03	1.060E-02	1.174E-02	1.287E-02	1.400E-02	1.551E-02
TH231	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04
TH232	4.764E-02	4.764E-02	4.764E-02	4.764E-02	4.764E-02	4.764E-02	4.764E-02	4.764E-02	4.764E-02	4.764E-02

DECAY TIMES (years out of core)
(Activities* in Ci/seed module)

Radionuclide	5	10	15	20	25	35	50	65	80	100
TH234	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05
PA231	1.235E+00	1.235E+00	1.234E+00	1.234E+00	1.234E+00	1.234E+00	1.233E+00	1.233E+00	1.233E+00	1.232E+00
PA233	1.268E-03	1.269E-03	1.272E-03	1.274E-03	1.278E-03	1.285E-03	1.296E-03	1.309E-03	1.321E-03	1.338E-03
PA234M	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05
PA234	2.362E-08	2.362E-08	2.362E-08	2.362E-08	2.362E-08	2.362E-08	2.362E-08	2.362E-08	2.362E-08	2.362E-08
U232	5.184E+02	4.941E+02	4.708E+02	4.487E+02	4.276E+02	3.884E+02	3.361E+02	2.909E+02	2.518E+02	2.077E+02
U233	1.292E+02	1.292E+02	1.292E+02	1.292E+02	1.292E+02	1.292E+02	1.292E+02	1.292E+02	1.292E+02	1.292E+02
U234	8.398E+00	8.397E+00	8.397E+00	8.397E+00	8.397E+00	8.397E+00	8.397E+00	8.397E+00	8.397E+00	8.396E+00
U235	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04	6.271E-04
U236	1.363E-03	1.363E-03	1.363E-03	1.363E-03	1.363E-03	1.363E-03	1.363E-03	1.363E-03	1.363E-03	1.363E-03
U237	1.569E-05	1.233E-05	9.694E-06	7.621E-06	5.990E-06	3.702E-06	1.798E-06	8.734E-07	4.243E-07	1.620E-07
U238	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05	1.817E-05
NP237	1.268E-03	1.269E-03	1.272E-03	1.274E-03	1.278E-03	1.285E-03	1.296E-03	1.309E-03	1.321E-03	1.338E-03
PU236	1.673E-04	4.960E-05	1.471E-05	4.364E-06	1.296E-06	1.164E-07	5.678E-09	2.791E-09	2.715E-09	2.713E-09
PU237	1.720E-15	1.512E-27	1.329E-39	1.168E-51	1.026E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU238	5.525E+00	5.311E+00	5.106E+00	4.909E+00	4.719E+00	4.362E+00	3.876E+00	3.444E+00	3.060E+00	2.615E+00
PU239	2.829E-01	2.828E-01	2.828E-01	2.828E-01	2.827E-01	2.826E-01	2.825E-01	2.824E-01	2.823E-01	2.821E-01
PU240	1.658E-01	1.660E-01	1.661E-01	1.661E-01	1.662E-01	1.662E-01	1.661E-01	1.659E-01	1.657E-01	1.654E-01
PU241	6.395E+01	5.027E+01	3.952E+01	3.106E+01	2.442E+01	1.509E+01	7.330E+00	3.560E+00	1.729E+00	6.604E-01
PU242	4.191E-04	4.191E-04	4.191E-04	4.191E-04	4.192E-04	4.192E-04	4.193E-04	4.193E-04	4.194E-04	4.194E-04
PU244	5.399E-11	5.399E-11	5.399E-11	5.399E-11	5.399E-11	5.399E-11	5.399E-11	5.399E-11	5.399E-11	5.399E-11
AM241	7.541E-01	1.202E+00	1.549E+00	1.817E+00	2.023E+00	2.299E+00	2.500E+00	2.564E+00	2.563E+00	2.517E+00
AM242M	1.745E-02	1.706E-02	1.668E-02	1.630E-02	1.593E-02	1.522E-02	1.422E-02	1.328E-02	1.240E-02	1.132E-02
AM242	1.737E-02	1.698E-02	1.659E-02	1.622E-02	1.585E-02	1.515E-02	1.415E-02	1.321E-02	1.234E-02	1.126E-02
AM243	3.208E-03	3.206E-03	3.205E-03	3.203E-03	3.202E-03	3.199E-03	3.194E-03	3.190E-03	3.185E-03	3.179E-03
CM242	2.021E-02	1.405E-02	1.373E-02	1.342E-02	1.312E-02	1.253E-02	1.170E-02	1.092E-02	1.020E-02	9.313E-03
CM243	6.518E-03	5.772E-03	5.111E-03	4.525E-03	4.007E-03	3.142E-03	2.182E-03	1.515E-03	1.052E-03	6.467E-04
CM244	4.580E-01	3.782E-01	3.123E-01	2.579E-01	2.130E-01	1.453E-01	8.181E-02	4.608E-02	2.595E-02	1.207E-02

DECAY TIMES (years out of core)
(Activities* in Ci/seed module)

Radionuclide	5	10	15	20	25	35	50	65	80	100
CM245	7.162E-05	7.159E-05	7.157E-05	7.154E-05	7.151E-05	7.145E-05	7.136E-05	7.127E-05	7.119E-05	7.107E-05
CM246	4.751E-06	4.747E-06	4.744E-06	4.741E-06	4.737E-06	4.730E-06	4.720E-06	4.709E-06	4.699E-06	4.685E-06
CM247	1.677E-11	1.677E-11	1.677E-11	1.677E-11	1.677E-11	1.677E-11	1.677E-11	1.677E-11	1.677E-11	1.677E-11
Subtotal**	1.531E+05	1.208E+05	1.044E+05	9.197E+04	8.149E+04	6.443E+04	4.565E+04	3.252E+04	2.329E+04	1.505E+04
Total***	1.531E+05	1.208E+05	1.044E+05	9.197E+04	8.151E+04	6.444E+04	4.565E+04	3.253E+04	2.330E+04	1.506E+04

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 24

Fuel-Specific Source Term Calculations Pressurized Water Reactor Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a generic source term for pressurized water reactor (PWR) or low-enriched uranium oxide spent nuclear fuel. The data sources for the analysis are documented in References 1 and 2, and the INEEL calculational methodology is described in detail in Reference 3.

Pressurized Water Reactor Data

PWR characteristics are based on the Westinghouse PWR 17×17 fuel assembly and corresponding fuel rod dimensions and materials (Reference 1).

The uranium enrichment is chosen to be 3.2 wt% U-235. In addition, small amounts of U-234 and U-236 impurities are also included in the beginning-of-life (BOL) uranium composition in order to maximize and account for production of other actinides.

The cladding material is assumed to be Zircaloy-4. Assembly structural hardware, including the spacers and top and bottom tie grids, is also included in the activation analysis. The spacers are composed of Zircaloy-4 and Inconel-718 pieces. The top and bottom tie grids are stainless steel-304 (SS304). The total assembly spacer and grid masses are based on estimates found in Reference 2 data for a 15×15 PWR assembly. The assumption here is that the 15×15 hardware or structural materials are the same and of similar mass to those expected for a 17×17 assembly. The 15×15 assembly hardware total masses are then divided by 289 (17×17) in order to get the associated structural masses per rod for the 17×17 assembly. The mass basis for the PWR template here is a single fuel rod from a 17×17 assembly. Table 1 lists the impurities and their concentrations for the materials considered in the depletion/activation analysis, namely, UO_2 , Zircaloy-4, Inconel-718, and SS-304.

The data below give specific dimensions, materials, loadings, densities, enrichment, etc., for the PWR fuel rod used in the burnup calculation for the source term generation.

Fuel Element:	Single rod in a 17×17 assembly
Pitch:	1.25 cm
Fuel Pellet Diameter:	0.819 cm
Gas Gap Thickness:	0.0082 cm
Clad Thickness:	0.0572 cm
Fuel Meat:	UO_2 3.2 wt% U-235 enrichment (BOL) Average Density = 10.412 g/cc
Clad:	Zircaloy-4 Density = 6.44 g/cc

Loading:	56.61	g/rod	U-235 (BOL)
	1,711.63	g/rod	U-238 (BOL)
	0.70	g/rod	U-234 (BOL)
	0.17	g/rod	U-236 (BOL)
	1,769.11	g/rod	TOTAL U
	2,006.26	g/rod	UO ₂ (fuel meat)
	1.7691E-3	MTU/rod	

Active Fuel Length:	144.0 in.
Fuel Rod Length:	168.0 in.

Assembly Structural Material/Masses:

456.40	g/rod	Zircaloy-4 (clad + spacer)
2.20	g/rod	Inconel-718 (spacer material)
62.78	g/rod	SS-304 (top/bottom tie grid plates)

Coolant/Moderator:	Light Water
Coolant Temperature:	600°F
Coolant Pressure:	2250 psi
Coolant Density:	0.6965 g/cc

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for all the material components in a single PWR fuel rod. Impurities in these materials were also included in the ORIGEN2 (Reference 4) depletion calculation in order to maximize the induced activation (see Table 1).

Burnup

The burnup chosen for this template is 35,000 MWd/MTU or 61.92 MWd for the single rod containing 1.7691E-3 MTU. The burnup period is assumed to be continuous over a 3-year period or 1,096 days. The fuel rod operates at a constant power over the burnup period with no refueling shutdowns. The relatively high burnup (35,000 MWd/MTU) is conservative for the buildup of fission products, activation products, and minor actinides in the source term and nonconservative with regard to criticality safety (i.e., fissile isotope concentrations, in particular U-235).

Cross-Section Development

The neutron cross sections used in the burnup or depletion calculation for the source term generation of a single PWR fuel rod are based on the methodology described in Reference 3. Cross sections from a standard ORIGEN2 PWR library were updated six times over the 3-year burnup period to ensure accurate production and activity levels for actinides, fission products, and activation products. The first update developed cross sections for BOL conditions followed by five subsequent updates every 180-days of fuel rod exposure. These cross-section updates take into account changes in the neutron flux spectrum and spatial profiles as a function of burnup. A simple PWR unit cell lattice was used to determine volume-averaged flux and reaction rate profiles for the cross-section development. The basic library updated was a standard ORIGEN2 PWR cross-section library.

Pressurized Water Reactor Single Rod Exposure History

Table 2 summarizes the hypothetical power or exposure history used in the burnup calculations for a single PWR fuel rod in a 17×17 PWR assembly. No refueling shutdowns are assumed in the calculation. Following the 3-year exposure, the radionuclide activities are decayed for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100 years. The relatively high burnup is conservative for the buildup of fission products, activation products, and minor actinides in the source term and nonconservative with regard to criticality safety. The 35,000 MWd/MTU exposure or burnup for the fuel is again relatively high and represents an upper burnup limit for most commercial spent nuclear fuels stored at the INEEL.

Burnup Calculation

The ORIGEN2 computer code was used to perform the depletion or burnup calculation for the PWR fuel rod. The radionuclide inventory or source term template that follows is for a single PWR 17×17 fuel rod. The fuel rod component masses and impurities (fuel meat, uranium, clad, spacers, and end fixtures), neutron cross sections, burnup, and hypothetical power history and power level as presented above are used as input data for the ORIGEN2 calculation. The radionuclide concentrations are given as a function of decay time in the template table.

The 145 radionuclides listed in the template here represent greater than 99.9% of the total curie inventory relative to the 684 activation products, 880 fission products, and 127 actinide/daughter isotopes in the complete ORIGEN2 output.

References

1. J. J. Duderstadt and L. J. Hamilton, *Nuclear Reactor Analysis*, Appendix H, John Wiley & Sons, Inc., New York, 1976.
2. R. K. McCardell, *Characteristics of Commercial Nuclear Materials Stored in the TAN Pool*, INEL/INT-98-00767, September 1998.
3. J. W. Sterbentz and C. A. Wemple, *Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels*, INEL-96/0304, September 1996.
4. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.

Table 1. Material constituent and impurity concentrations for the various materials in a pressurized water reactor fuel rod/assembly.

Constituent or Impurity	UO2 Concentration (ppm)	Zircaloy-4 Concentration (ppm)	Inconel-718 Concentration (wt%)	Stainless Steel-304 Concentration (ppm)
H		25		
Li	1			0.13
Be				
B	1	0.5		
C	89.4	270	0.08	0.08 wt%
N	25	80		525
O	134454	950		
F	10.7			
Na	15			37
Mg	2			
Al	16.7	75	0.70	200
Si	12.1	120	0.70	1.00 wt%
P	35	100		
S		35	0.01	
Cl	5.3			130
K				3
Ca	2			19
Sc				0.03
Ti	1	50	2.30	600
V	3	50		690
Cr	4	1250	15.50	18.40 wt%
Mn	1.7	50	1.00	1.53 wt%
Fe	18	2250	5.90	68.99 wt%
Co	1	20	0.006488	2570
Ni	24	70	73.304	10.00 wt%
Cu	1	50	0.50	8150
Zn	40.3	100		2230
Ga				450
As				1010
Se				70
Br				8
Rb				10
Sr				0.2
Y				5
Zr		979069		20
Nb		70		300

Constituent or Impurity	UO ₂ Concentration (ppm)	Zircaloy-4 Concentration (ppm)	Inconel-718 Concentration (wt%)	Stainless Steel-304 Concentration (ppm)
Mo	10	50		5500
Ag	0.1			2
Cd	25	0.5		
In	2			
Sn	4	16000		
Sb				17
Cs				0.3
Ba				500
La				2.1
Ce				550
Pr				
Nd				
Sm		10		0.15
Eu				0.02
Gd		5		
Tb				0.71
Dy				1
Ho				1
Er				
Tm				
Yb				2
Lu				0.8
Hf		35		2
Ta		200		
W	2	100		520
Tl				
Pb	1	100		139
Bi	0.4			
Th		7		1
U	1000000	3.5		2

Table 2. Hypothetical power history for a 35,000 MWd/MTU burnup PWR fuel rod.

Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MWth)
180	180	0.0565
180	360	0.0565
180	540	0.0565
180	720	0.0565
180	900	0.0565
196	1096	0.0565
1825	2921	0.0
1825	4746	0.0
1825	6571	0.0
1825	8396	0.0
1825	10221	0.0
3650	13871	0.0
5475	19346	0.0
5475	24821	0.0
5475	30296	0.0
7300	37596	0.0

The ten dates with zero associated power represent the ten different cooling or decay dates after exposure. These ten dates are specifically the 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling or decay times designated for the template methodology.

Zirconium Cladding, 0 to 5% Enriched U-235 Fuel

Reactor Moderator/Coolant:	Light Water
Fuel Meat:	UO ₂
Clad:	Zircaloy-4
Burnup:	35000 MWd/MTU
Burnup:	61.92 MWd/single rod (high burnup)
Burnup:	73.4 % U-235 depletion (fissioned and transmuted)
Basis of Calculation:	Single rod in a 17x17 assembly
BOL U-235:	56.61 g U-235 per rod
BOL U-238:	1711.63 g U-238 per rod
BOL U-234:	0.70 g U-234 per rod
BOL U-236:	0.17 g U-236 per rod
BOL Total U per element:	1769.11 g U per rod
BOL Fuel Enrichment:	3.2 wt% U-235

(Activities* in Ci/rod)

[illegible]

DECAY TIMES (years out of core)
(Activities* in Ci/rod)

Radionuclide	5	10	15	20	25	35	50	65	80	100
ZR-95	6.572E-06	1.702E-14	4.412E-23	1.143E-31	2.961E-40	1.988E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-93M	9.813E-04	1.534E-03	1.962E-03	2.294E-03	2.551E-03	2.905E-03	3.190E-03	3.323E-03	3.384E-03	3.419E-03
NB-94	8.828E-05	8.826E-05	8.825E-05	8.823E-05	8.822E-05	8.819E-05	8.814E-05	8.810E-05	8.805E-05	8.799E-05
NB-95	1.459E-05	3.781E-14	9.795E-23	2.537E-31	6.575E-40	4.414E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-95M	4.875E-08	1.263E-16	3.273E-25	8.480E-34	2.197E-42	1.474E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO-93	2.257E-05	2.255E-05	2.253E-05	2.250E-05	2.248E-05	2.244E-05	2.237E-05	2.230E-05	2.224E-05	2.215E-05
TC-99	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.437E-02	2.436E-02
RU-103	2.668E-11	2.759E-25	2.853E-39	2.951E-53	3.052E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU-106	3.400E+01	1.095E+00	3.525E-02	1.135E-03	3.654E-05	3.787E-08	1.264E-12	4.219E-17	1.408E-21	1.513E-27
RH-103M	2.405E-11	2.487E-25	2.572E-39	2.660E-53	2.751E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH-106	3.400E+01	1.095E+00	3.525E-02	1.135E-03	3.654E-05	3.788E-08	1.264E-12	4.219E-17	1.408E-21	1.513E-27
PD-107	2.296E-04	2.296E-04	2.296E-04	2.296E-04	2.296E-04	2.296E-04	2.296E-04	2.296E-04	2.296E-04	2.296E-04
AG-110	8.434E-04	5.339E-06	3.380E-08	2.140E-10	1.355E-12	5.430E-17	1.378E-23	3.496E-30	8.870E-37	1.425E-45
AG-110M	6.342E-02	4.014E-04	2.541E-06	1.609E-08	1.019E-10	4.082E-15	1.036E-21	2.628E-28	6.670E-35	1.072E-43
AG-111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-113M	9.764E-02	7.701E-02	6.073E-02	4.790E-02	3.778E-02	2.350E-02	1.153E-02	5.655E-03	2.774E-03	1.073E-03
CD-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-115M	1.632E-12	7.823E-25	3.750E-37	1.797E-49	8.618E-62	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114	1.075E-12	8.627E-24	6.924E-35	5.558E-46	4.461E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114M	1.123E-12	9.014E-24	7.236E-35	5.808E-46	4.661E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-115M	1.129E-16	5.412E-29	2.594E-41	1.244E-53	5.961E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-119M	8.362E-02	4.788E-04	2.741E-06	1.570E-08	8.987E-11	2.947E-15	5.532E-22	1.039E-28	1.950E-35	2.096E-44
SN-121M	1.768E-03	1.649E-03	1.539E-03	1.436E-03	1.340E-03	1.167E-03	9.475E-04	7.696E-04	6.252E-04	4.738E-04
SN-123	4.105E-04	2.291E-08	1.279E-12	7.136E-17	3.983E-21	1.241E-29	2.158E-42	3.751E-55	6.522E-68	6.328E-85
SN-125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-126	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.560E-03	1.560E-03	1.560E-03
SB-124	2.599E-09	1.943E-18	1.452E-27	1.085E-36	8.113E-46	4.533E-64	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB-125	9.405E+00	2.694E+00	7.715E-01	2.210E-01	6.328E-02	5.190E-03	1.220E-04	2.864E-06	6.729E-08	4.526E-10
SB-126	2.185E-04	2.185E-04	2.185E-04	2.185E-04	2.185E-04	2.185E-04	2.185E-04	2.185E-04	2.184E-04	2.184E-04
SB-126M	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.561E-03	1.560E-03	1.560E-03	1.560E-03
TE-123M	1.816E-06	4.663E-11	1.197E-15	3.072E-20	7.887E-25	5.197E-34	8.792E-48	1.487E-61	2.516E-75	1.093E-93
TE-125M	2.295E+00	6.572E-01	1.883E-01	5.390E-02	1.544E-02	1.266E-03	2.975E-05	6.988E-07	1.641E-08	1.104E-10
TE-127	2.330E-04	2.125E-09	1.938E-14	1.768E-19	1.613E-24	1.341E-34	1.018E-49	7.723E-65	5.860E-80	4.055E-100
TE-127M	2.379E-04	2.170E-09	1.979E-14	1.805E-19	1.646E-24	1.370E-34	1.039E-49	7.884E-65	5.982E-80	4.140E-100
TE-129	2.279E-15	1.016E-31	4.530E-48	2.020E-64	9.005E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

DECAY TIMES (years out of core)

(Activities* in Ci/rod)

Radionuclide	5	10	15	20	25	35	50	65	80	100
TE-129M	3.501E-15	1.561E-31	6.959E-48	3.103E-64	1.383E-80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I-129	6.086E-05	6.086E-05	6.086E-05	6.086E-05	6.086E-05	6.086E-05	6.086E-05	6.086E-05	6.086E-05	6.086E-05
I-131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-134	5.977E+01	1.114E+01	2.077E+00	3.873E-01	7.221E-02	2.510E-03	1.626E-05	1.054E-07	6.830E-10	8.253E-13
CS-135	8.937E-04	8.937E-04	8.937E-04	8.937E-04	8.937E-04	8.937E-04	8.937E-04	8.937E-04	8.937E-04	8.937E-04
CS-136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-137	1.730E+02	1.542E+02	1.374E+02	1.224E+02	1.090E+02	8.656E+01	6.122E+01	4.330E+01	3.063E+01	1.930E+01
BA-136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA-137M	1.637E+02	1.459E+02	1.300E+02	1.158E+02	1.032E+02	8.189E+01	5.792E+01	4.096E+01	2.897E+01	1.826E+01
BA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-141	3.156E-14	3.992E-31	5.050E-48	6.387E-65	8.078E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-142	5.022E-08	5.022E-08	5.022E-08	5.022E-08	5.022E-08	5.022E-08	5.022E-08	5.022E-08	5.022E-08	5.022E-08
CE-144	2.277E+01	2.659E-01	3.105E-03	3.625E-05	4.233E-07	5.772E-11	9.190E-17	1.463E-22	2.330E-28	4.331E-36
PR-143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR-144	2.277E+01	2.659E-01	3.105E-03	3.625E-05	4.233E-07	5.772E-11	9.190E-17	1.463E-22	2.330E-28	4.331E-36
PR-144M	2.732E-01	3.191E-03	3.726E-05	4.350E-07	5.080E-09	6.926E-13	1.103E-18	1.756E-24	2.796E-30	5.197E-38
ND-144	2.777E-12	2.786E-12	2.786E-12	2.786E-12	2.786E-12	2.786E-12	2.786E-12	2.786E-12	2.786E-12	2.786E-12
ND-147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-145	2.823E-05	2.351E-05	1.934E-05	1.590E-05	1.308E-05	8.843E-06	4.917E-06	2.734E-06	1.520E-06	6.949E-07
PM-147	6.231E+01	1.664E+01	4.445E+00	1.187E+00	3.171E-01	2.262E-02	4.310E-04	8.213E-06	1.565E-07	7.965E-10
PM-148M	3.611E-12	1.796E-25	8.931E-39	4.441E-52	2.209E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-148	2.034E-13	1.011E-26	5.030E-40	2.502E-53	1.244E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM-145	6.700E-06	1.624E-07	3.935E-09	9.534E-11	2.310E-12	1.357E-15	1.931E-20	2.747E-25	3.909E-30	1.348E-36
SM-147	6.632E-09	7.751E-09	8.050E-09	8.130E-09	8.152E-09	8.159E-09	8.159E-09	8.159E-09	8.159E-09	8.159E-09
SM-151	7.859E-01	7.562E-01	7.277E-01	7.002E-01	6.738E-01	6.239E-01	5.558E-01	4.952E-01	4.412E-01	3.783E-01
EU-152	8.270E-03	6.411E-03	4.970E-03	3.852E-03	2.987E-03	1.794E-03	8.359E-04	3.894E-04	1.814E-04	6.550E-05
EU-154	1.401E+01	9.366E+00	6.261E+00	4.186E+00	2.799E+00	1.251E+00	3.735E-01	1.116E-01	3.334E-02	6.659E-03
EU-155	7.232E+00	3.597E+00	1.789E+00	8.900E-01	4.426E-01	1.095E-01	1.348E-02	1.659E-03	2.041E-04	1.249E-05
EU-156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD-153	8.191E-04	4.398E-06	2.361E-08	1.268E-10	6.810E-13	1.964E-17	3.041E-24	4.708E-31	7.290E-38	6.062E-47
TB-160	5.592E-08	1.410E-15	3.557E-23	8.970E-31	2.262E-38	1.439E-53	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL-206	3.867E-11	3.867E-11	3.867E-11	3.867E-11	3.867E-11	3.867E-11	3.867E-11	3.867E-11	3.867E-11	3.867E-11

DECAY TIMES (years out of core) (Activities* in Ci/rod)										
Radionuclide	5	10	15	20	25	35	50	65	80	100
TL-207	8.190E-09	1.456E-08	2.049E-08	2.606E-08	3.131E-08	4.104E-08	5.424E-08	6.635E-08	7.778E-08	9.236E-08
TL-208	9.550E-06	1.217E-05	1.263E-05	1.237E-05	1.189E-05	1.082E-05	9.372E-06	8.113E-06	7.023E-06	5.799E-06
PB-210	2.969E-11	1.006E-10	2.493E-10	5.007E-10	8.770E-10	2.082E-09	5.268E-09	1.042E-08	1.783E-08	3.158E-08
PB-211	8.213E-09	1.460E-08	2.055E-08	2.613E-08	3.140E-08	4.116E-08	5.439E-08	6.654E-08	7.800E-08	9.262E-08
PB-212	2.658E-05	3.388E-05	3.516E-05	3.442E-05	3.308E-05	3.013E-05	2.609E-05	2.258E-05	1.955E-05	1.614E-05
BI-211	8.213E-09	1.460E-08	2.055E-08	2.613E-08	3.140E-08	4.116E-08	5.439E-08	6.654E-08	7.800E-08	9.262E-08
BI-212	2.658E-05	3.388E-05	3.516E-05	3.442E-05	3.308E-05	3.013E-05	2.609E-05	2.258E-05	1.955E-05	1.614E-05
PO-212	1.703E-05	2.171E-05	2.253E-05	2.205E-05	2.119E-05	1.930E-05	1.671E-05	1.447E-05	1.252E-05	1.034E-05
PO-215	8.213E-09	1.460E-08	2.055E-08	2.613E-08	3.140E-08	4.116E-08	5.439E-08	6.654E-08	7.800E-08	9.262E-08
PO-216	2.658E-05	3.388E-05	3.516E-05	3.442E-05	3.308E-05	3.013E-05	2.609E-05	2.258E-05	1.955E-05	1.614E-05
RN-219	8.213E-09	1.460E-08	2.055E-08	2.613E-08	3.140E-08	4.116E-08	5.439E-08	6.654E-08	7.800E-08	9.262E-08
RN-220	2.658E-05	3.388E-05	3.516E-05	3.442E-05	3.308E-05	3.013E-05	2.609E-05	2.258E-05	1.955E-05	1.614E-05
FR-223	1.133E-10	2.012E-10	2.832E-10	3.601E-10	4.326E-10	5.672E-10	7.498E-10	9.172E-10	1.075E-09	1.277E-09
RA-223	8.213E-09	1.460E-08	2.055E-08	2.613E-08	3.140E-08	4.116E-08	5.439E-08	6.654E-08	7.800E-08	9.262E-08
RA-224	2.658E-05	3.388E-05	3.516E-05	3.442E-05	3.308E-05	3.013E-05	2.609E-05	2.258E-05	1.955E-05	1.614E-05
RA-226	2.939E-10	7.807E-10	1.514E-09	2.502E-09	3.750E-09	7.054E-09	1.412E-08	2.384E-08	3.634E-08	5.752E-08
RA-228	1.835E-10	2.414E-10	2.761E-10	2.967E-10	3.091E-10	3.210E-10	3.264E-10	3.279E-10	3.284E-10	3.290E-10
AC-227	8.211E-09	1.458E-08	2.052E-08	2.609E-08	3.135E-08	4.110E-08	5.434E-08	6.646E-08	7.790E-08	9.253E-08
TH-227	8.100E-09	1.440E-08	2.026E-08	2.577E-08	3.097E-08	4.059E-08	5.365E-08	6.562E-08	7.692E-08	9.135E-08
TH-228	2.657E-05	3.386E-05	3.513E-05	3.439E-05	3.305E-05	3.012E-05	2.608E-05	2.258E-05	1.955E-05	1.614E-05
TH-229	1.156E-09	1.833E-09	2.516E-09	3.204E-09	3.899E-09	5.306E-09	7.466E-09	9.687E-09	1.197E-08	1.513E-08
TH-230	1.692E-07	2.821E-07	3.986E-07	5.184E-07	6.416E-07	8.974E-07	1.303E-06	1.732E-06	2.181E-06	2.809E-06
TH-231	3.258E-05	3.259E-05	3.259E-05	3.259E-05	3.260E-05	3.260E-05	3.262E-05	3.263E-05	3.264E-05	3.265E-05
TH-232	3.270E-10	3.271E-10	3.272E-10	3.273E-10	3.275E-10	3.277E-10	3.280E-10	3.284E-10	3.287E-10	3.292E-10
TH-234	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04
PA-231	4.975E-08	5.320E-08	5.664E-08	6.008E-08	6.352E-08	7.040E-08	8.072E-08	9.104E-08	1.014E-07	1.151E-07
PA-233	5.948E-04	6.001E-04	6.078E-04	6.173E-04	6.282E-04	6.530E-04	6.946E-04	7.385E-04	7.830E-04	8.417E-04
PA-234M	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04
PA-234	7.268E-07	7.268E-07	7.268E-07	7.268E-07	7.268E-07	7.268E-07	7.268E-07	7.268E-07	7.268E-07	7.268E-07
U-232	3.362E-05	3.567E-05	3.507E-05	3.374E-05	3.225E-05	2.933E-05	2.539E-05	2.198E-05	1.903E-05	1.570E-05
U-233	1.429E-06	1.442E-06	1.455E-06	1.468E-06	1.482E-06	1.510E-06	1.554E-06	1.601E-06	1.650E-06	1.721E-06
U-234	2.469E-03	2.550E-03	2.628E-03	2.703E-03	2.775E-03	2.911E-03	3.096E-03	3.261E-03	3.407E-03	3.576E-03
U-235	3.258E-05	3.259E-05	3.259E-05	3.259E-05	3.260E-05	3.260E-05	3.262E-05	3.263E-05	3.264E-05	3.265E-05
U-236	4.683E-04	4.684E-04	4.686E-04	4.687E-04	4.688E-04	4.691E-04	4.695E-04	4.699E-04	4.704E-04	4.709E-04
U-237	5.791E-05	4.553E-05	3.580E-05	2.814E-05	2.213E-05	1.368E-05	6.647E-06	3.231E-06	1.570E-06	6.001E-07

DECAY TIMES (years out of core)

(Activities* in Ci/rod)

Radionuclide	5	10	15	20	25	35	50	65	80	100
U-238	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04	5.591E-04
NP-237	5.948E-04	6.001E-04	6.078E-04	6.173E-04	6.282E-04	6.530E-04	6.946E-04	7.385E-04	7.830E-04	8.417E-04
PU-236	1.340E-04	3.977E-05	1.180E-05	3.503E-06	1.041E-06	9.267E-08	3.521E-09	1.190E-09	1.129E-09	1.128E-09
PU-237	8.206E-15	7.350E-27	6.584E-39	5.898E-51	5.283E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU-238	5.847E+00	5.621E+00	5.404E+00	5.196E+00	4.995E+00	4.617E+00	4.103E+00	3.646E+00	3.241E+00	2.769E+00
PU-239	7.202E-01	7.201E-01	7.201E-01	7.200E-01	7.199E-01	7.197E-01	7.194E-01	7.191E-01	7.188E-01	7.184E-01
PU-240	9.197E-01	9.238E-01	9.271E-01	9.298E-01	9.319E-01	9.348E-01	9.370E-01	9.376E-01	9.373E-01	9.361E-01
PU-241	2.361E+02	1.856E+02	1.459E+02	1.147E+02	9.020E+01	5.575E+01	2.710E+01	1.317E+01	6.401E+00	2.446E+00
PU-242	3.979E-03	3.979E-03	3.979E-03	3.979E-03	3.979E-03	3.979E-03	3.979E-03	3.979E-03	3.979E-03	3.979E-03
PU-244	1.203E-09	1.203E-09	1.203E-09	1.203E-09	1.203E-09	1.203E-09	1.203E-09	1.203E-09	1.203E-09	1.203E-09
AM-241	2.420E+00	4.075E+00	5.359E+00	6.351E+00	7.114E+00	8.139E+00	8.887E+00	9.134E+00	9.140E+00	8.981E+00
AM-242M	2.038E-02	1.992E-02	1.947E-02	1.903E-02	1.860E-02	1.777E-02	1.660E-02	1.550E-02	1.448E-02	1.322E-02
AM-242	2.028E-02	1.982E-02	1.937E-02	1.894E-02	1.851E-02	1.769E-02	1.652E-02	1.543E-02	1.441E-02	1.315E-02
AM-243	3.885E-02	3.883E-02	3.882E-02	3.880E-02	3.878E-02	3.874E-02	3.869E-02	3.863E-02	3.858E-02	3.851E-02
CM-242	6.123E-02	1.642E-02	1.603E-02	1.567E-02	1.531E-02	1.463E-02	1.366E-02	1.276E-02	1.191E-02	1.088E-02
CM-243	3.220E-02	2.852E-02	2.526E-02	2.237E-02	1.981E-02	1.553E-02	1.079E-02	7.492E-03	5.203E-03	3.200E-03
CM-244	9.561E+00	7.897E+00	6.522E+00	5.387E+00	4.449E+00	3.035E+00	1.710E+00	9.635E-01	5.428E-01	2.526E-01
CM-245	1.223E-03	1.222E-03	1.222E-03	1.221E-03	1.221E-03	1.220E-03	1.218E-03	1.217E-03	1.215E-03	1.213E-03
CM-246	1.796E-04	1.795E-04	1.793E-04	1.792E-04	1.791E-04	1.788E-04	1.784E-04	1.780E-04	1.776E-04	1.771E-04
CM-247	6.257E-10	6.257E-10	6.257E-10	6.257E-10	6.257E-10	6.257E-10	6.257E-10	6.257E-10	6.257E-10	6.257E-10
SUBTOTAL**	1.130E+03	7.795E+02	6.452E+02	5.510E+02	4.760E+02	3.611E+02	2.449E+02	1.701E+02	1.207E+02	7.877E+01
TOTAL***	1.130E+03	7.795E+02	6.452E+02	5.510E+02	4.761E+02	3.612E+02	2.449E+02	1.702E+02	1.207E+02	7.879E+01

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 26

Fuel-Specific Source Term Calculations

Aluminum-Clad TRIGA Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a generic source term for aluminum-clad TRIGA (Training, Research, and Isotope General Atomics) spent nuclear fuel elements currently stored at the INEEL. The data sources for the analysis are documented in References 1 and 2, and the INEEL calculational methodology is described in detail in Reference 3.

TRIGA Data

TRIGA reactors are light-water-cooled reactors designed for training, research, and isotope production. One type of fuel element used in a TRIGA reactor is an aluminum-clad, uranium-zirconium-hydride (U-Zr-H) fuel element. The enriched uranium is homogeneously mixed in the ZrH matrix. The cylindrical active fuel region in each aluminum-clad element is approximately 1.4-in. in diameter and 14 or 15 in. in length. Figure 1 shows a typical aluminum-clad fuel element with dimensions and materials. The data below give specific dimensions, materials, loadings, densities, enrichment, etc., for the aluminum-clad element used in the burnup calculation for the source term generation.

Fuel Element:

Fuel Meat:	U-Zr-H Zr:H ratio is 1.0 Density = 6.28 g/cc
Clad:	Aluminum-1100 Density = 2.70 g/cc
Loading:	36.0 g/element U-235 BOL 144.0 g/element U-238 BOL 180.0 g/element U BOL 2070.0 g/element ZrH in fuel meat 8.0 weight % U in U-ZrH ₁₀ 20% enrichment U-235 BOL 280.0 g/element aluminum cladding 450.0 g/element graphite top/bottom end reflectors 19.7 g/element Sm ₂ O ₃ (two poison disks)

Active Fuel Length: 14 in.
Fuel Element Length: 28 in. (approximate)

Water Temperature: 77.5°F
Water Pressure: 14.7 psia

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for all the material components in a single aluminum-clad TRIGA fuel element. In addition, for the ORIGEN2 (Reference 4) depletion or burnup calculation, conservative and detailed impurity concentrations were added for the aluminum-clad, zirconium-hydride, and graphite end reflector masses. Table 1 gives the impurity concentrations for these three materials.

Burnup

Reference 1 is a parametric study and includes radionuclide inventories or source terms for eight different burnups ranging up to 19.44%. The burnup chosen for this template is based on the 19.44% burnup of the initial U-235 or the maximum burnup used in the parametric study. This burnup is equivalent to 6.65 MWd, 36,944 MWd/MTU, and 8.07 g of U-235 depleted per element and represents the upper end of typical aluminum-clad TRIGA fuel element burnups. The assumption of maximum burnup is conservative for the buildup of fission products, activation products, and minor actinides in the source term and nonconservative with regard to criticality safety.

Cross-Section Development

An MCNP4A (Reference 5) partial core model of a MARK I TRIGA reactor core was used to generate neutron cross sections specifically for the aluminum-clad TRIGA fuel element. The MCNP4A one-twelfth core model is shown in Figure 2. The cross sections are spectrally and spatially weighted over all the fuel elements shown in Figure 2. These cross sections are in turn used in the fuel element ORIGEN2 depletion calculation.

Parametric TRIGA Single Element Exposure History

Table 2 summarizes the single element exposure history of the aluminum-clad TRIGA fuel element from Reference 1. The burnup period is a hypothetical 4-year continuous exposure. TRIGA fuel elements typically remain in the core for much longer periods of time relative to the assumed 4-year in-core residency. Therefore, typical fuel elements would have more time to decay away their source term; therefore, the 4-year assumption is expected to produce a conservative source term.

Burnup Calculation

The ORIGEN2 computer code was used to perform the depletion or burnup calculation for the aluminum-clad TRIGA fuel element. The radionuclide inventory or source term template that follows is for a single aluminum-clad TRIGA fuel element. The fuel element component masses and impurities (fuel meat, uranium, clad, burnable poison, end fixtures), neutron cross sections, burnup, and hypothetical power history and power level as discussed above are input data for the ORIGEN2 calculation. The radionuclide concentrations are given as a function of decay time in the template table.

The 145 radionuclides listed in the template represent greater than 99.9% of the total curie inventory had all 684 activation products, 880 fission products, and 127 actinide/daughter isotopes from the ORIGEN2 output been included in the template.

References

1. J.W. Sterbentz, *Radionuclide Mass Inventory, Activity, Decay Heat, and Dose Rate Parametric Data for TRIGA Spent Nuclear Fuels*, INEL-96/0482, Idaho National Engineering Laboratory, March 1997.
2. N. Tomsio, *Characterization of TRIGA Fuel*, ORNL/Sub//86-22047/3, GA-C18542, GA Technologies, October 1986.
3. J. W. Sterbentz and C. A. Wemple, *Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels*, INEL-96/0304, September 1996.

4. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.
5. "MCNP4A: Monte Carlo N-Particle Transport Code System," LA-12625M, contributed by Los Alamos National Laboratory, Los Alamos, New Mexico, 1994, and distributed as package CCC-200 by Oak Ridge National Laboratory.

Table 1. Material constituent and impurity concentrations for the various materials in an aluminum-clad TRIGA fuel element.

Constituent or Impurity	Graphite Concentration (ppm)	ZrH Concentration (wt%)	Aluminum-1100 Concentration (wt%)
H		1.0628	
Li	0.45		
Be	0.005		
B	2.5	0.00005	
C	100 wt%	0.026968	
N		0.00799	
O		0.094887	
Na	10.4		
Mg	1		
Al	4.1	0.007491	99.3
Si	26	0.011986	0.25
P	1	0.009988	
S	9.4	0.003496	
Cl	3		
K	3		
Ca	22.5		
Sc	0.01		
Ti	16	0.004994	
V	18.9	0.004994	
Cr	1	0.124851	
Mn	1	0.004994	0.025
Fe	11.1	0.224731	0.25
Co	4	0.001998	
Ni	4.6	0.006992	
Cu	0.47	0.004994	0.125
Zn	1	0.009988	0.05
Rb	1		
Sr	0.47		
Zr	0.5	98.9082	
Nb	1.74	0.006992	
Mo	1	0.004994	
Ag	0.5		
Cd	0.5	0.000050	
In	1		
Sn	1	1.598089	
Sb	1		
Cs	1		
Ba	2.9		
La	1.38		

Table 1. (continued).

Constituent or Impurity	Graphite Concentration (ppm)	ZrH Concentration (wt%)	Aluminum-1100 Concentration (wt%)
Ce	0.56		
Pr	0.64		
Nd	0.36		
Sm	0.61	0.000999	
Gd	0.08	0.000499	
Tb	0.26		
Dy	0.16		
Ho	0.08		
Er	0.04		
Tm	0.04		
Yb	0.06		
Lu	0.02		
Hf	0.17	0.003496	
Ta	0.35	0.019976	
W	25.5	0.009988	
Tl	1		
Pb	6.9	0.009988	
Bi	1		
Th		0.000699	
U		0.000350	

Table 2. Hypothetical power history for a maximum burnup aluminum-clad TRIGA fuel element

Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MWth)
365	365	0.004555
365	730	0.004555
365	1095	0.004555
365	1460	0.004555
1825	3285	0.0
1825	5110	0.0
1825	6935	0.0
1825	8760	0.0
1825	10585	0.0
3650	14235	0.0
5475	19710	0.0
5475	25185	0.0
5475	30660	0.0
7300	37960	0.0

The ten decay times following the hypothetical 4-year exposure are for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling time periods designated for the template methodology.

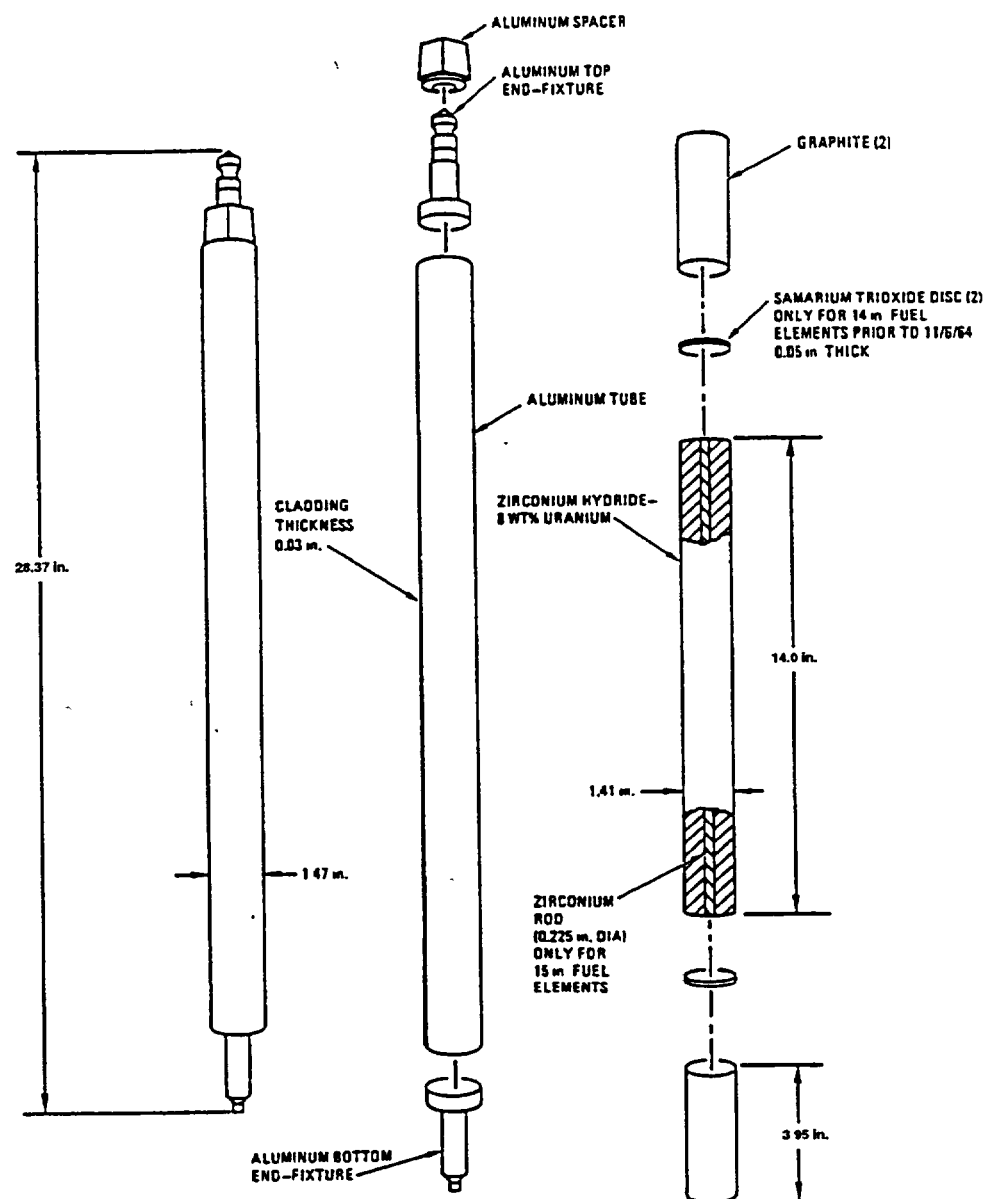


Figure 1. A typical aluminum-clad Mark I TRIGA fuel element.

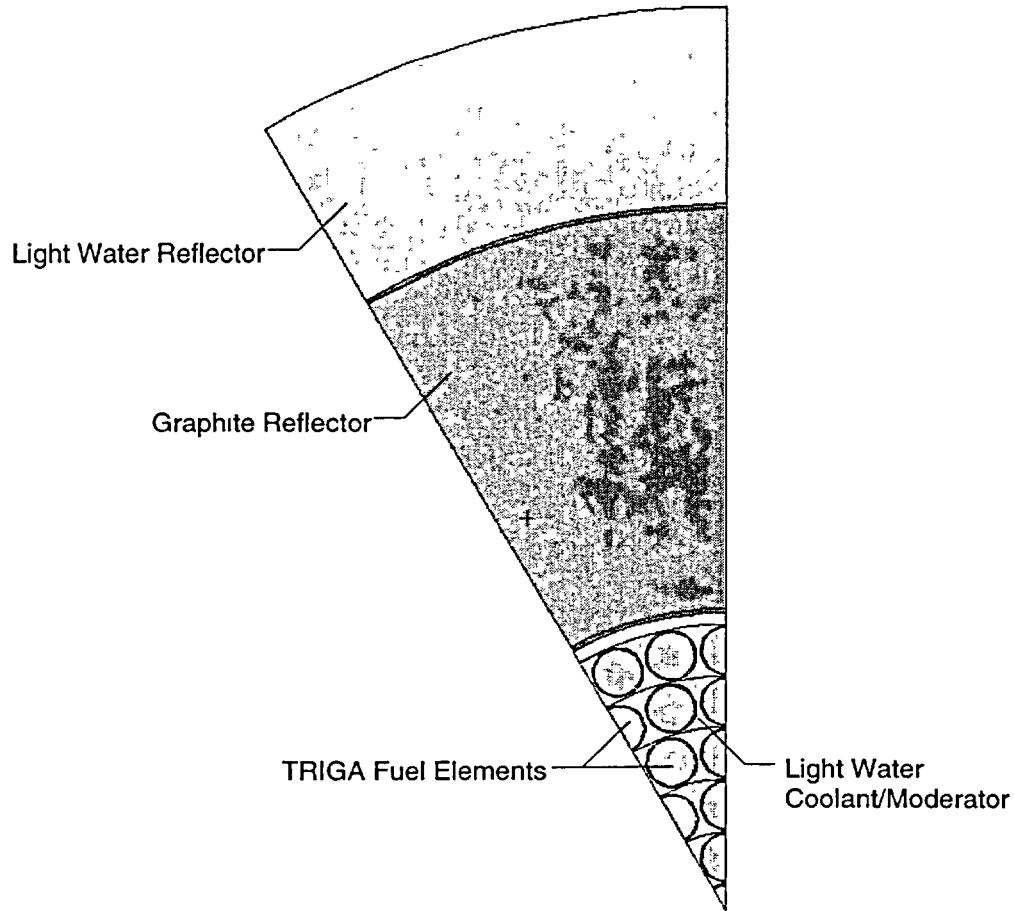


Figure 2. MCNP partial core model of a Mark I TRIGA reactor core.

TRIGA Element

Aluminum Cladding, 10 to 20% Enriched U-235 Fuel

Reactor Moderator/Coolant: Light Water
Fuel Meat: U-Zr-H₁₀
Clad: Aluminum
Burnup: 6.65 MWd/element (maximum element burnup)
Burnup: 19.44% U-235 burnup (amount fissioned)
Burnup: 8.07 g U-235 depletion (amount fissioned and transmuted)
Basis of Calculation: Single element
BOL U-235: 36.0 g U-235 per element (design basis)
BOL U-238: 144.0 g U-238 per element
BOL Total U per element: 180.0 g U per element
BOL Fuel Enrichment: 20.0 wt%

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
H-3	7.185E-02	5.427E-02	4.100E-02	3.097E-02	2.339E-02	1.335E-02	5.757E-03	2.482E-03	1.070E-03	3.485E-04
BE-10	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07	1.565E-07
C-14	2.880E-04	2.878E-04	2.877E-04	2.875E-04	2.873E-04	2.870E-04	2.865E-04	2.859E-04	2.854E-04	2.847E-04
CL-36	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.861E-07	2.860E-07
CR-51	1.398E-20	2.081E-40	3.097E-60	4.611E-80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MN-54	5.494E-04	9.591E-06	1.674E-07	2.923E-09	5.103E-11	1.555E-14	8.274E-20	4.402E-25	2.342E-30	2.176E-37
FE-55	5.771E-02	1.523E-02	4.020E-03	1.061E-03	2.800E-04	1.951E-05	3.587E-07	6.594E-09	1.212E-10	5.883E-13
FE-59	6.039E-15	3.737E-27	2.312E-39	1.431E-51	8.855E-64	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO-60	2.062E-01	1.069E-01	5.540E-02	2.872E-02	1.488E-02	3.998E-03	5.566E-04	7.750E-05	1.079E-05	7.786E-07
NI-59	7.771E-06	7.770E-06	7.770E-06	7.770E-06	7.769E-06	7.769E-06	7.768E-06	7.767E-06	7.766E-06	7.764E-06
NI-63	9.698E-04	9.340E-04	8.995E-04	8.662E-04	8.342E-04	7.737E-04	6.911E-04	6.173E-04	5.514E-04	4.743E-04
ZN-65	3.987E-04	2.228E-06	1.245E-08	6.954E-11	3.885E-13	1.213E-17	2.116E-24	3.690E-31	6.437E-38	6.273E-47
SE-79	8.604E-05	8.603E-05	8.603E-05	8.602E-05	8.602E-05	8.601E-05	8.599E-05	8.598E-05	8.597E-05	8.595E-05
KR-85	1.677E+00	1.214E+00	8.790E-01	6.363E-01	4.606E-01	2.414E-01	9.158E-02	3.475E-02	1.318E-02	3.620E-03
RB-87	5.715E-09	5.715E-09	5.715E-09	5.715E-09	5.715E-09	5.715E-09	5.715E-09	5.715E-09	5.715E-09	5.715E-09
SR-89	2.298E-09	3.034E-20	4.007E-31	5.290E-42	6.984E-53	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR-90	1.729E+01	1.536E+01	1.363E+01	1.210E+01	1.075E+01	8.472E+00	5.930E+00	4.151E+00	2.905E+00	1.805E+00
Y-90	1.730E+01	1.536E+01	1.364E+01	1.211E+01	1.075E+01	8.475E+00	5.932E+00	4.152E+00	2.906E+00	1.806E+00
Y-91	8.752E-08	3.565E-17	1.452E-26	5.917E-36	2.411E-45	4.000E-64	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR-93	5.433E-04	5.433E-04	5.433E-04	5.433E-04	5.433E-04	5.433E-04	5.433E-04	5.433E-04	5.433E-04	5.433E-04
ZR-95	6.734E-07	1.744E-15	4.521E-24	1.172E-32	3.034E-41	2.037E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-93M	1.542E-04	2.355E-04	2.986E-04	3.475E-04	3.854E-04	4.376E-04	4.795E-04	4.991E-04	5.081E-04	5.132E-04

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
NB-94	2.386E-05	2.386E-05	2.385E-05	2.385E-05	2.385E-05	2.384E-05	2.383E-05	2.381E-05	2.380E-05	2.379E-05
NB-95	1.495E-06	3.874E-15	1.004E-23	2.600E-32	6.737E-41	4.523E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-95M	4.996E-09	1.294E-17	3.353E-26	8.690E-35	2.252E-43	1.512E-60	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO-93	5.903E-07	5.897E-07	5.891E-07	5.885E-07	5.880E-07	5.868E-07	5.851E-07	5.833E-07	5.816E-07	5.793E-07
TC-99	2.934E-03	2.934E-03	2.934E-03	2.934E-03	2.934E-03	2.934E-03	2.934E-03	2.934E-03	2.933E-03	2.933E-03
RU-103	1.281E-12	1.325E-26	1.370E-40	1.417E-54	1.466E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU-106	6.234E-01	2.007E-02	6.463E-04	2.081E-05	6.700E-07	6.945E-10	2.318E-14	7.736E-19	2.582E-23	2.775E-29
RH-103M	1.155E-12	1.195E-26	1.235E-40	1.278E-54	1.321E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH-106	6.234E-01	2.007E-02	6.463E-04	2.081E-05	6.700E-07	6.945E-10	2.318E-14	7.737E-19	2.582E-23	2.775E-29
PD-107	4.271E-06	4.271E-06	4.271E-06	4.271E-06	4.271E-06	4.271E-06	4.271E-06	4.271E-06	4.271E-06	4.271E-06
AG-110	9.707E-07	6.146E-09	3.890E-11	2.463E-13	1.559E-15	6.250E-20	1.585E-26	4.024E-33	1.021E-39	1.640E-48
AG-110M	7.299E-05	4.621E-07	2.925E-09	1.852E-11	1.173E-13	4.699E-18	1.193E-24	3.025E-31	7.676E-38	1.233E-46
AG-111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-113M	2.179E-03	1.718E-03	1.355E-03	1.069E-03	8.430E-04	5.244E-04	2.572E-04	1.262E-04	6.191E-05	2.395E-05
CD-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-115M	3.075E-14	1.474E-26	7.065E-39	3.387E-51	1.624E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114	1.644E-14	1.320E-25	1.060E-36	8.503E-48	6.825E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114M	1.718E-14	1.379E-25	1.107E-36	8.885E-48	7.132E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-115M	2.159E-18	1.035E-30	4.960E-43	2.378E-55	1.140E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-119M	1.902E-02	1.089E-04	6.236E-07	3.570E-09	2.044E-11	6.702E-16	1.258E-22	2.362E-29	4.434E-36	4.767E-45
SN-121M	4.467E-04	4.168E-04	3.889E-04	3.629E-04	3.386E-04	2.947E-04	2.394E-04	1.945E-04	1.580E-04	1.197E-04
SN-123	2.183E-05	1.219E-09	6.802E-14	3.797E-18	2.119E-22	6.600E-31	1.148E-43	1.996E-56	3.469E-69	3.367E-86
SN-125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-126	8.139E-05	8.138E-05	8.138E-05	8.138E-05	8.138E-05	8.137E-05	8.136E-05	8.135E-05	8.134E-05	8.133E-05
SB-124	9.863E-12	7.372E-21	5.510E-30	4.119E-39	3.079E-48	1.720E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB-125	6.261E-01	1.793E-01	5.135E-02	1.471E-02	4.212E-03	3.455E-04	8.116E-06	1.907E-07	4.479E-09	3.013E-11
SB-126	1.139E-05	1.139E-05	1.139E-05	1.139E-05	1.139E-05	1.139E-05	1.139E-05	1.139E-05	1.139E-05	1.139E-05
SB-126M	8.139E-05	8.138E-05	8.138E-05	8.138E-05	8.138E-05	8.137E-05	8.136E-05	8.135E-05	8.134E-05	8.133E-05
TE-123M	5.982E-10	1.536E-14	3.943E-19	1.012E-23	2.598E-28	1.712E-37	2.896E-51	4.899E-65	8.289E-79	3.599E-97
TE-125M	1.527E-01	4.375E-02	1.253E-02	3.588E-03	1.028E-03	8.430E-05	1.980E-06	4.652E-08	1.093E-09	7.352E-12
TE-127	8.452E-06	7.709E-11	7.031E-16	6.413E-21	5.849E-26	4.866E-36	3.692E-51	2.801E-66	2.126E-81	0.000E+00
TE-127M	8.629E-06	7.871E-11	7.179E-16	6.547E-21	5.972E-26	4.968E-36	3.769E-51	2.860E-66	2.170E-81	0.000E+00
TE-129	1.160E-16	5.172E-33	2.306E-49	1.028E-65	4.583E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE-129M	1.782E-16	7.945E-33	3.542E-49	1.579E-65	7.041E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I-129	4.908E-06	4.908E-06	4.908E-06	4.908E-06	4.908E-06	4.908E-06	4.908E-06	4.908E-06	4.908E-06	4.908E-06

Radionuclide	DECAY TIMES (years out of core) (Activities* in Ci/element)									
	5	10	15	20	25	35	50	65	80	100
I-131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-134	6.894E-01	1.285E-01	2.396E-02	4.468E-03	8.329E-04	2.895E-05	1.876E-07	1.216E-09	7.879E-12	9.520E-15
CS-135	2.098E-04	2.098E-04	2.098E-04	2.098E-04	2.098E-04	2.098E-04	2.098E-04	2.098E-04	2.098E-04	2.098E-04
CS-136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-137	1.833E+01	1.633E+01	1.455E+01	1.296E+01	1.155E+01	9.169E+00	6.485E+00	4.586E+00	3.244E+00	2.044E+00
BA-136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA-137M	1.734E+01	1.545E+01	1.376E+01	1.226E+01	1.093E+01	8.674E+00	6.135E+00	4.339E+00	3.069E+00	1.934E+00
BA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-141	2.761E-15	3.492E-32	4.417E-49	5.587E-66	7.066E-83	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-142	5.891E-09	5.891E-09	5.891E-09	5.891E-09	5.891E-09	5.891E-09	5.891E-09	5.891E-09	5.891E-09	5.891E-09
CE-144	2.304E+00	2.691E-02	3.142E-04	3.669E-06	4.284E-08	5.841E-12	9.300E-18	1.481E-23	2.358E-29	4.383E-37
PR-143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR-144	2.304E+00	2.691E-02	3.142E-04	3.669E-06	4.284E-08	5.841E-12	9.301E-18	1.481E-23	2.358E-29	4.383E-37
PR-144M	2.765E-02	3.229E-04	3.770E-06	4.403E-08	5.141E-10	7.010E-14	1.116E-19	1.777E-25	2.829E-31	5.260E-39
ND-144	2.873E-13	2.882E-13	2.882E-13	2.882E-13	2.882E-13	2.882E-13	2.882E-13	2.882E-13	2.882E-13	2.882E-13
ND-147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-145	8.891E-03	7.387E-03	6.076E-03	4.996E-03	4.108E-03	2.778E-03	1.545E-03	8.587E-04	4.775E-04	2.183E-04
PM-147	1.381E+01	3.688E+00	9.849E-01	2.631E-01	7.027E-02	5.013E-03	9.551E-05	1.820E-06	3.468E-08	1.765E-10
PM-148M	1.009E-13	5.016E-27	2.495E-40	1.241E-53	6.170E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-148	5.681E-15	2.825E-28	1.405E-41	6.987E-55	3.475E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM-145	1.706E-03	4.135E-05	1.002E-06	2.428E-08	5.884E-10	3.455E-13	4.916E-18	6.996E-23	9.955E-28	3.433E-34
SM-147	6.419E-08	6.444E-08	6.451E-08	6.452E-08	6.453E-08	6.453E-08	6.453E-08	6.453E-08	6.453E-08	6.453E-08
SM-151	1.810E+00	1.742E+00	1.676E+00	1.612E+00	1.552E+00	1.437E+00	1.280E+00	1.141E+00	1.016E+00	8.711E-01
EU-152	5.693E-02	4.413E-02	3.421E-02	2.652E-02	2.056E-02	1.236E-02	5.755E-03	2.680E-03	1.249E-03	4.508E-04
EU-154	8.971E+00	5.997E+00	4.009E+00	2.680E+00	1.792E+00	8.007E-01	2.392E-01	7.146E-02	2.135E-02	4.264E-03
EU-155	2.918E+00	1.451E+00	7.220E-01	3.591E-01	1.786E-01	4.419E-02	5.438E-03	6.691E-04	8.235E-05	5.040E-06
EU-156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD-153	1.521E-04	8.172E-07	4.388E-09	2.356E-11	1.266E-13	3.648E-18	5.649E-25	8.747E-32	1.355E-38	1.126E-47
TB-160	1.431E-10	3.609E-18	9.101E-26	2.295E-33	5.788E-41	3.681E-56	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL-206	1.688E-12	1.688E-12	1.688E-12	1.688E-12	1.688E-12	1.688E-12	1.688E-12	1.688E-12	1.688E-12	1.688E-12
TL-207	2.692E-09	5.352E-09	8.560E-09	1.223E-08	1.631E-08	2.541E-08	4.083E-08	5.765E-08	7.534E-08	9.970E-08
TL-208	1.209E-07	1.294E-07	1.262E-07	1.210E-07	1.155E-07	1.049E-07	9.089E-08	7.876E-08	6.825E-08	5.645E-08

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
PB-210	2.012E-14	5.487E-14	1.253E-13	2.431E-13	4.200E-13	9.972E-13	2.589E-12	5.305E-12	9.409E-12	1.745E-11
PB-211	2.699E-09	5.367E-09	8.584E-09	1.227E-08	1.635E-08	2.548E-08	4.094E-08	5.781E-08	7.555E-08	9.998E-08
PB-212	3.364E-07	3.603E-07	3.513E-07	3.367E-07	3.214E-07	2.920E-07	2.530E-07	2.192E-07	1.899E-07	1.571E-07
BI-211	2.699E-09	5.367E-09	8.584E-09	1.227E-08	1.635E-08	2.548E-08	4.094E-08	5.781E-08	7.555E-08	9.998E-08
BI-212	3.364E-07	3.603E-07	3.513E-07	3.367E-07	3.214E-07	2.920E-07	2.530E-07	2.192E-07	1.899E-07	1.571E-07
PO-212	2.155E-07	2.308E-07	2.251E-07	2.157E-07	2.059E-07	1.871E-07	1.621E-07	1.404E-07	1.217E-07	1.007E-07
PO-215	2.699E-09	5.367E-09	8.584E-09	1.227E-08	1.635E-08	2.548E-08	4.094E-08	5.781E-08	7.555E-08	9.998E-08
PO-216	3.364E-07	3.603E-07	3.513E-07	3.367E-07	3.214E-07	2.920E-07	2.530E-07	2.192E-07	1.899E-07	1.571E-07
RN-219	2.699E-09	5.367E-09	8.584E-09	1.227E-08	1.635E-08	2.548E-08	4.094E-08	5.781E-08	7.555E-08	9.998E-08
RN-220	3.364E-07	3.603E-07	3.513E-07	3.367E-07	3.214E-07	2.920E-07	2.530E-07	2.192E-07	1.899E-07	1.571E-07
FR-223	3.723E-11	7.399E-11	1.183E-10	1.691E-10	2.253E-10	3.512E-10	5.645E-10	7.970E-10	1.041E-09	1.378E-09
RA-223	2.699E-09	5.367E-09	8.584E-09	1.227E-08	1.635E-08	2.548E-08	4.094E-08	5.781E-08	7.555E-08	9.998E-08
RA-224	3.364E-07	3.603E-07	3.513E-07	3.367E-07	3.214E-07	2.920E-07	2.530E-07	2.192E-07	1.899E-07	1.571E-07
RA-226	1.546E-13	3.814E-13	7.197E-13	1.181E-12	1.776E-12	3.411E-12	7.118E-12	1.254E-11	1.990E-11	3.302E-11
RA-228	9.560E-10	1.207E-09	1.357E-09	1.447E-09	1.500E-09	1.551E-09	1.573E-09	1.578E-09	1.579E-09	1.579E-09
AC-227	2.698E-09	5.362E-09	8.573E-09	1.225E-08	1.633E-08	2.545E-08	4.090E-08	5.775E-08	7.547E-08	9.988E-08
TH-227	2.662E-09	5.293E-09	8.465E-09	1.210E-08	1.613E-08	2.513E-08	4.038E-08	5.702E-08	7.451E-08	9.860E-08
TH-228	3.363E-07	3.600E-07	3.510E-07	3.364E-07	3.211E-07	2.919E-07	2.530E-07	2.192E-07	1.899E-07	1.571E-07
TH-229	5.691E-10	9.808E-10	1.392E-09	1.804E-09	2.215E-09	3.038E-09	4.271E-09	5.503E-09	6.734E-09	8.374E-09
TH-230	8.096E-11	1.300E-10	1.845E-10	2.444E-10	3.094E-10	4.540E-10	7.045E-10	9.914E-10	1.311E-09	1.781E-09
TH-231	6.040E-05	6.040E-05	6.040E-05	6.040E-05	6.040E-05	6.040E-05	6.041E-05	6.041E-05	6.041E-05	6.041E-05
TH-232	1.579E-09	1.579E-09	1.579E-09	1.579E-09	1.579E-09	1.579E-09	1.579E-09	1.579E-09	1.579E-09	1.579E-09
TH-234	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05
PA-231	1.753E-08	2.392E-08	3.030E-08	3.669E-08	4.308E-08	5.584E-08	7.498E-08	9.411E-08	1.132E-07	1.387E-07
PA-233	9.598E-06	9.618E-06	9.646E-06	9.681E-06	9.721E-06	9.810E-06	9.960E-06	1.012E-05	1.028E-05	1.049E-05
PA-234M	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05
PA-234	6.259E-08	6.259E-08	6.259E-08	6.259E-08	6.259E-08	6.259E-08	6.259E-08	6.259E-08	6.259E-08	6.259E-08
U-232	3.725E-07	3.581E-07	3.423E-07	3.265E-07	3.112E-07	2.827E-07	2.447E-07	2.118E-07	1.834E-07	1.513E-07
U-233	8.731E-07	8.733E-07	8.735E-07	8.736E-07	8.738E-07	8.742E-07	8.748E-07	8.754E-07	8.760E-07	8.769E-07
U-234	1.027E-06	1.152E-06	1.273E-06	1.389E-06	1.501E-06	1.711E-06	1.997E-06	2.252E-06	2.478E-06	2.742E-06
U-235	6.040E-05	6.040E-05	6.040E-05	6.040E-05	6.040E-05	6.040E-05	6.041E-05	6.041E-05	6.041E-05	6.041E-05
U-236	8.457E-05	8.457E-05	8.458E-05	8.458E-05	8.458E-05	8.458E-05	8.459E-05	8.460E-05	8.460E-05	8.461E-05
U-237	2.051E-07	1.613E-07	1.268E-07	9.969E-08	7.838E-08	4.845E-08	2.355E-08	1.144E-08	5.561E-09	2.125E-09
U-238	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05	4.814E-05
NP-237	9.598E-06	9.618E-06	9.646E-06	9.681E-06	9.721E-06	9.810E-06	9.960E-06	1.012E-05	1.028E-05	1.049E-05

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
PU-236	1.173E-07	3.483E-08	1.034E-08	3.069E-09	9.121E-10	8.206E-11	3.991E-12	1.950E-12	1.897E-12	1.895E-12
PU-237	1.346E-18	1.206E-30	1.080E-42	9.678E-55	8.669E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU-238	8.987E-03	8.640E-03	8.306E-03	7.985E-03	7.676E-03	7.094E-03	6.303E-03	5.600E-03	4.976E-03	4.250E-03
PU-239	3.787E-02	3.786E-02	3.786E-02	3.785E-02	3.785E-02	3.784E-02	3.782E-02	3.780E-02	3.779E-02	3.776E-02
PU-240	1.506E-02	1.505E-02	1.504E-02	1.504E-02	1.503E-02	1.501E-02	1.499E-02	1.496E-02	1.494E-02	1.491E-02
PU-241	8.362E-01	6.574E-01	5.169E-01	4.064E-01	3.195E-01	1.975E-01	9.598E-02	4.665E-02	2.267E-02	8.661E-03
PU-242	2.035E-06	2.035E-06	2.035E-06	2.035E-06	2.035E-06	2.035E-06	2.035E-06	2.035E-06	2.035E-06	2.035E-06
PU-244	4.531E-15	4.531E-15	4.531E-15	4.531E-15	4.531E-15	4.531E-15	4.531E-15	4.531E-15	4.531E-15	4.531E-15
AM-241	9.166E-03	1.502E-02	1.957E-02	2.308E-02	2.577E-02	2.939E-02	3.203E-02	3.289E-02	3.290E-02	3.232E-02
AM-242M	1.325E-05	1.296E-05	1.266E-05	1.238E-05	1.210E-05	1.156E-05	1.080E-05	1.008E-05	9.417E-06	8.597E-06
AM-242	1.319E-05	1.289E-05	1.260E-05	1.232E-05	1.204E-05	1.150E-05	1.074E-05	1.003E-05	9.370E-06	8.554E-06
AM-243	1.551E-06	1.550E-06	1.550E-06	1.549E-06	1.548E-06	1.547E-06	1.545E-06	1.542E-06	1.540E-06	1.537E-06
CM-242	3.330E-05	1.067E-05	1.043E-05	1.019E-05	9.961E-06	9.513E-06	8.884E-06	8.297E-06	7.749E-06	7.074E-06
CM-243	1.824E-06	1.615E-06	1.430E-06	1.267E-06	1.122E-06	8.797E-07	6.110E-07	4.243E-07	2.947E-07	1.812E-07
CM-244	2.095E-05	1.730E-05	1.429E-05	1.180E-05	9.749E-06	6.650E-06	3.747E-06	2.111E-06	1.189E-06	5.535E-07
CM-245	2.407E-10	2.406E-10	2.405E-10	2.404E-10	2.403E-10	2.401E-10	2.398E-10	2.395E-10	2.392E-10	2.388E-10
CM-246	7.528E-12	7.522E-12	7.517E-12	7.511E-12	7.506E-12	7.495E-12	7.478E-12	7.462E-12	7.446E-12	7.424E-12
CM-247	1.887E-18	1.887E-18	1.887E-18	1.887E-18	1.887E-18	1.887E-18	1.887E-18	1.887E-18	1.887E-18	1.887E-18
SUBTOTAL**	1.081E+02	7.800E+01	6.469E+01	5.559E+01	4.851E+01	3.764E+01	2.630E+01	1.862E+01	1.330E+01	8.573E+00
TOTAL***	1.081E+02	7.801E+01	6.469E+01	5.560E+01	4.852E+01	3.764E+01	2.631E+01	1.863E+01	1.330E+01	8.573E+00

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 27

Fuel-Specific Source Term Calculations

TRIGA FLIP Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a source term for the Training, Research, and Isotope General Atomics (TRIGA) high-enrichment Fuel Life Improvement Program (FLIP) spent nuclear fuel elements currently stored at the INEEL. The data sources are documented in References 1 and 2 and the INEEL calculational methodology is described in detail in Reference 3.

TRIGA Data

TRIGA reactors are light-water-cooled reactors designed for training, research, and isotope production. One type of fuel element used in a TRIGA reactor is a highly enriched, stainless steel-clad, uranium-zirconium-hydride (U-Zr-H) fuel element. The highly enriched uranium is homogeneously mixed in the ZrH matrix. The cylindrical active fuel region in each element is approximately 1.4 in. in diameter and 15 in. in length. Figure 1 shows a typical TRIGA FLIP fuel element with dimensions and materials. The data below give specific dimensions, materials, loadings, densities, enrichment, etc., for the fuel element used in the burnup calculation for the source term generation.

Fuel Element:

Fuel Meat:	U-Zr-H Zr:H ratio is 1.6 Density = 5.92 g/cc
Clad:	Stainless Steel Density = 7.92 g/cc
Loading:	137.0 g/element U-235 BOL 59.0 g/element U-238 BOL 196.0 g/element U BOL 2060.0 g/element Zr in fuel meat 8.5 weight % U in U-ZrH _{1.6} 70% enrichment U-235 BOL 800.0 g/element stainless steel cladding (819.414 g/element with impurities) 450.0 g/element carbon in reflector 36.0 g/element natural erbium poison

Active Fuel Length:	15 in.
Fuel Element Length:	29 in. (approximate)

Water Temperature:	77.5°F
Water Pressure:	14.7 psia

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for all the material components in a single TRIGA FLIP fuel element. In addition, for the ORIGEN2 (Reference 4) depletion or burnup calculation, conservative and detailed impurity

concentrations were added for the stainless steel clad, zirconium-hydride, and graphite end reflectors. Table 1 gives the impurity concentrations for these materials.

Burnup

Reference 1 is a parametric study and includes radionuclide inventories or source terms for 14 different burnups ranging up to 51.09%. The burnup chosen for this template is based on the 51.09% burnup of the initial U-235 or the maximum burnup used in the parametric study. This burnup is equivalent to 66.52 MWd, 339,388 MWd/MTU, and 81.84 grams of U-235 depleted per element and represents the upper end of typical TRIGA FLIP fuel element burnups. The assumption of maximum burnup is conservative for the buildup of fission products, activation products, and minor actinides in the source term and nonconservative with regard to criticality safety.

Cross-Section Development

An MCNP4A (Reference 5) partial core model of a MARK I TRIGA reactor core was used to generate neutron cross sections specifically for the TRIGA FLIP fuel element. The MCNP4A one-twelfth core model is shown in Figure 2 with all fuel elements modeled as TRIGA FLIP elements. The cross sections are spectrally and spatially weighted over all the fuel elements shown in Figure 2. These cross sections are in turn used in the fuel element ORIGEN2 depletion calculation.

Parametric TRIGA Single Element Exposure History

Table 2 summarizes the single element exposure history of the TRIGA FLIP fuel element from Reference 1. The burnup period is a hypothetical 4-year continuous exposure. TRIGA fuel elements typically remain in the core for much longer periods of time relative to the assumed 4-year in-core residency. Therefore, typical fuel elements would have more time to decay away their source term; therefore, the 4-year assumption is expected to produce a conservative source term.

Burnup Calculation

The ORIGEN2 computer code was used to perform the depletion or burnup calculation for the TRIGA FLIP fuel element. The radionuclide inventory or source term template that follows is for a single TRIGA FLIP fuel element. The fuel element component masses and impurities (fuel meat, uranium, clad, burnable poison, end fixtures), neutron cross sections, burnup, and hypothetical power history and power level as discussed above are input data for the ORIGEN2 calculation. The radionuclide concentrations are given as a function of decay time in the template table.

The 145 radionuclides listed in the template represent greater than 99.1% of the total curie inventory had all 684 activation products, 880 fission products, and 127 actinide/daughter isotopes from the ORIGEN2 output been included in the template.

References

1. J. W. Sterbentz, *Radionuclide Mass Inventory, Activity, Decay Heat, and Dose Rate Parametric Data for TRIGA Spent Nuclear Fuels*, INEL-96/0482, Idaho National Engineering Laboratory, March 1997.
2. N. Tomsio, *Characterization of TRIGA Fuel*, ORNL/Sub//86-22047/3, GA-C18542, GA Technologies, October 1986.

3. J. W. Sterbentz and C. A. Wemple, *Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels*, INEL-96/0304, September 1996.
4. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.
5. "MCNP4A: Monte Carlo N-Particle Transport Code System," LA-12625M, contributed by Los Alamos National Laboratory, Los Alamos, New Mexico, 1994, and distributed as package CCC-200 by Oak Ridge National Laboratory.

Table 1. Material constituent and impurity concentrations for the various materials in a TRIGA FLIP fuel element.

Constituent or Impurity	Graphite Concentration (ppm)	ZrH Concentration (wt%)	Stainless Steel Concentration (ppm)
H		1.7373	
Li	0.45		0.13
Be	0.005		
B	2.5	0.00005	
C	100 wt%	0.026968	0.08 wt%
N		0.00799	525
O		0.094887	
Na	10.4		37
Mg	1		
Al	4.1	0.007491	200
Si	26	0.011986	1.00 wt%
P	1	0.009988	
S	9.4	0.003496	
Cl	3		130
K	3		3
Ca	22.5		19
Sc	0.01		0.03
Ti	16	0.004994	600
V	18.9	0.004994	690
Cr	1	0.124851	18.40 wt%
Mn	1	0.004994	1.53 wt%
Fe	11.1	0.224731	68.99 wt%
Co	4	0.001998	2570
Ni	4.6	0.006992	10.00 wt%
Cu	0.47	0.004994	8150
Zn	1	0.009988	2230
Ga			450
As			1010
Se			70
Br			8
Rb	1		10
Sr	0.47		0.2
Y			5
Zr	0.5	98.2627	20
Nb	1.74	0.006992	300
Mo	1	0.004994	5500
Ag	0.5		2

Table 1. (continued).

Constituent or Impurity	Graphite Concentration (ppm)	ZrH Concentration (wt%)	Stainless Steel Concentration (ppm)
Cd	0.5	0.000050	
In	1		
Sn	1	1.598089	
Sb	1		17
Cs	1		0.3
Ba	2.9		500
La	1.38		2.1
Ce	0.56		550
Pr	0.64		
Nd	0.36		
Sm	0.61	0.000999	0.15
Eu			0.02
Gd	0.08	0.000499	
Tb	0.26		0.71
Dy	0.16		1
Ho	0.08		1
Er	0.04		
Tm	0.04		
Yb	0.06		2
Lu	0.02		0.8
Hf	0.17	0.003496	2
Ta	0.35	0.019976	
W	25.5	0.009988	520
Tl	1		
Pb	6.9	0.009988	139
Bi	1		
Th		0.000699	1
U		0.000350	2

Table 2. Hypothetical power history for a maximum burnup TRIGA FLIP fuel element.

Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MWth)
365	365	0.04555
365	730	0.04555
365	1095	0.04555
365	1460	0.04555
1825	3285	0.0
1825	5110	0.0
1825	6935	0.0
1825	8760	0.0
1825	10585	0.0
3650	14235	0.0
5475	19710	0.0
5475	25185	0.0
5475	30660	0.0
7300	37960	0.0

The ten decay times following the hypothetical 4-year exposure are for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling time periods designated for the template methodology.

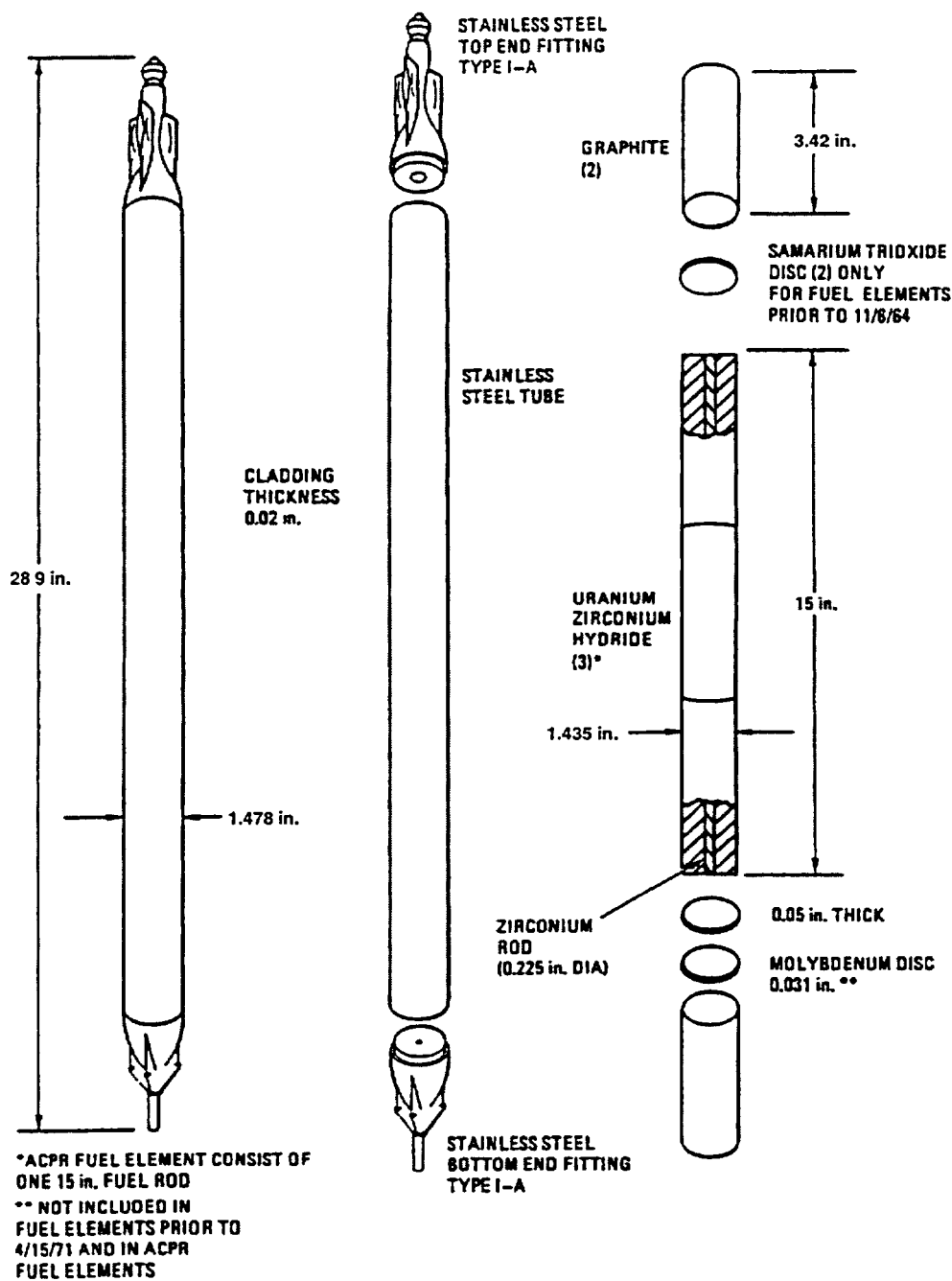


Figure 1. A typical stainless steel-clad Mark I TRIGA fuel element.

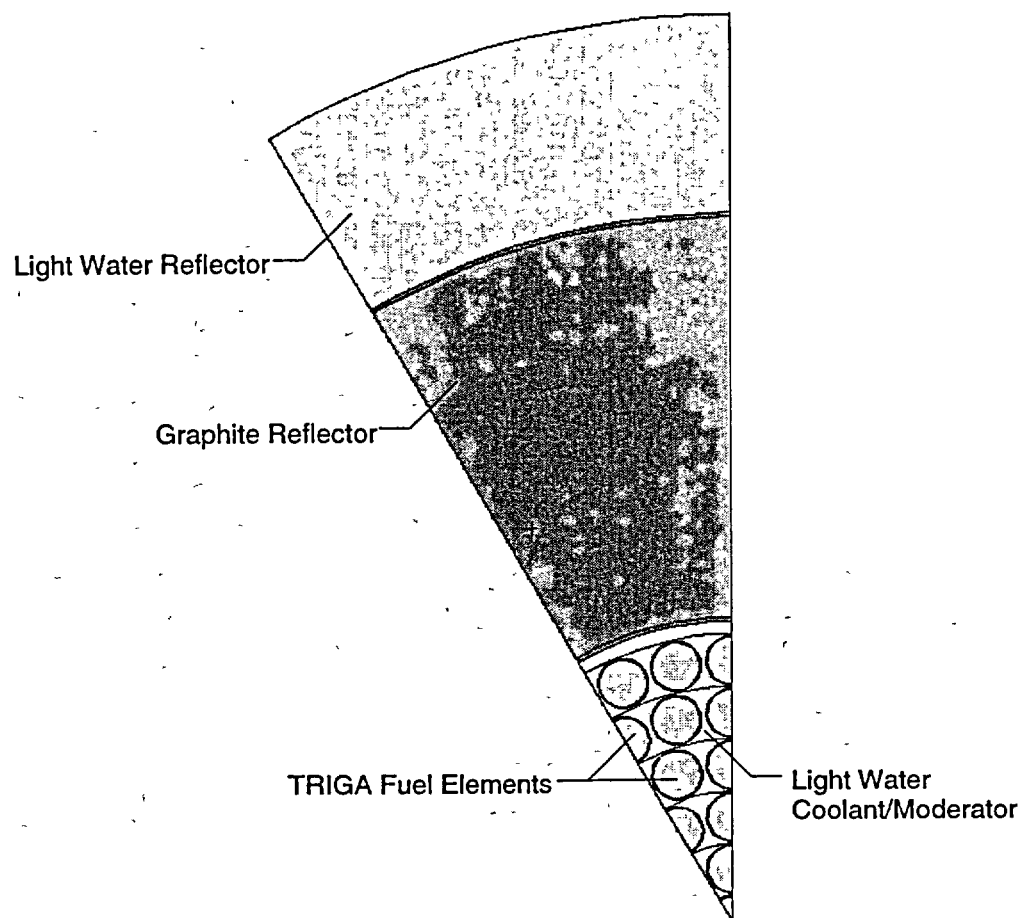


Figure 2. MCNP partial core model of a Mark I TRIGA reactor core.

TRIGA Element

FLIP, 60 to 100% Enriched U-235 Fuel

Reactor Moderator/Coolant: Light Water
Fuel Meat: U-Zr-H₁₆
Clad: Stainless Steel
Burnup: 66.52 MWd/element (maximum element burnup)
Burnup: 51.09% U-235 burnup (amount fissioned)
Burnup: 81.84 g U-235 depletion (amount fissioned and transmuted)
Basis of Calculation: Single element
BOL U-235: 137.0 g U-235 per element (design basis)
BOL U-238: 59.0 g U-238 per element
BOL Total U per element: 196.0 g U per element
BOL Fuel Enrichment: 70.0 wt%

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
H-3	7.005E-01	5.292E-01	3.998E-01	3.020E-01	2.282E-01	1.302E-01	5.613E-02	2.420E-02	1.043E-02	3.398E-03
BE-10	1.313E-06	1.313E-06	1.313E-06	1.313E-06	1.313E-06	1.313E-06	1.313E-06	1.313E-06	1.313E-06	1.313E-06
C-14	8.375E-03	8.369E-03	8.364E-03	8.359E-03	8.354E-03	8.344E-03	8.329E-03	8.314E-03	8.299E-03	8.279E-03
CL-36	1.771E-04	1.771E-04	1.771E-04	1.771E-04	1.771E-04	1.771E-04	1.771E-04	1.771E-04	1.771E-04	1.770E-04
CR-51	8.242E-18	1.227E-37	1.826E-57	2.718E-77	4.046E-97	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MN-54	5.368E-01	9.371E-03	1.636E-04	2.856E-06	4.986E-08	1.520E-11	8.085E-17	4.302E-22	2.289E-27	2.126E-34
FE-55	5.292E+01	1.397E+01	3.686E+00	9.730E-01	2.568E-01	1.789E-02	3.289E-04	6.047E-06	1.112E-07	5.395E-10
FE-59	6.733E-12	4.166E-24	2.578E-36	1.595E-48	9.873E-61	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO-60	8.255E+01	4.278E+01	2.218E+01	1.149E+01	5.957E+00	1.600E+00	2.228E-01	3.102E-02	4.318E-03	3.116E-04
NI-59	3.223E-02	3.223E-02	3.223E-02	3.223E-02	3.223E-02	3.222E-02	3.222E-02	3.221E-02	3.221E-02	3.220E-02
NI-63	4.106E+00	3.955E+00	3.808E+00	3.668E+00	3.532E+00	3.276E+00	2.926E+00	2.614E+00	2.335E+00	2.008E+00
ZN-65	2.221E-02	1.241E-04	6.934E-07	3.874E-09	2.165E-11	6.757E-16	1.179E-22	2.056E-29	3.586E-36	3.495E-45
SE-79	8.536E-04	8.535E-04	8.535E-04	8.534E-04	8.534E-04	8.533E-04	8.532E-04	8.530E-04	8.529E-04	8.527E-04
KR-85	1.660E+01	1.202E+01	8.699E+00	6.297E+00	4.559E+00	2.389E+00	9.063E-01	3.438E-01	1.304E-01	3.583E-02
RB-87	5.649E-08	5.649E-08	5.649E-08	5.649E-08	5.649E-08	5.649E-08	5.649E-08	5.649E-08	5.649E-08	5.649E-08
SR-89	2.078E-08	2.744E-19	3.624E-30	4.785E-41	6.318E-52	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR-90	1.706E+02	1.514E+02	1.344E+02	1.194E+02	1.060E+02	8.355E+01	5.848E+01	4.093E+01	2.865E+01	1.780E+01
Y-90	1.706E+02	1.515E+02	1.345E+02	1.194E+02	1.060E+02	8.357E+01	5.849E+01	4.094E+01	2.866E+01	1.781E+01
Y-91	7.992E-07	3.256E-16	1.326E-25	5.403E-35	2.201E-44	3.653E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR-93	5.170E-03	5.170E-03	5.170E-03	5.170E-03	5.170E-03	5.170E-03	5.170E-03	5.169E-03	5.169E-03	5.169E-03
ZR-95	6.280E-06	1.627E-14	4.216E-23	1.092E-31	2.830E-40	1.900E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-93M	1.466E-03	2.240E-03	2.841E-03	3.306E-03	3.667E-03	4.163E-03	4.562E-03	4.749E-03	4.836E-03	4.884E-03

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
NB-94	5.086E-04	5.085E-04	5.084E-04	5.084E-04	5.083E-04	5.081E-04	5.078E-04	5.076E-04	5.073E-04	5.070E-04
NB-95	1.394E-05	3.613E-14	9.360E-23	2.425E-31	6.284E-40	4.218E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-95M	4.660E-08	1.208E-16	3.128E-25	8.104E-34	2.100E-42	1.410E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO-93	2.140E-04	2.138E-04	2.136E-04	2.134E-04	2.132E-04	2.127E-04	2.121E-04	2.115E-04	2.108E-04	2.100E-04
TC-99	2.682E-02	2.682E-02	2.682E-02	2.682E-02	2.682E-02	2.682E-02	2.681E-02	2.681E-02	2.681E-02	2.681E-02
RU-103	1.208E-11	1.249E-25	1.292E-39	1.336E-53	1.381E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU-106	6.880E+00	2.215E-01	7.132E-03	2.296E-04	7.394E-06	7.664E-09	2.558E-13	8.538E-18	2.850E-22	3.062E-28
RH-103M	1.089E-11	1.126E-25	1.164E-39	1.204E-53	1.245E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH-106	6.880E+00	2.215E-01	7.132E-03	2.296E-04	7.394E-06	7.665E-09	2.558E-13	8.538E-18	2.850E-22	3.062E-28
PD-107	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05	4.694E-05
AG-110	8.759E-05	5.545E-07	3.510E-09	2.222E-11	1.407E-13	5.639E-18	1.431E-24	3.630E-31	9.212E-38	1.480E-46
AG-110M	6.585E-03	4.169E-05	2.639E-07	1.671E-09	1.058E-11	4.240E-16	1.076E-22	2.729E-29	6.926E-36	1.113E-44
AG-111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-113M	2.366E-02	1.866E-02	1.472E-02	1.161E-02	9.155E-03	5.695E-03	2.794E-03	1.371E-03	6.724E-04	2.601E-04
CD-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-115M	2.911E-13	1.396E-25	6.689E-38	3.206E-50	1.537E-62	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114	1.148E-12	9.216E-24	7.397E-35	5.937E-46	4.766E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114M	1.200E-12	9.629E-24	7.729E-35	6.204E-46	4.980E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-115M	2.043E-17	9.794E-30	4.695E-42	2.251E-54	1.079E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-119M	1.829E-01	1.048E-03	5.999E-06	3.435E-08	1.967E-10	6.449E-15	1.210E-21	2.273E-28	4.266E-35	4.586E-44
SN-121M	3.765E-03	3.513E-03	3.278E-03	3.058E-03	2.854E-03	2.484E-03	2.018E-03	1.639E-03	1.332E-03	1.009E-03
SN-123	2.127E-04	1.187E-08	6.626E-13	3.698E-17	2.064E-21	6.431E-30	1.118E-42	1.944E-55	3.380E-68	3.280E-85
SN-125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-126	8.042E-04	8.042E-04	8.042E-04	8.041E-04	8.041E-04	8.041E-04	8.040E-04	8.039E-04	8.038E-04	8.037E-04
SB-124	1.148E-09	8.584E-19	6.416E-28	4.795E-37	3.585E-46	2.003E-64	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB-125	5.752E+00	1.647E+00	4.718E-01	1.351E-01	3.870E-02	3.174E-03	7.457E-05	1.752E-06	4.115E-08	2.769E-10
SB-126	1.126E-04	1.126E-04	1.126E-04	1.126E-04	1.126E-04	1.126E-04	1.126E-04	1.125E-04	1.125E-04	1.125E-04
SB-126M	8.042E-04	8.042E-04	8.042E-04	8.041E-04	8.041E-04	8.041E-04	8.040E-04	8.039E-04	8.038E-04	8.037E-04
TE-123M	6.604E-07	1.695E-11	4.352E-16	1.117E-20	2.868E-25	1.890E-34	3.197E-48	5.409E-62	9.150E-76	3.974E-94
TE-125M	1.403E+00	4.020E-01	1.151E-01	3.297E-02	9.442E-03	7.745E-04	1.819E-05	4.274E-07	1.004E-08	6.754E-11
TE-127	8.178E-05	7.459E-10	6.803E-15	6.205E-20	5.660E-25	4.708E-35	3.572E-50	2.711E-65	2.057E-80	1.423-100
TE-127M	8.349E-05	7.615E-10	6.946E-15	6.335E-20	5.778E-25	4.807E-35	3.647E-50	2.767E-65	2.100E-80	1.453-100
TE-129	1.045E-15	4.659E-32	2.077E-48	9.261E-65	4.129E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE-129M	1.605E-15	7.157E-32	3.191E-48	1.423E-64	6.343E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I-129	4.742E-05	4.742E-05	4.742E-05	4.742E-05	4.742E-05	4.742E-05	4.742E-05	4.742E-05	4.742E-05	4.742E-05

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
I-131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-134	4.354E+01	8.116E+00	1.514E+00	2.821E-01	5.260E-02	1.828E-03	1.184E-05	7.678E-08	4.975E-10	6.011E-13
CS-135	1.314E-03	1.314E-03	1.314E-03	1.314E-03	1.314E-03	1.313E-03	1.313E-03	1.313E-03	1.313E-03	1.313E-03
CS-136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-137	1.821E+02	1.622E+02	1.445E+02	1.288E+02	1.147E+02	9.108E+01	6.442E+01	4.556E+01	3.222E+01	2.031E+01
BA-136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA-137M	1.723E+02	1.535E+02	1.367E+02	1.218E+02	1.085E+02	8.616E+01	6.094E+01	4.310E+01	3.048E+01	1.921E+01
BA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-141	2.429E-14	3.072E-31	3.886E-48	4.914E-65	6.216E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-142	5.961E-08	5.961E-08	5.961E-08	5.961E-08	5.961E-08	5.961E-08	5.961E-08	5.961E-08	5.961E-08	5.961E-08
CE-144	2.238E+01	2.613E-01	3.051E-03	3.563E-05	4.160E-07	5.673E-11	9.032E-17	1.438E-22	2.290E-28	4.257E-36
PR-143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR-144	2.238E+01	2.613E-01	3.051E-03	3.563E-05	4.161E-07	5.673E-11	9.032E-17	1.438E-22	2.290E-28	4.257E-36
PR-144M	2.685E-01	3.136E-03	3.662E-05	4.276E-07	4.993E-09	6.807E-13	1.084E-18	1.726E-24	2.748E-30	5.108E-38
ND-144	3.266E-12	3.274E-12	3.274E-12	3.274E-12	3.274E-12	3.274E-12	3.274E-12	3.274E-12	3.274E-12	3.274E-12
ND-147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-145	7.672E-05	6.381E-05	5.249E-05	4.316E-05	3.549E-05	2.400E-05	1.334E-05	7.418E-06	4.125E-06	1.886E-06
PM-147	7.518E+01	2.008E+01	5.363E+00	1.432E+00	3.826E-01	2.729E-02	5.201E-04	9.910E-06	1.888E-07	9.610E-10
PM-148M	2.623E-12	1.304E-25	6.487E-39	3.226E-52	1.604E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-148	1.477E-13	7.347E-27	3.654E-40	1.817E-53	9.037E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM-145	1.629E-05	3.948E-07	9.566E-09	2.318E-10	5.617E-12	3.299E-15	4.694E-20	6.679E-25	9.504E-30	3.277E-36
SM-147	9.760E-09	1.112E-08	1.148E-08	1.157E-08	1.160E-08	1.161E-08	1.161E-08	1.161E-08	1.161E-08	1.161E-08
SM-151	6.322E-01	6.083E-01	5.853E-01	5.633E-01	5.420E-01	5.019E-01	4.471E-01	3.984E-01	3.550E-01	3.043E-01
EU-152	1.646E-02	1.276E-02	9.891E-03	7.667E-03	5.943E-03	3.572E-03	1.664E-03	7.750E-04	3.610E-04	1.303E-04
EU-154	8.198E+00	5.481E+00	3.663E+00	2.449E+00	1.637E+00	7.318E-01	2.187E-01	6.531E-02	1.951E-02	3.897E-03
EU-155	3.528E+00	1.755E+00	8.727E-01	4.341E-01	2.159E-01	5.341E-02	6.573E-03	8.089E-04	9.954E-05	6.092E-06
EU-156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD-153	7.084E-04	3.804E-06	2.043E-08	1.097E-10	5.889E-13	1.699E-17	2.629E-24	4.072E-31	6.305E-38	5.243E-47
TB-160	1.022E-08	2.577E-16	6.501E-24	1.639E-31	4.134E-39	2.630E-54	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL-206	1.413E-11	1.413E-11	1.413E-11	1.413E-11	1.413E-11	1.413E-11	1.413E-11	1.413E-11	1.413E-11	1.413E-11
TL-207	1.037E-08	1.891E-08	2.806E-08	3.771E-08	4.779E-08	6.898E-08	1.027E-07	1.379E-07	1.741E-07	2.232E-07
TL-208	7.503E-06	9.521E-06	9.883E-06	9.676E-06	9.301E-06	8.472E-06	7.335E-06	6.350E-06	5.497E-06	4.538E-06

DECAY TIMES (years out of core)

(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
PB-210	3.226E-12	4.100E-12	7.451E-12	1.514E-11	2.943E-11	8.833E-11	2.970E-10	7.267E-10	1.465E-09	3.078E-09
PB-211	1.040E-08	1.897E-08	2.813E-08	3.781E-08	4.793E-08	6.917E-08	1.030E-07	1.383E-07	1.746E-07	2.238E-07
PB-212	2.088E-05	2.650E-05	2.751E-05	2.693E-05	2.589E-05	2.358E-05	2.042E-05	1.767E-05	1.530E-05	1.263E-05
BI-211	1.040E-08	1.897E-08	2.813E-08	3.781E-08	4.793E-08	6.917E-08	1.030E-07	1.383E-07	1.746E-07	2.238E-07
BI-212	2.088E-05	2.650E-05	2.751E-05	2.693E-05	2.589E-05	2.358E-05	2.042E-05	1.767E-05	1.530E-05	1.263E-05
PO-212	1.338E-05	1.698E-05	1.762E-05	1.725E-05	1.659E-05	1.511E-05	1.308E-05	1.132E-05	9.801E-06	8.093E-06
PO-215	1.040E-08	1.897E-08	2.813E-08	3.781E-08	4.793E-08	6.917E-08	1.030E-07	1.383E-07	1.746E-07	2.238E-07
PO-216	2.088E-05	2.650E-05	2.751E-05	2.693E-05	2.589E-05	2.358E-05	2.042E-05	1.767E-05	1.530E-05	1.263E-05
RN-219	1.040E-08	1.897E-08	2.813E-08	3.781E-08	4.793E-08	6.917E-08	1.030E-07	1.383E-07	1.746E-07	2.238E-07
RN-220	2.088E-05	2.650E-05	2.751E-05	2.693E-05	2.589E-05	2.358E-05	2.042E-05	1.767E-05	1.530E-05	1.263E-05
FR-223	1.434E-10	2.615E-10	3.877E-10	5.211E-10	6.603E-10	9.535E-10	1.420E-09	1.907E-09	2.407E-09	3.086E-09
RA-223	1.040E-08	1.897E-08	2.813E-08	3.781E-08	4.793E-08	6.917E-08	1.030E-07	1.383E-07	1.746E-07	2.238E-07
RA-224	2.088E-05	2.650E-05	2.751E-05	2.693E-05	2.589E-05	2.358E-05	2.042E-05	1.767E-05	1.530E-05	1.263E-05
RA-226	4.133E-12	1.597E-11	4.084E-11	8.342E-11	1.482E-10	3.618E-10	9.513E-10	1.951E-09	3.448E-09	6.346E-09
RA-228	9.586E-10	1.212E-09	1.363E-09	1.453E-09	1.507E-09	1.559E-09	1.581E-09	1.587E-09	1.589E-09	1.590E-09
AC-227	1.039E-08	1.895E-08	2.810E-08	3.776E-08	4.785E-08	6.909E-08	1.029E-07	1.382E-07	1.744E-07	2.236E-07
TH-227	1.025E-08	1.870E-08	2.775E-08	3.729E-08	4.727E-08	6.822E-08	1.016E-07	1.364E-07	1.722E-07	2.207E-07
TH-228	2.088E-05	2.648E-05	2.748E-05	2.691E-05	2.586E-05	2.357E-05	2.041E-05	1.767E-05	1.530E-05	1.263E-05
TH-229	3.004E-09	5.147E-09	7.299E-09	9.457E-09	1.162E-08	1.598E-08	2.256E-08	2.921E-08	3.593E-08	4.499E-08
TH-230	3.216E-09	8.123E-09	1.526E-08	2.455E-08	3.591E-08	6.449E-08	1.209E-07	1.921E-07	2.762E-07	4.062E-07
TH-231	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04
TH-232	1.586E-09	1.586E-09	1.586E-09	1.587E-09	1.587E-09	1.587E-09	1.588E-09	1.589E-09	1.589E-09	1.590E-09
TH-234	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05
PA-231	6.209E-08	7.470E-08	8.731E-08	9.992E-08	1.125E-07	1.377E-07	1.755E-07	2.133E-07	2.511E-07	3.014E-07
PA-233	8.056E-04	8.063E-04	8.072E-04	8.084E-04	8.097E-04	8.128E-04	8.178E-04	8.232E-04	8.286E-04	8.358E-04
PA-234M	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05
PA-234	2.381E-08	2.381E-08	2.381E-08	2.381E-08	2.381E-08	2.381E-08	2.381E-08	2.381E-08	2.381E-08	2.381E-08
U-232	2.624E-05	2.789E-05	2.744E-05	2.640E-05	2.524E-05	2.295E-05	1.987E-05	1.720E-05	1.489E-05	1.228E-05
U-233	4.538E-06	4.556E-06	4.573E-06	4.591E-06	4.608E-06	4.644E-06	4.697E-06	4.750E-06	4.804E-06	4.876E-06
U-234	8.363E-05	1.343E-04	1.830E-04	2.298E-04	2.748E-04	3.596E-04	4.750E-04	5.774E-04	6.684E-04	7.742E-04
U-235	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04	1.193E-04
U-236	9.030E-04	9.030E-04	9.030E-04	9.030E-04	9.031E-04	9.031E-04	9.031E-04	9.031E-04	9.032E-04	9.032E-04
U-237	7.017E-06	5.517E-06	4.337E-06	3.410E-06	2.681E-06	1.657E-06	8.054E-07	3.914E-07	1.902E-07	7.269E-08
U-238	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05	1.832E-05
NP-237	8.056E-04	8.063E-04	8.072E-04	8.084E-04	8.097E-04	8.128E-04	8.178E-04	8.232E-04	8.286E-04	8.358E-04

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
PU-236	1.067E-04	3.166E-05	9.396E-06	2.789E-06	8.285E-07	7.395E-08	2.987E-09	1.132E-09	1.084E-09	1.082E-09
PU-237	3.072E-15	2.751E-27	2.465E-39	2.208E-51	1.978E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU-238	3.647E+00	3.506E+00	3.371E+00	3.240E+00	3.115E+00	2.878E+00	2.557E+00	2.272E+00	2.018E+00	1.724E+00
PU-239	9.350E-02	9.349E-02	9.347E-02	9.346E-02	9.345E-02	9.342E-02	9.338E-02	9.334E-02	9.330E-02	9.325E-02
PU-240	7.665E-02	7.674E-02	7.680E-02	7.685E-02	7.689E-02	7.692E-02	7.690E-02	7.684E-02	7.675E-02	7.661E-02
PU-241	2.860E+01	2.249E+01	1.768E+01	1.390E+01	1.093E+01	6.756E+00	3.283E+00	1.596E+00	7.754E-01	2.963E-01
PU-242	3.320E-04	3.320E-04	3.320E-04	3.320E-04	3.320E-04	3.320E-04	3.320E-04	3.320E-04	3.320E-04	3.320E-04
PU-244	4.447E-11	4.447E-11	4.447E-11	4.447E-11	4.447E-11	4.447E-11	4.447E-11	4.447E-11	4.447E-11	4.447E-11
AM-241	3.036E-01	5.040E-01	6.595E-01	7.796E-01	8.720E-01	9.960E-01	1.086E+00	1.116E+00	1.117E+00	1.097E+00
AM-242M	1.627E-03	1.590E-03	1.554E-03	1.519E-03	1.485E-03	1.419E-03	1.325E-03	1.237E-03	1.156E-03	1.055E-03
AM-242	1.618E-03	1.582E-03	1.546E-03	1.512E-03	1.477E-03	1.412E-03	1.318E-03	1.231E-03	1.150E-03	1.050E-03
AM-243	2.061E-03	2.060E-03	2.059E-03	2.058E-03	2.057E-03	2.055E-03	2.052E-03	2.049E-03	2.046E-03	2.042E-03
CM-242	5.433E-03	1.311E-03	1.279E-03	1.251E-03	1.222E-03	1.167E-03	1.090E-03	1.018E-03	9.510E-04	8.682E-04
CM-243	2.544E-03	2.253E-03	1.995E-03	1.767E-03	1.565E-03	1.227E-03	8.523E-04	5.919E-04	4.111E-04	2.528E-04
CM-244	2.728E-01	2.253E-01	1.861E-01	1.537E-01	1.270E-01	8.661E-02	4.880E-02	2.749E-02	1.549E-02	7.209E-03
CM-245	2.599E-05	2.598E-05	2.597E-05	2.596E-05	2.595E-05	2.593E-05	2.590E-05	2.586E-05	2.583E-05	2.579E-05
CM-246	3.089E-06	3.087E-06	3.085E-06	3.083E-06	3.080E-06	3.076E-06	3.069E-06	3.062E-06	3.056E-06	3.047E-06
CM-247	7.681E-12	7.681E-12	7.681E-12	7.681E-12	7.681E-12	7.681E-12	7.681E-12	7.681E-12	7.681E-12	7.681E-12
SUBTOTAL**	1.083E+03	7.579E+02	6.237E+02	5.358E+02	4.679E+02	3.641E+02	2.544E+02	1.793E+02	1.271E+02	8.087E+01
TOTAL***	1.093E+03	7.601E+02	6.245E+02	5.363E+02	4.684E+02	3.644E+02	2.546E+02	1.795E+02	1.272E+02	8.096E+01

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Template 28

Fuel-Specific Source Term Calculations Stainless Steel-Clad TRIGA Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a generic source term for stainless steel-clad TRIGA (Training, Research, and Isotope General Atomics) spent nuclear fuel elements currently stored at the INEEL. The data sources for the analysis are documented in References 1 and 2, and the INEEL calculational methodology is described in detail in Reference 3.

TRIGA Data

TRIGA reactors are light-water-cooled reactors designed for training, research, and isotope production. One type of fuel element used in a TRIGA reactor is a stainless steel-clad, uranium-zirconium-hydride (U-Zr-H) fuel element. The enriched uranium is homogeneously mixed in the ZrH matrix. The cylindrical active fuel region in each stainless steel-clad element is approximately 1.4 in. in diameter and 15 in. in length. Figure 1 shows a typical stainless steel-clad fuel element with dimensions and materials. The data below give specific dimensions, materials, loadings, densities, enrichment, etc., for the stainless steel-clad element used in the burnup calculation for the source term generation.

Fuel Element:

Fuel Meat:	U-Zr-H Zr:H ratio is 1.7 Density = 5.76 g/cc
Clad:	Stainless Steel Density = 7.92 g/cc
Loading:	39.0 g/element U-235 BOL 156.0 g/element U-238 BOL 195.0 g/element U BOL 2088.0 g/element ZrH in fuel meat 8.5 weight % U in U-ZrH _{1.7} 20% enrichment U-235 BOL 800.0 g/element stainless steel cladding (819.414 g/element with impurities) 450.0 g/element graphite top/bottom end reflectors 8.38 g/element molybdenum (single poison disc)

Active Fuel Length: 15 in.

Fuel Element Length: 29 in. (approximate)

Water Temperature: 77.5°F

Water Pressure: 14.7 psia

From the above data (materials, enrichments, and densities), material masses and number densities were calculated for all the material components in a single stainless steel-clad TRIGA fuel element. In addition, for the ORIGEN2 (Reference 4) depletion or burnup calculation, conservative and

detailed impurity concentrations were added for the stainless steel-clad, zirconium-hydride, and graphite end reflector masses. Table 1 gives the impurity concentrations for these three materials.

Burnup

Reference 1 is a parametric study and includes radionuclide inventories or source terms for eight different burnups ranging up to 17.95%. The burnup chosen for this template is based on the 17.95% burnup of the initial U-235 or the maximum burnup used in the parametric study. This burnup is equivalent to 6.65 MWd, 34,103 MWd/MTU, and 8.08 g U-235 depleted per element and represents the upper end of typical stainless steel-clad TRIGA fuel element burnups. The assumption of maximum burnup is conservative for the buildup of fission products, activation products, and minor actinides in the source term and nonconservative with regard to criticality safety.

Cross-Section Development

An MCNP4A (Reference 5) partial core model of a MARK I TRIGA reactor core was used to generate neutron cross sections specifically for the stainless steel-clad TRIGA fuel element. The MCNP4A one-twelfth core model is shown in Figure 2. The cross sections are spectrally and spatially weighted over all the fuel elements shown in Figure 2. These cross sections are in turn used in the fuel element ORIGEN2 depletion calculation.

Parametric TRIGA Single Element Exposure History

Table 2 summarizes the single element exposure history of the stainless steel-clad TRIGA fuel element from Reference 1. The burnup period is a hypothetical 4-year continuous exposure. TRIGA fuel elements typically remain in the core for much longer periods of time relative to the assumed 4-year in-core residency. Therefore, typical fuel elements would have more time to decay away their source term; therefore, the 4-year assumption is expected to produce a conservative source term.

Burnup Calculation

The ORIGEN2 computer code was used to perform the depletion or burnup calculation for the stainless steel-clad TRIGA fuel element. The radionuclide inventory or source term template that follows is for a single stainless steel-clad TRIGA fuel element. The fuel element component masses and impurities (fuel meat, uranium, clad, burnable poison, end fixtures), neutron cross sections, burnup, and hypothetical power history and power level as discussed above are input data for the ORIGEN2 calculation. The radionuclide concentrations are given as a function of decay time in the template table.

The 145 radionuclides listed in the template represent greater than 99.9% of the total curie inventory had all 684 activation products, 880 fission products, and 127 actinide/daughter isotopes from the ORIGEN2 output been included in the template.

References

1. J. W. Sterbentz, *Radionuclide Mass Inventory, Activity, Decay Heat, and Dose Rate Parametric Data for TRIGA Spent Nuclear Fuels*, INEL-96/0482, Idaho National Engineering Laboratory, March 1997.
2. N. Tomsio, *Characterization of TRIGA Fuel*, ORNL/Sub//86-22047/3, GA-C18542, GA Technologies, October 1986.

3. J. W. Sterbentz and C. A. Wemple, "Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels", INEL-96/0304, September 1996.
4. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.
5. "MCNP4A: Monte Carlo N-Particle Transport Code System," LA-12625M, contributed by Los Alamos National Laboratory, Los Alamos, New Mexico, 1994, and distributed as package CCC-200 by Oak Ridge National Laboratory.

Table 1. Material constituent and impurity concentrations for the various materials in a stainless steel-clad TRIGA fuel element.

Constituent or Impurity	Graphite Concentration (ppm)	ZrH Concentration (wt%)	Stainless Steel Concentration (ppm)
H		1.8439	
Li	0.45		0.13
Be	0.005		
B	2.5	0.00005	
C	100 wt%	0.026968	0.08 wt%
N		0.00799	525
O		0.094887	
Na	10.4		37
Mg	1		
Al	4.1	0.007491	200
Si	26	0.011986	1.00 wt%
P	1	0.009988	
S	9.4	0.003496	
Cl	3		130
K	3		3
Ca	22.5		19
Sc	0.01		0.03
Ti	16	0.004994	600
V	18.9	0.004994	690
Cr	1	0.124851	18.40 wt%
Mn	1	0.004994	1.53 wt%
Fe	11.1	0.224731	68.99 wt%
Co	4	0.001998	2570
Ni	4.6	0.006992	10.00 wt%
Cu	0.47	0.004994	8150
Zn	1	0.009988	2230
Ga			450
As			1010
Se			70
Br			8
Rb	1		10
Sr	0.47		0.2
Y			5
Zr	0.5	98.1560	20
Nb	1.74	0.006992	300
Mo	1	0.004994	5500
Ag	0.5		2

Table 1. (continued).

Constituent or Impurity	Graphite Concentration (ppm)	ZrH Concentration (wt%)	Stainless Steel Concentration (ppm)
Cd	0.5	0.000050	
In	1		
Sn	1	1.598089	
Sb	1		17
Cs	1		0.3
Ba	2.9		500
La	1.38		2.1
Ce	0.56		550
Pr	0.64		
Nd	0.36		
Sm	0.61	0.000999	0.15
Eu			0.02
Gd	0.08	0.000499	
Tb	0.26		0.71
Dy	0.16		1
Ho	0.08		1
Er	0.04		
Tm	0.04		
Yb	0.06		2
Lu	0.02		0.8
Hf	0.17	0.003496	2
Ta	0.35	0.019976	
W	25.5	0.009988	520
Tl	1		
Pb	6.9	0.009988	139
Bi	1		
Th		0.000699	1
U		0.000350	2

Table 2. Hypothetical power history for a maximum burnup stainless steel-clad TRIGA fuel element

Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MWth)
365	365	0.004555
365	730	0.004555
365	1095	0.004555
365	1460	0.004555
1825	3285	0.0
1825	5110	0.0
1825	6935	0.0
1825	8760	0.0
1825	10585	0.0
3650	14235	0.0
5475	19710	0.0
5475	25185	0.0
5475	30660	0.0
7300	37960	0.0

The ten decay times following the hypothetical 4-year exposure are for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling time periods designated for the template methodology.

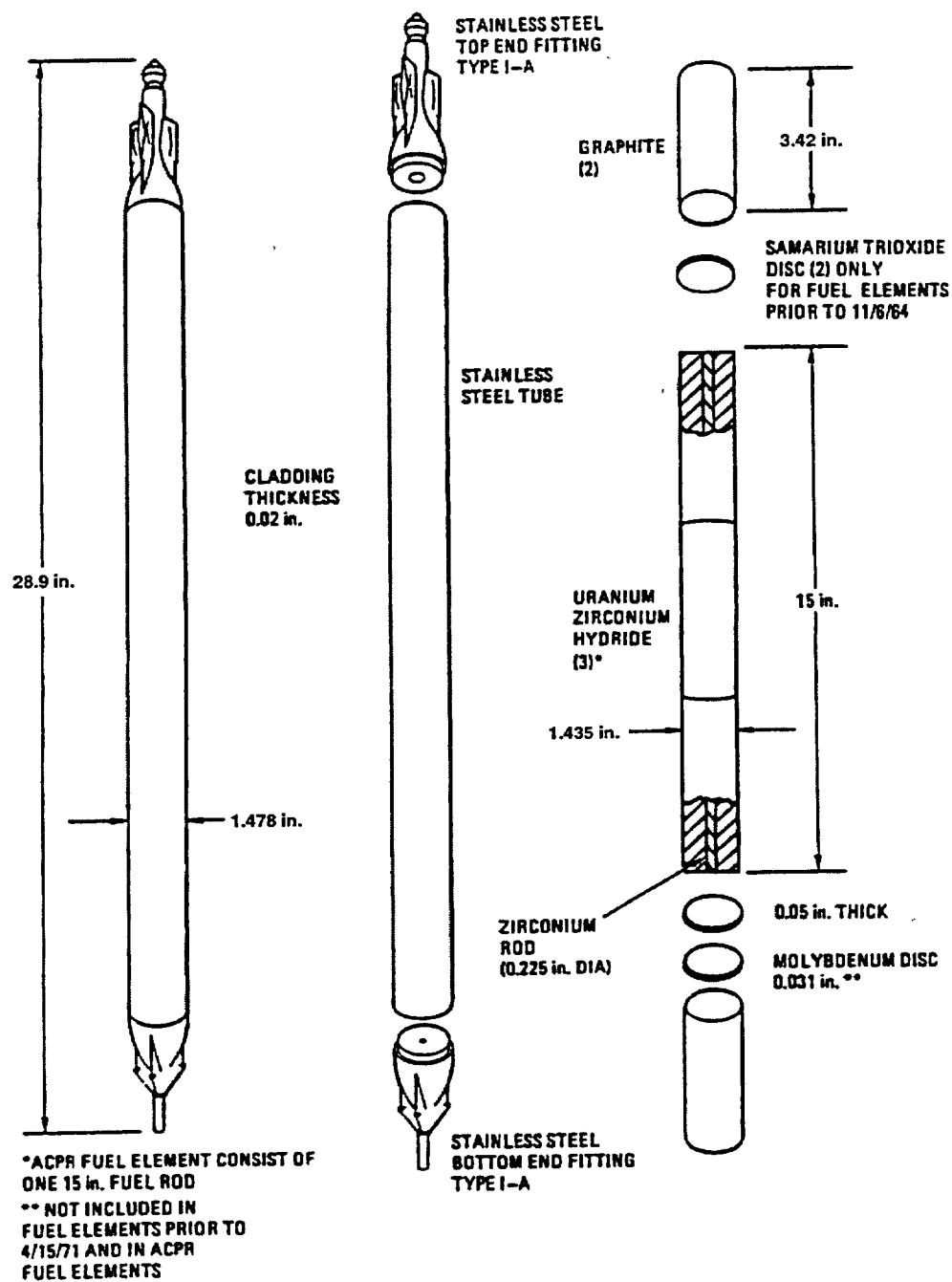


Figure 1. A typical stainless steel-clad Mark I TRIGA fuel element.

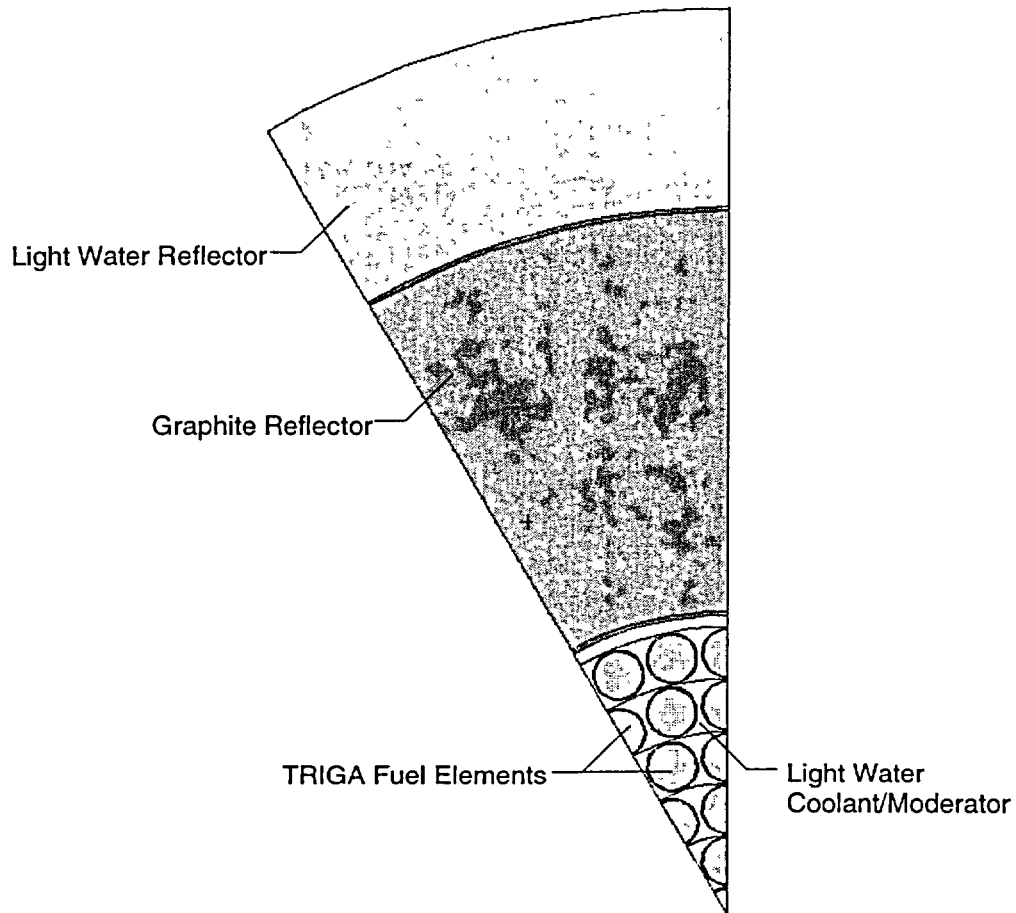


Figure 2. MCNP partial core model of a Mark I TRIGA reactor core.

TRIGA Element

Stainless Steel Cladding, 10 to 20% Enriched U-235 Fuel

Reactor Moderator/Coolant: Light Water
Fuel Meat: U-Zr-H₁₇
Clad: Stainless Steel
Burnup: 6.65 MWd/element (maximum element burnup)
Burnup: 17.95% U-235 burnup (amount fissioned)
Burnup: 8.08 g U-235 depletion (amount fissioned and transmuted)
Basis of Calculation: Single element
BOL U-235: 39.0 grams U-235 per element (design basis)
BOL U-238: 156.0 grams U-238 per element
BOL Total U per element: 195.0 grams U per element
BOL Fuel Enrichment: 20.0 wt%

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
H-3	7.389E-02	5.582E-02	4.217E-02	3.185E-02	2.406E-02	1.373E-02	5.921E-03	2.552E-03	1.100E-03	3.583E-04
BE-10	1.334E-07	1.334E-07	1.334E-07	1.334E-07	1.334E-07	1.334E-07	1.334E-07	1.334E-07	1.334E-07	1.334E-07
C-14	8.559E-04	8.554E-04	8.548E-04	8.543E-04	8.538E-04	8.528E-04	8.512E-04	8.497E-04	8.481E-04	8.461E-04
CL-36	1.870E-05	1.870E-05	1.870E-05	1.870E-05	1.870E-05	1.870E-05	1.870E-05	1.870E-05	1.870E-05	1.870E-05
CR-51	6.851E-19	1.020E-38	1.518E-58	2.260E-78	3.364E-98	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MN-54	4.834E-02	8.439E-04	1.473E-05	2.572E-07	4.490E-09	1.368E-12	7.281E-18	3.874E-23	2.061E-28	1.914E-35
FE-55	5.131E+00	1.354E+00	3.574E-01	9.433E-02	2.490E-02	1.734E-03	3.189E-05	5.863E-07	1.078E-08	5.231E-11
FE-59	5.296E-13	3.277E-25	2.028E-37	1.255E-49	7.766E-62	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CO-60	8.538E+00	4.425E+00	2.293E+00	1.189E+00	6.161E-01	1.655E-01	2.304E-02	3.208E-03	4.466E-04	3.223E-05
NI-59	3.612E-03	3.612E-03	3.611E-03	3.611E-03	3.611E-03	3.611E-03	3.610E-03	3.610E-03	3.609E-03	3.609E-03
NI-63	4.280E-01	4.122E-01	3.970E-01	3.823E-01	3.682E-01	3.415E-01	3.050E-01	2.724E-01	2.433E-01	2.093E-01
ZN-65	1.938E-03	1.083E-05	6.050E-08	3.380E-10	1.889E-12	5.896E-17	1.028E-23	1.794E-30	3.129E-37	3.049E-46
SE-79	8.657E-05	8.656E-05	8.656E-05	8.655E-05	8.655E-05	8.654E-05	8.653E-05	8.651E-05	8.650E-05	8.648E-05
KR-85	1.680E+00	1.216E+00	8.802E-01	6.372E-01	4.613E-01	2.417E-01	9.171E-02	3.479E-02	1.320E-02	3.625E-03
RB-87	5.922E-09	5.922E-09	5.922E-09	5.922E-09	5.922E-09	5.922E-09	5.922E-09	5.922E-09	5.922E-09	5.922E-09
SR-89	2.308E-09	3.048E-20	4.025E-31	5.314E-42	7.016E-53	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR-90	1.732E+01	1.538E+01	1.366E+01	1.212E+01	1.077E+01	8.487E+00	5.940E+00	4.157E+00	2.910E+00	1.808E+00
Y-90	1.733E+01	1.538E+01	1.366E+01	1.213E+01	1.077E+01	8.489E+00	5.941E+00	4.159E+00	2.911E+00	1.809E+00
Y-91	8.787E-08	3.580E-17	1.458E-26	5.942E-36	2.421E-45	4.017E-64	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR-93	5.294E-04	5.294E-04	5.294E-04	5.294E-04	5.293E-04	5.293E-04	5.293E-04	5.293E-04	5.293E-04	5.292E-04
ZR-95	6.666E-07	1.727E-15	4.475E-24	1.159E-32	3.004E-41	2.017E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-93M	1.502E-04	2.295E-04	2.910E-04	3.386E-04	3.756E-04	4.263E-04	4.672E-04	4.862E-04	4.951E-04	5.001E-04

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
NB-94	5.404E-05	5.403E-05	5.402E-05	5.401E-05	5.400E-05	5.398E-05	5.395E-05	5.393E-05	5.390E-05	5.386E-05
NB-95	1.479E-06	3.834E-15	9.934E-24	2.574E-32	6.669E-41	4.477E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB-95M	4.946E-09	1.281E-17	3.319E-26	8.601E-35	2.228E-43	1.496E-60	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO-93	6.219E-05	6.213E-05	6.207E-05	6.201E-05	6.194E-05	6.182E-05	6.164E-05	6.146E-05	6.127E-05	6.103E-05
TC-99	2.942E-03	2.942E-03	2.942E-03	2.942E-03	2.942E-03	2.942E-03	2.942E-03	2.942E-03	2.942E-03	2.941E-03
RU-103	1.277E-12	1.321E-26	1.366E-40	1.413E-54	1.461E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU-106	6.097E-01	1.963E-02	6.320E-04	2.035E-05	6.552E-07	6.792E-10	2.267E-14	7.566E-19	2.525E-23	2.714E-29
RH-103M	1.152E-12	1.191E-26	1.232E-40	1.274E-54	1.317E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH-106	6.097E-01	1.963E-02	6.320E-04	2.035E-05	6.552E-07	6.792E-10	2.267E-14	7.566E-19	2.525E-23	2.714E-29
PD-107	4.165E-06	4.165E-06	4.165E-06	4.165E-06	4.165E-06	4.165E-06	4.165E-06	4.165E-06	4.165E-06	4.165E-06
AG-110	1.079E-06	6.829E-09	4.323E-11	2.737E-13	1.733E-15	6.944E-20	1.763E-26	4.471E-33	1.135E-39	1.822E-48
AG-110M	8.110E-05	5.134E-07	3.250E-09	2.057E-11	1.303E-13	5.221E-18	1.325E-24	3.362E-31	8.530E-38	1.370E-46
AG-111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-113M	2.149E-03	1.695E-03	1.337E-03	1.054E-03	8.314E-04	5.172E-04	2.537E-04	1.245E-04	6.106E-05	2.362E-05
CD-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD-115M	3.028E-14	1.451E-26	6.958E-39	3.335E-51	1.599E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114	1.220E-14	9.789E-26	7.858E-37	6.307E-48	5.062E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-114M	1.274E-14	1.023E-25	8.211E-37	6.590E-48	5.290E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN-115M	2.126E-18	1.019E-30	4.885E-43	2.342E-55	1.123E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-119M	1.626E-02	9.310E-05	5.330E-07	3.052E-09	1.747E-11	5.730E-16	1.076E-22	2.019E-29	3.791E-36	4.075E-45
SN-121M	3.857E-04	3.598E-04	3.358E-04	3.133E-04	2.923E-04	2.545E-04	2.067E-04	1.680E-04	1.364E-04	1.034E-04
SN-123	2.044E-05	1.141E-09	6.368E-14	3.555E-18	1.984E-22	6.180E-31	1.074E-43	1.868E-56	3.248E-69	3.152E-86
SN-125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN-126	8.091E-05	8.091E-05	8.090E-05	8.090E-05	8.090E-05	8.089E-05	8.088E-05	8.088E-05	8.087E-05	8.086E-05
SB-124	3.777E-11	2.823E-20	2.110E-29	1.577E-38	1.179E-47	6.588E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB-125	5.772E-01	1.653E-01	4.735E-02	1.356E-02	3.884E-03	3.186E-04	7.483E-06	1.758E-07	4.129E-09	2.778E-11
SB-126	1.133E-05	1.133E-05	1.133E-05	1.133E-05	1.133E-05	1.132E-05	1.132E-05	1.132E-05	1.132E-05	1.132E-05
SB-126M	8.091E-05	8.091E-05	8.090E-05	8.090E-05	8.090E-05	8.089E-05	8.088E-05	8.088E-05	8.087E-05	8.086E-05
TE-123M	3.346E-09	8.588E-14	2.204E-18	5.659E-23	1.453E-27	9.574E-37	1.620E-50	2.739E-64	4.635E-78	2.013E-96
TE-125M	1.408E-01	4.033E-02	1.155E-02	3.309E-03	9.475E-04	7.772E-05	1.826E-06	4.288E-08	1.008E-09	6.778E-12
TE-127	8.388E-06	7.650E-11	6.978E-16	6.364E-21	5.805E-26	4.829E-36	3.664E-51	2.780E-66	2.109E-81	1.460-101
TE-127M	8.563E-06	7.811E-11	7.124E-16	6.498E-21	5.926E-26	4.930E-36	3.741E-51	2.838E-66	2.153E-81	1.490-101
TE-129	1.157E-16	5.160E-33	2.301E-49	1.026E-65	4.573E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE-129M	1.778E-16	7.927E-33	3.534E-49	1.576E-65	7.025E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I-129	4.900E-06	4.900E-06	4.900E-06	4.900E-06	4.900E-06	4.900E-06	4.900E-06	4.900E-06	4.900E-06	4.900E-06

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
I-131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE-133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-134	6.021E-01	1.123E-01	2.093E-02	3.903E-03	7.275E-04	2.529E-05	1.638E-07	1.062E-09	6.882E-12	8.315E-15
CS-135	2.141E-04	2.141E-04	2.141E-04	2.141E-04	2.141E-04	2.141E-04	2.141E-04	2.141E-04	2.141E-04	2.141E-04
CS-136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS-137	1.833E+01	1.633E+01	1.455E+01	1.296E+01	1.155E+01	9.169E+00	6.485E+00	4.587E+00	3.244E+00	2.044E+00
BA-136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA-137M	1.734E+01	1.545E+01	1.377E+01	1.226E+01	1.093E+01	8.674E+00	6.135E+00	4.339E+00	3.069E+00	1.934E+00
BA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-141	2.771E-15	3.504E-32	4.432E-49	5.606E-66	7.090E-83	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE-142	7.084E-09	7.084E-09	7.084E-09	7.084E-09	7.084E-09	7.084E-09	7.084E-09	7.084E-09	7.084E-09	7.084E-09
CE-144	2.308E+00	2.695E-02	3.147E-04	3.675E-06	4.291E-08	5.850E-12	9.315E-18	1.483E-23	2.361E-29	4.390E-37
PR-143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR-144	2.308E+00	2.695E-02	3.147E-04	3.675E-06	4.291E-08	5.851E-12	9.315E-18	1.483E-23	2.361E-29	4.390E-37
PR-144M	2.770E-02	3.234E-04	3.776E-06	4.410E-08	5.149E-10	7.021E-14	1.118E-19	1.780E-25	2.834E-31	5.268E-39
ND-144	2.861E-13	2.870E-13	2.870E-13	2.870E-13	2.870E-13	2.870E-13	2.870E-13	2.870E-13	2.870E-13	2.870E-13
ND-147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-145	8.156E-06	6.776E-06	5.574E-06	4.583E-06	3.769E-06	2.548E-06	1.417E-06	7.878E-07	4.380E-07	2.003E-07
PM-147	1.398E+01	3.735E+00	9.976E-01	2.665E-01	7.117E-02	5.077E-03	9.674E-05	1.843E-06	3.512E-08	1.788E-10
PM-148M	8.755E-14	4.354E-27	2.165E-40	1.077E-53	5.356E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM-148	4.931E-15	2.453E-28	1.220E-41	6.066E-55	3.017E-68	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM-145	1.561E-06	3.782E-08	9.165E-10	2.221E-11	5.382E-13	3.160E-16	4.497E-21	6.399E-26	9.105E-31	3.140E-37
SM-147	1.801E-09	2.052E-09	2.119E-09	2.137E-09	2.142E-09	2.143E-09	2.144E-09	2.144E-09	2.144E-09	2.144E-09
SM-151	1.517E-01	1.460E-01	1.404E-01	1.352E-01	1.300E-01	1.204E-01	1.073E-01	9.560E-02	8.518E-02	7.302E-02
EU-152	9.765E-03	7.570E-03	5.869E-03	4.549E-03	3.526E-03	2.119E-03	9.871E-04	4.598E-04	2.142E-04	7.735E-05
EU-154	1.022E-01	6.828E-02	4.565E-02	3.052E-02	2.040E-02	9.118E-03	2.723E-03	8.138E-04	2.431E-04	4.856E-05
EU-155	1.948E-01	9.689E-02	4.820E-02	2.397E-02	1.192E-02	2.950E-03	3.630E-04	4.466E-05	5.496E-06	3.364E-07
EU-156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD-153	3.421E-05	1.837E-07	9.866E-10	5.298E-12	2.845E-14	8.203E-19	1.271E-25	1.967E-32	3.045E-39	2.532E-48
TB-160	4.416E-10	1.114E-17	2.809E-25	7.082E-33	1.786E-40	1.136E-55	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL-206	1.436E-12	1.436E-12	1.436E-12	1.436E-12	1.436E-12	1.436E-12	1.436E-12	1.436E-12	1.436E-12	1.436E-12
TL-207	2.810E-09	5.653E-09	9.117E-09	1.311E-08	1.756E-08	2.753E-08	4.450E-08	6.306E-08	8.260E-08	1.095E-07
TL-208	1.054E-07	1.127E-07	1.098E-07	1.052E-07	1.004E-07	9.126E-08	7.908E-08	6.853E-08	5.941E-08	4.915E-08

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
PB-210	1.703E-14	4.913E-14	1.142E-13	2.230E-13	3.857E-13	9.129E-13	2.350E-12	4.772E-12	8.392E-12	1.541E-11
PB-211	2.818E-09	5.669E-09	9.143E-09	1.315E-08	1.760E-08	2.760E-08	4.462E-08	6.324E-08	8.283E-08	1.098E-07
PB-212	2.932E-07	3.135E-07	3.056E-07	2.928E-07	2.795E-07	2.540E-07	2.201E-07	1.907E-07	1.653E-07	1.368E-07
BI-211	2.818E-09	5.669E-09	9.143E-09	1.315E-08	1.760E-08	2.760E-08	4.462E-08	6.324E-08	8.283E-08	1.098E-07
BI-212	2.932E-07	3.135E-07	3.056E-07	2.928E-07	2.795E-07	2.540E-07	2.201E-07	1.907E-07	1.653E-07	1.368E-07
PO-212	1.879E-07	2.009E-07	1.958E-07	1.876E-07	1.791E-07	1.627E-07	1.410E-07	1.222E-07	1.059E-07	8.765E-08
PO-215	2.818E-09	5.669E-09	9.143E-09	1.315E-08	1.760E-08	2.760E-08	4.462E-08	6.324E-08	8.283E-08	1.098E-07
PO-216	2.932E-07	3.135E-07	3.056E-07	2.928E-07	2.795E-07	2.540E-07	2.201E-07	1.907E-07	1.653E-07	1.368E-07
RN-219	2.818E-09	5.669E-09	9.143E-09	1.315E-08	1.760E-08	2.760E-08	4.462E-08	6.324E-08	8.283E-08	1.098E-07
RN-220	2.932E-07	3.135E-07	3.056E-07	2.928E-07	2.795E-07	2.540E-07	2.201E-07	1.907E-07	1.653E-07	1.368E-07
FR-223	3.887E-11	7.816E-11	1.260E-10	1.812E-10	2.426E-10	3.805E-10	6.152E-10	8.718E-10	1.142E-09	1.514E-09
RA-223	2.818E-09	5.669E-09	9.143E-09	1.315E-08	1.760E-08	2.760E-08	4.462E-08	6.324E-08	8.283E-08	1.098E-07
RA-224	2.932E-07	3.135E-07	3.056E-07	2.928E-07	2.795E-07	2.540E-07	2.201E-07	1.907E-07	1.653E-07	1.368E-07
RA-226	1.411E-13	3.510E-13	6.635E-13	1.087E-12	1.631E-12	3.109E-12	6.416E-12	1.119E-11	1.760E-11	2.892E-11
RA-228	1.018E-09	1.286E-09	1.445E-09	1.541E-09	1.597E-09	1.651E-09	1.675E-09	1.680E-09	1.681E-09	1.681E-09
AC-227	2.817E-09	5.664E-09	9.131E-09	1.313E-08	1.758E-08	2.757E-08	4.458E-08	6.317E-08	8.274E-08	1.097E-07
TH-227	2.779E-09	5.591E-09	9.017E-09	1.297E-08	1.736E-08	2.722E-08	4.401E-08	6.236E-08	8.169E-08	1.083E-07
TH-228	2.931E-07	3.133E-07	3.053E-07	2.925E-07	2.793E-07	2.539E-07	2.201E-07	1.907E-07	1.653E-07	1.368E-07
TH-229	5.293E-10	9.119E-10	1.294E-09	1.677E-09	2.059E-09	2.823E-09	3.969E-09	5.114E-09	6.258E-09	7.781E-09
TH-230	7.486E-11	1.203E-10	1.700E-10	2.238E-10	2.816E-10	4.083E-10	6.243E-10	8.684E-10	1.137E-09	1.530E-09
TH-231	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.687E-05	6.687E-05
TH-232	1.681E-09	1.681E-09	1.681E-09	1.681E-09	1.681E-09	1.681E-09	1.681E-09	1.681E-09	1.681E-09	1.682E-09
TH-234	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05
PA-231	1.854E-08	2.561E-08	3.268E-08	3.975E-08	4.682E-08	6.095E-08	8.214E-08	1.033E-07	1.245E-07	1.527E-07
PA-233	8.248E-06	8.264E-06	8.287E-06	8.315E-06	8.347E-06	8.420E-06	8.541E-06	8.670E-06	8.799E-06	8.971E-06
PA-234M	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05
PA-234	6.785E-08	6.785E-08	6.785E-08	6.785E-08	6.785E-08	6.785E-08	6.785E-08	6.785E-08	6.785E-08	6.785E-08
U-232	3.241E-07	3.113E-07	2.974E-07	2.836E-07	2.704E-07	2.456E-07	2.126E-07	1.840E-07	1.593E-07	1.314E-07
U-233	8.114E-07	8.115E-07	8.117E-07	8.119E-07	8.120E-07	8.124E-07	8.129E-07	8.134E-07	8.139E-07	8.146E-07
U-234	9.621E-07	1.059E-06	1.152E-06	1.241E-06	1.327E-06	1.489E-06	1.710E-06	1.906E-06	2.080E-06	2.284E-06
U-235	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.686E-05	6.687E-05	6.687E-05
U-236	8.440E-05	8.441E-05	8.441E-05	8.441E-05	8.441E-05	8.442E-05	8.442E-05	8.443E-05	8.443E-05	8.444E-05
U-237	1.663E-07	1.308E-07	1.028E-07	8.083E-08	6.355E-08	3.928E-08	1.909E-08	9.278E-09	4.509E-09	1.723E-09
U-238	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05	5.219E-05
NP-237	8.248E-06	8.264E-06	8.287E-06	8.315E-06	8.347E-06	8.420E-06	8.541E-06	8.670E-06	8.799E-06	8.971E-06

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
PU-236	9.008E-08	2.673E-08	7.935E-09	2.356E-09	7.002E-10	6.302E-11	3.091E-12	1.524E-12	1.483E-12	1.482E-12
PU-237	9.582E-19	8.583E-31	7.689E-43	6.887E-55	6.170E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU-238	6.905E-03	6.638E-03	6.382E-03	6.135E-03	5.898E-03	5.451E-03	4.843E-03	4.303E-03	3.823E-03	3.265E-03
PU-239	3.677E-02	3.677E-02	3.676E-02	3.676E-02	3.675E-02	3.674E-02	3.672E-02	3.671E-02	3.669E-02	3.667E-02
PU-240	1.415E-02	1.414E-02	1.413E-02	1.413E-02	1.412E-02	1.410E-02	1.408E-02	1.406E-02	1.404E-02	1.401E-02
PU-241	6.780E-01	5.331E-01	4.191E-01	3.295E-01	2.591E-01	1.601E-01	7.782E-02	3.782E-02	1.838E-02	7.023E-03
PU-242	1.538E-06	1.538E-06	1.538E-06	1.538E-06	1.538E-06	1.538E-06	1.538E-06	1.538E-06	1.538E-06	1.538E-06
PU-244	2.551E-15	2.551E-15	2.551E-15	2.551E-15	2.551E-15	2.551E-15	2.551E-15	2.551E-15	2.551E-15	2.551E-15
AM-241	7.438E-03	1.219E-02	1.587E-02	1.872E-02	2.090E-02	2.384E-02	2.598E-02	2.668E-02	2.668E-02	2.621E-02
AM-242M	9.396E-06	9.185E-06	8.978E-06	8.775E-06	8.578E-06	8.196E-06	7.654E-06	7.148E-06	6.676E-06	6.095E-06
AM-242	9.349E-06	9.139E-06	8.933E-06	8.732E-06	8.535E-06	8.155E-06	7.616E-06	7.113E-06	6.643E-06	6.064E-06
AM-243	9.825E-07	9.820E-07	9.816E-07	9.811E-07	9.807E-07	9.797E-07	9.784E-07	9.770E-07	9.756E-07	9.738E-07
CM-242	2.435E-05	7.568E-06	7.391E-06	7.224E-06	7.062E-06	6.744E-06	6.298E-06	5.882E-06	5.494E-06	5.015E-06
CM-243	1.193E-06	1.057E-06	9.360E-07	8.289E-07	7.340E-07	5.756E-07	3.998E-07	2.777E-07	1.928E-07	1.186E-07
CM-244	1.128E-05	9.315E-06	7.694E-06	6.355E-06	5.248E-06	3.580E-06	2.017E-06	1.137E-06	6.404E-07	2.980E-07
CM-245	1.101E-10	1.101E-10	1.100E-10	1.100E-10	1.099E-10	1.098E-10	1.097E-10	1.096E-10	1.094E-10	1.093E-10
CM-246	3.142E-12	3.140E-12	3.138E-12	3.135E-12	3.133E-12	3.129E-12	3.122E-12	3.115E-12	3.108E-12	3.099E-12
CM-247	6.602E-19	6.602E-19	6.602E-19	6.602E-19	6.602E-19	6.602E-19	6.602E-19	6.602E-19	6.602E-19	6.602E-19
SUBTOTAL**	1.086E+02	7.508E+01	6.143E+01	5.270E+01	4.610E+01	3.597E+01	2.521E+01	1.778E+01	1.259E+01	7.978E+00
TOTAL***	1.086E+02	7.509E+01	6.143E+01	5.271E+01	4.610E+01	3.597E+01	2.521E+01	1.778E+01	1.259E+01	7.979E+00

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Fuel-Specific Source Term Calculations Hypothetical Fuel

Introduction

The following data have been used in the Idaho National Engineering and Environmental Laboratory (INEEL) spent nuclear fuel source term calculational methodology to generate a source term template for a single hypothetical spent nuclear fuel element. This single-element source term is intended to be a bounding source term for spent nuclear fuel elements with no specific fuel category and those fuels currently without a developed template. This fuel is a hypothetical construction of reactor materials and heavy metal constituents designed specifically with the intention of maximizing activation products, actinides, and fission products. A description of the construction data is given below, and the INEEL calculational methodology is described in detail in Reference 1.

Hypothetical Fuel Data

The hypothetical fuel was chosen to be a ternary oxide fuel composed of urania (UO_2), plutonia (PuO_2), and thoria (ThO_2). The urania, plutonia, and thoria oxide volume percentages are 40%, 40%, and 20%, respectively. The uranium metal is assumed to be 50% enriched in U-235, the plutonium metal is reactor grade, and the thorium is 100% Th-232. This heavy metal oxide composition was designed specifically to maximize higher order actinide concentrations in the spent fuel.

The fuel pellet and inner clad are based on the dimensions of a Pressurized Water Reactor (PWR) Westinghouse 17×17 fuel assembly fuel rod. The ternary fuel rod here is assumed to have an inner and an outer clad. The inner clad is assumed to be Stainless Steel-304, and the outer clad is assumed to be Inconel X-750. The dual clads are intended to maximize the structural material mass and, therefore, the activation products. The dimensions for the fuel pellet and clads are given below.

In order to further increase the concentration and spectrum of activation products, cylindrical graphite reflectors are assumed to be located at the top and bottom of the active fuel.

Although the dimensions of the fuel element are similar to a PWR element, the neutron cross sections selected for the burnup calculation are based on a high-temperature graphite reactor in order to maximize the production of activation and transmutation products. Of course, a high-temperature reactor would not have metallic clad fuel rods. So again, it should be remembered that this fuel and reactor are strictly hypothetical.

The fuel element described above is a hypothetical construct intended to produce a maximum or bounding source term. The following data provide the specific fuel element dimensions, materials, densities, enrichment, etc., of the hypothetical fuel element described above.

Fuel Element:	Cylindrical rod
Length:	144.0 in.
Fuel Pellet:	Oxide Ceramic UO_2 - PuO_2 - ThO_2 matrix
Fuel Pellet Radius:	0.4095 cm

Uranium Enrichment:	4.0 wt % U-234
	50.0 wt % U-235
	6.0 wt % U-236
	40.0 wt % U-238
Plutonium Enrichment:	1.8 wt % Pu-238
	60.0 wt % Pu-239
	20.9 wt % Pu-240
	11.9 wt % Pu-241
	5.4 wt % Pu-242
Thorium Enrichment:	100.0 wt % Th-232
Heavy Metal Loading:	29.7592 g/element U-234 (BOL)
	371.9897 g/element U-235 (BOL)
	44.6388 g/element U-236 (BOL)
	297.5918 g/element U-238 (BOL)
	743.9795 g/element TOTAL U (BOL)
	14.0261 g/element Pu-238 (BOL)
	467.5381 g/element Pu-239 (BOL)
	162.8591 g/element Pu-240 (BOL)
	92.7284 g/element Pu-241 (BOL)
	42.0784 g/element Pu-242 (BOL)
	779.2301 g/element TOTAL Pu (BOL)
	345.4439 g/element Th-232 (BOL)
	1,868.6536 g/element total heavy metal (BOL)
	1.86865E-3 Total MTIHM/element (BOL)
Inner Clad Material:	SS-304
Inner Clad Density:	8.02 g/cc
Inner Clad Mass:	486.03 g
Inner Clad Radius:	0.4695 cm
Outer Clad Material:	Inconel X-750
Outer Clad Density:	8.3 g/cc
Outer Clad Mass:	571.66 g
Outer Clad Radius:	0.5295 cm
End Reflector Material:	H451 Graphite
End Reflector Mass:	450.0 g

From the above data (materials, enrichments, and densities), material masses were calculated for all the material components in a single hypothetical fuel element. In addition, for the ORIGEN2 (Reference 2) depletion calculation, conservative and detailed impurity concentrations were added for UO_2 - PuO_2 - ThO_2 , SS-304, Inconel X-750, and H-451 fuel element materials. Impurities for the UO_2 - PuO_2 - ThO_2 fuel composition are based on the available UO_2 uranium metal impurities, and it is assumed to be the same for the plutonium and thorium metal as well. Table 1 lists the impurities and their concentrations for the mentioned materials.

Burnup

The burnup chosen for this template is 62.5 MWd or 33,447 MWd/MTIHM for a single hypothetical fuel element.

Cross-Section Development

The neutron cross sections used in the fuel burnup calculation and the source term generation are based on a standard High Temperature Gas Reactor (HTGR) cross-section library. This library comes with the ORIGEN2 computer code package. The selection of the HTGR cross section was based on a parametric study involving several cross-section libraries representing different reactor types (energy spectral characteristics). Included in the study were libraries for a fast reactor, heavy water reactor (CANDU), breeder water reactor, pressurized water reactor, Advanced Water Reactor, and the HTGR. The HTGR neutron cross sections produced the highest concentrations of higher-order actinides (plutonium, americium, and curium). Because of the hypothetical nature of the reactor, no attempt was made to update the HTGR cross sections as a function of burnup.

Single Element Exposure History

Table 2 summarizes the assumed 3-year constant power or exposure history used in the burnup or source term calculations for the single fuel element. Following the burnup or exposure period, the radionuclide activities are decayed for 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100 years.

Burnup Calculation

The ORIGEN2 computer code was used to perform the depletion or burnup calculation for a single fuel element. The fuel element masses and impurities (uranium, plutonium, thorium, steel, inconel, and graphite), neutron cross sections, burnup, power history, and power level as discussed above are input data for the ORIGEN2 calculation. The radionuclide concentrations are given as a function of time in the template table.

The 145 radionuclides listed in the template represent greater than 99.8% of the total curie inventory had all 684 activation products, 880 fission products, and 127 actinide/daughter isotopes from the ORIGEN2 output been included in the template.

References

1. J. W. Sterbentz and C. A. Wemple, *Calculational Burnup Methodology and Validation for the Idaho National Engineering Laboratory Spent Nuclear Fuels*, INEL-96/0304, September 1996.
2. A. G. Croff, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code*, ORNL-5621, Oak Ridge National Laboratory, July 1980.

Table 1. Hypothetical fuel element material impurity concentrations.

Constituent or Impurity	Uranium Metal Concentration (ppm)	SS-304 Concentration (wt%)	Inconel X-750 Concentration (ppm)	Graphite Concentration (ppm)
H		0.0007		
Li	1	0.13 ppm		0.45
Be				0.005
B	1	0.0005		2.5
C	89.4	0.07	800	100 wt%
N	25	0.047	400	
O		0.015		
F	10.7			
Na	15	37 ppm		10.4
Mg	2			1
Al	16.7	0.01	10000	4.1
Si	12.1	0.6	5000	26
P	35	0.0375	400	1
S		0.02	100	9.4
Cl	5.3	130 ppm		3
K		3 ppm		3
Ca	2	19 ppm		22.5
Sc		0.03 ppm		0.01
Ti	1	0.05	27500	16
V	3	0.05		18.9
Cr	4	18.8	170000	1
Mn	1.7	1.41	10000	1
Fe	18	68.8	90000	11.1
Co	1	0.17	10000	4
Ni	24	9.23	651400	4.6
Cu	1	0.25	5000	0.47
Zn	40.3	0.01		1
Ga		450 ppm		
As		0.01		
Se		0.02		
Br		8 ppm		
Rb		10 ppm		1
Sr		0.2 ppm		0.47
Y		5 ppm		
Zr		20 ppm		0.5
Nb		0.012	9500	1.74
Mo	10	0.37	400	1

Table 1. (continued).

Constituent or Impurity	Uranium Metal Concentration (ppm)	SS-304 Concentration (wt%)	Inconel X-750 Concentration (ppm)	Graphite Concentration (ppm)
Ag	0.1	2 ppm		0.5
Cd	25			0.5
In	2			1
Sn	4	0.01		1
Sb		0.01		1
Cs		0.3 ppm		1
Ba		500 ppm		2.9
La		2.1 ppm		1.38
Ce		550 ppm		0.56
Pr				0.64
Nd				0.36
Sm		0.15 ppm		0.61
Eu		0.02 ppm		
Gd				0.08
Tb		0.71 ppm		0.26
Dy		1 ppm		0.16
Ho		1 ppm		0.08
Er				0.04
Tm				0.04
Yb		2 ppm		0.06
Lu		0.8 ppm		0.02
Hf		2 ppm		0.17
Ta			9500	0.35
W	2	520 ppm		25.5
Tl				1
Pb	1	0.002		6.9
Bi	0.4			1
Th		1 ppm		
U		2 ppm		

Table 2. Hypothetical fuel power history for a 62.5 MWd burnup.

Duration (days)	Cumulative Duration (days)	Time-Averaged Power (MWth)
365.25	365.25	0.05704
365.25	730.50	0.05704
365.25	1095.75	0.05704
1826.25	2922.00	0.0
1826.25	4748.25	0.0
1826.25	6574.50	0.0
1826.25	8400.75	0.0
1826.25	10227.00	0.0
3652.50	13879.50	0.0
5478.75	19358.25	0.0
5478.75	24837.00	0.0
5478.75	30315.75	0.0
7305.00	37620.75	0.0

The ten dates with zero associated power represent the ten different cooling or decay dates after exposure. These ten dates are specifically the 5, 10, 15, 20, 25, 35, 50, 65, 80, and 100-year cooling times designated for the template methodology.

Stainless Steel/Inconel Cladding, Uranium-Plutonium-Thorium Oxide Fuel

Fuel Meat:	Oxide ceramic $\text{UO}_2\text{-PuO}_2\text{-ThO}_2$ matrix
Inner Clad:	SS304
Outer Clad	Inconel X-750
Burnup:	62.5 MWd/element (maximum element burnup)
Basis of Calculation:	Single element (single rod)
BOL U-235:	371.9897 grams U-235 per element
BOL U-238:	297.5918 grams U-238 per element
BOL U-234:	29.7592 grams U-234 per element
BOL U-236:	44.6388 grams U-236 per element
BOL Total U:	743.9795 grams U per element
BOL Pu-238:	14.0261 grams Pu-238 per element
BOL Pu-239:	467.5381 grams Pu-239 per element
BOL Pu-240:	162.8591 grams Pu-240 per element
BOL Pu-241:	92.7284 grams Pu-241 per element
BOL Pu-242:	42.0784 grams Pu-242 per element
BOL Total Pu:	779.2301 grams Pu per element
BOL Th-232:	345.4439 grams th-232 per element
BOL U-235 Fuel Enrichment:	50 wt%
BOL Pu-239 Fuel Enrichment:	60 wt%

(Activities* in Ci/element)

[illegible]

DECAY TIMES (years out of core)										
(Activities* in Ci/element)										
Radionuclide	5	10	15	20	25	35	50	65	80	100
SR 89	1.455E-08	1.889E-19	2.452E-30	3.182E-41	4.130E-52	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SR 90	8.478E+01	7.527E+01	6.683E+01	5.933E+01	5.267E+01	4.151E+01	2.905E+01	2.033E+01	1.422E+01	8.837E+00
Y 90	8.481E+01	7.529E+01	6.684E+01	5.934E+01	5.268E+01	4.153E+01	2.906E+01	2.033E+01	1.423E+01	8.839E+00
Y 91	6.036E-07	2.423E-16	9.726E-26	3.904E-35	1.567E-44	2.525E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00
ZR 93	2.791E-03	2.791E-03	2.791E-03	2.791E-03	2.791E-03	2.791E-03	2.791E-03	2.791E-03	2.791E-03	2.791E-03
ZR 95	6.008E-06	1.536E-14	3.925E-23	1.003E-31	2.564E-40	1.676E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 93M	7.534E-04	1.180E-03	1.511E-03	1.768E-03	1.967E-03	2.240E-03	2.460E-03	2.562E-03	2.610E-03	2.637E-03
NB 94	9.911E-04	9.909E-04	9.907E-04	9.906E-04	9.904E-04	9.901E-04	9.896E-04	9.891E-04	9.885E-04	9.879E-04
NB 95	1.334E-05	3.409E-14	8.714E-23	2.227E-31	5.693E-40	3.720E-57	0.000E+00	0.000E+00	0.000E+00	0.000E+00
NB 95M	4.457E-08	1.139E-16	2.912E-25	7.443E-34	1.902E-42	1.243E-59	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MO 93	1.282E-05	1.280E-05	1.279E-05	1.278E-05	1.277E-05	1.274E-05	1.270E-05	1.267E-05	1.263E-05	1.258E-05
TC 99	2.705E-02	2.705E-02	2.705E-02	2.705E-02	2.705E-02	2.705E-02	2.705E-02	2.705E-02	2.704E-02	2.704E-02
RU103	2.683E-11	2.714E-25	2.746E-39	2.778E-53	2.810E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RU106	4.723E+01	1.517E+00	4.873E-02	1.565E-03	5.028E-05	5.188E-08	1.719E-12	5.698E-17	1.888E-21	2.010E-27
RH103M	2.419E-11	2.447E-25	2.475E-39	2.504E-53	2.533E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
RH106	4.723E+01	1.517E+00	4.873E-02	1.565E-03	5.028E-05	5.188E-08	1.719E-12	5.698E-17	1.888E-21	2.010E-27
PD107	4.142E-04	4.142E-04	4.142E-04	4.142E-04	4.142E-04	4.142E-04	4.142E-04	4.142E-04	4.142E-04	4.142E-04
AG110	2.636E-04	1.662E-06	1.049E-08	6.618E-11	4.175E-13	1.661E-17	4.173E-24	1.048E-30	2.632E-37	4.169E-46
AG110M	1.982E-02	1.250E-04	7.886E-07	4.975E-09	3.139E-11	1.250E-15	3.138E-22	7.878E-29	1.979E-35	3.135E-44
AG111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD113M	7.053E-02	5.562E-02	4.386E-02	3.458E-02	2.727E-02	1.696E-02	8.315E-03	4.077E-03	1.999E-03	7.730E-04
CD113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CD115M	8.304E-13	3.904E-25	1.836E-37	8.629E-50	4.057E-62	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114	2.717E-14	2.144E-25	1.691E-36	1.333E-47	1.052E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN114M	2.839E-14	2.240E-25	1.766E-36	1.393E-47	1.099E-58	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
IN115M	5.824E-17	2.738E-29	1.287E-41	6.052E-54	2.845E-66	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN119M	1.236E-03	7.054E-06	4.024E-08	2.297E-10	1.310E-12	4.265E-17	7.922E-24	1.472E-30	2.734E-37	2.897E-46
SN121M	4.948E-04	4.617E-04	4.307E-04	4.019E-04	3.749E-04	3.263E-04	2.650E-04	2.153E-04	1.748E-04	1.325E-04
SN123	2.207E-04	1.224E-08	6.784E-13	3.761E-17	2.085E-21	6.409E-30	1.092E-42	1.861E-55	3.171E-68	2.995E-85
SN125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SN126	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.393E-03	1.393E-03
SB124	4.256E-10	3.135E-19	2.310E-28	1.702E-37	1.254E-46	6.808E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SB125	6.364E+00	1.821E+00	5.211E-01	1.491E-01	4.266E-02	3.493E-03	8.187E-05	1.918E-06	4.494E-08	3.013E-10
SB126	1.952E-04	1.952E-04	1.952E-04	1.952E-04	1.951E-04	1.951E-04	1.951E-04	1.951E-04	1.951E-04	1.950E-04
SB126M	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.394E-03	1.393E-03	1.393E-03

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
TE123M	2.881E-08	7.341E-13	1.871E-17	4.768E-22	1.215E-26	7.893E-36	1.306E-49	2.162E-63	3.580E-77	1.511E-95
TE125M	1.553E+00	4.443E-01	1.271E-01	3.638E-02	1.041E-02	8.525E-04	1.997E-05	4.680E-07	1.096E-08	7.353E-11
TE127	2.084E-04	1.886E-09	1.706E-14	1.544E-19	1.397E-24	1.144E-34	8.474E-50	6.278E-65	4.651E-80	0.000E+00
TE127M	2.128E-04	1.925E-09	1.742E-14	1.576E-19	1.426E-24	1.168E-34	8.652E-50	6.410E-65	4.749E-80	0.000E+00
TE129	2.111E-15	9.172E-32	3.985E-48	1.732E-64	7.524E-81	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TE129M	3.243E-15	1.409E-31	6.122E-48	2.660E-64	1.156E-80	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
I129	6.993E-05	6.993E-05	6.993E-05	6.993E-05	6.993E-05	6.993E-05	6.993E-05	6.993E-05	6.993E-05	6.993E-05
I131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE131M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
XE133	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS134	9.325E+00	1.736E+00	3.234E-01	6.023E-02	1.121E-02	3.889E-04	2.512E-06	1.622E-08	1.047E-10	1.260E-13
CS135	2.882E-03	2.882E-03	2.882E-03	2.882E-03	2.882E-03	2.882E-03	2.882E-03	2.882E-03	2.882E-03	2.882E-03
CS136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CS137	1.771E+02	1.578E+02	1.405E+02	1.252E+02	1.115E+02	8.854E+01	6.260E+01	4.427E+01	3.130E+01	1.972E+01
BA136M	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
BA137M	1.675E+02	1.492E+02	1.330E+02	1.184E+02	1.055E+02	8.376E+01	5.922E+01	4.188E+01	2.961E+01	1.865E+01
BA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
LA140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE141	3.077E-14	3.790E-31	4.667E-48	5.748E-65	7.078E-82	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
CE142	4.827E-08	4.827E-08	4.827E-08	4.827E-08	4.827E-08	4.827E-08	4.827E-08	4.827E-08	4.827E-08	4.827E-08
CE144	2.163E+01	2.517E-01	2.931E-03	3.412E-05	3.972E-07	5.383E-11	8.492E-17	1.340E-22	2.114E-28	3.882E-36
PR143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PR144	2.163E+01	2.518E-01	2.931E-03	3.412E-05	3.972E-07	5.383E-11	8.492E-17	1.340E-22	2.114E-28	3.882E-36
PR144M	2.595E-01	3.021E-03	3.517E-05	4.094E-07	4.766E-09	6.459E-13	1.019E-18	1.608E-24	2.536E-30	4.658E-38
ND144	1.998E-12	2.006E-12	2.006E-12	2.006E-12	2.006E-12	2.006E-12	2.006E-12	2.006E-12	2.006E-12	2.006E-12
ND147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM145	1.748E-07	1.455E-07	1.196E-07	9.837E-08	8.088E-08	5.467E-08	3.039E-08	1.689E-08	9.386E-09	4.289E-09
PM147	1.324E+02	3.533E+01	9.428E+00	2.516E+00	6.714E-01	4.781E-02	9.085E-04	1.726E-05	3.281E-07	1.664E-09
PM148M	2.514E-12	1.224E-25	5.962E-39	2.903E-52	1.414E-65	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PM148	1.416E-13	6.895E-27	3.358E-40	1.635E-53	7.964E-67	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
SM145	3.949E-08	9.545E-10	2.307E-11	5.576E-13	1.348E-14	7.874E-18	1.112E-22	1.570E-27	2.217E-32	7.568E-39
SM147	1.418E-08	1.656E-08	1.719E-08	1.736E-08	1.741E-08	1.742E-08	1.742E-08	1.742E-08	1.742E-08	1.742E-08
SM151	5.445E+00	5.239E+00	5.042E+00	4.851E+00	4.668E+00	4.322E+00	3.850E+00	3.430E+00	3.056E+00	2.620E+00
EU152	7.184E-02	5.568E-02	4.315E-02	3.345E-02	2.593E-02	1.557E-02	7.250E-03	3.375E-03	1.571E-03	5.671E-04
EU154	2.401E+00	1.604E+00	1.072E+00	7.166E-01	4.789E-01	2.140E-01	6.386E-02	1.907E-02	5.691E-03	1.135E-03

DECAY TIMES (years out of core) (Activities* in Ci/element)										
Radionuclide	5	10	15	20	25	35	50	65	80	100
EU155	1.047E+01	5.206E+00	2.588E+00	1.287E+00	6.397E-01	1.581E-01	1.943E-02	2.388E-03	2.934E-04	1.792E-05
EU156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
GD153	1.962E-04	1.050E-06	5.619E-09	3.006E-11	1.609E-13	4.605E-18	7.055E-25	1.081E-31	1.656E-38	1.357E-47
TB160	1.330E-08	3.314E-16	8.258E-24	2.057E-31	5.127E-39	3.184E-54	0.000E+00	0.000E+00	0.000E+00	0.000E+00
TL206	4.953E-12	4.953E-12	4.953E-12	4.953E-12	4.953E-12	4.953E-12	4.953E-12	4.953E-12	4.953E-12	4.953E-12
TL207	3.320E-05	5.457E-05	7.281E-05	8.838E-05	1.017E-04	1.226E-04	1.439E-04	1.572E-04	1.656E-04	1.720E-04
TL208	1.981E-03	2.113E-03	2.053E-03	1.964E-03	1.874E-03	1.703E-03	1.476E-03	1.279E-03	1.109E-03	9.179E-04
PB210	1.948E-09	7.501E-09	1.886E-08	3.774E-08	6.563E-08	1.536E-07	3.815E-07	7.438E-07	1.256E-06	2.192E-06
PB211	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
PB212	5.512E-03	5.882E-03	5.714E-03	5.467E-03	5.216E-03	4.739E-03	4.107E-03	3.560E-03	3.087E-03	2.555E-03
BI211	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
BI212	5.512E-03	5.882E-03	5.714E-03	5.467E-03	5.216E-03	4.739E-03	4.107E-03	3.560E-03	3.087E-03	2.555E-03
PO212	3.532E-03	3.769E-03	3.661E-03	3.503E-03	3.342E-03	3.037E-03	2.632E-03	2.281E-03	1.978E-03	1.637E-03
PO215	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
PO216	5.512E-03	5.882E-03	5.714E-03	5.467E-03	5.216E-03	4.739E-03	4.107E-03	3.560E-03	3.087E-03	2.555E-03
RN219	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
RN220	5.512E-03	5.882E-03	5.714E-03	5.467E-03	5.216E-03	4.739E-03	4.107E-03	3.560E-03	3.087E-03	2.555E-03
FR223	4.592E-07	7.543E-07	1.006E-06	1.221E-06	1.404E-06	1.695E-06	1.989E-06	2.173E-06	2.288E-06	2.378E-06
RA223	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
RA224	5.512E-03	5.882E-03	5.714E-03	5.467E-03	5.216E-03	4.739E-03	4.107E-03	3.560E-03	3.087E-03	2.555E-03
RA226	2.309E-08	6.006E-08	1.146E-07	1.869E-07	2.773E-07	5.133E-07	1.009E-06	1.678E-06	2.527E-06	3.943E-06
RA228	2.118E-05	2.782E-05	3.178E-05	3.414E-05	3.555E-05	3.689E-05	3.747E-05	3.760E-05	3.762E-05	3.763E-05
AC227	3.327E-05	5.466E-05	7.291E-05	8.848E-05	1.018E-04	1.228E-04	1.442E-04	1.575E-04	1.658E-04	1.723E-04
TH227	3.283E-05	5.397E-05	7.201E-05	8.741E-05	1.005E-04	1.213E-04	1.423E-04	1.555E-04	1.637E-04	1.701E-04
TH228	5.511E-03	5.877E-03	5.709E-03	5.462E-03	5.211E-03	4.739E-03	4.107E-03	3.560E-03	3.086E-03	2.555E-03
TH229	1.363E-05	2.428E-05	3.493E-05	4.558E-05	5.622E-05	7.749E-05	1.093E-04	1.412E-04	1.729E-04	2.152E-04
TH230	1.308E-05	2.116E-05	2.938E-05	3.773E-05	4.623E-05	6.359E-05	9.051E-05	1.184E-04	1.471E-04	1.865E-04
TH231	7.574E-04	7.575E-04	7.576E-04	7.578E-04	7.579E-04	7.581E-04	7.585E-04	7.589E-04	7.593E-04	7.598E-04
TH232	3.763E-05	3.763E-05	3.763E-05	3.763E-05	3.763E-05	3.763E-05	3.763E-05	3.763E-05	3.763E-05	3.763E-05
TH234	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05
PA231	1.786E-04	1.786E-04	1.787E-04	1.788E-04	1.788E-04	1.789E-04	1.791E-04	1.793E-04	1.795E-04	1.797E-04
PA233	1.544E-03	1.908E-03	2.400E-03	2.992E-03	3.661E-03	5.160E-03	7.643E-03	1.025E-02	1.287E-02	1.634E-02
PA234M	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05
PA234	1.286E-07	1.286E-07	1.286E-07	1.286E-07	1.286E-07	1.286E-07	1.286E-07	1.286E-07	1.286E-07	1.286E-07
U232	6.108E-03	5.822E-03	5.549E-03	5.288E-03	5.040E-03	4.577E-03	3.962E-03	3.429E-03	2.968E-03	2.448E-03

DECAY TIMES (years out of core)
(Activities* in Ci/element)

Radionuclide	5	10	15	20	25	35	50	65	80	100
U233	2.259E-02	2.259E-02	2.258E-02	2.258E-02	2.258E-02	2.258E-02	2.258E-02	2.258E-02	2.258E-02	2.258E-02
U234	1.778E-01	1.811E-01	1.842E-01	1.872E-01	1.902E-01	1.956E-01	2.031E-01	2.097E-01	2.156E-01	2.225E-01
U235	7.574E-04	7.575E-04	7.576E-04	7.578E-04	7.579E-04	7.581E-04	7.585E-04	7.589E-04	7.593E-04	7.598E-04
U236	3.196E-03	3.199E-03	3.201E-03	3.204E-03	3.207E-03	3.212E-03	3.220E-03	3.229E-03	3.237E-03	3.247E-03
U237	3.165E-03	2.488E-03	1.955E-03	1.537E-03	1.208E-03	7.467E-04	3.627E-04	1.762E-04	8.557E-05	3.268E-05
U238	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05	9.890E-05
NP237	1.544E-03	1.908E-03	2.400E-03	2.992E-03	3.661E-03	5.160E-03	7.643E-03	1.025E-02	1.287E-02	1.634E-02
PU236	3.763E-05	1.116E-05	3.309E-06	9.811E-07	2.910E-07	2.568E-08	7.713E-10	1.218E-10	1.049E-10	1.044E-10
PU237	5.975E-15	5.252E-27	4.616E-39	4.057E-51	3.566E-63	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
PU238	2.358E+02	2.268E+02	2.180E+02	2.096E+02	2.015E+02	1.863E+02	1.656E+02	1.471E+02	1.308E+02	1.118E+02
PU239	2.605E+01	2.605E+01	2.604E+01	2.604E+01	2.604E+01	2.603E+01	2.602E+01	2.601E+01	2.600E+01	2.598E+01
PU240	1.828E+01	1.829E+01	1.829E+01	1.829E+01	1.829E+01	1.829E+01	1.827E+01	1.825E+01	1.822E+01	1.819E+01
PU241	1.290E+04	1.014E+04	7.971E+03	6.266E+03	4.926E+03	3.044E+03	1.478E+03	7.181E+02	3.488E+02	1.332E+02
PU242	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01
PU244	4.492E-09	4.492E-09	4.492E-09	4.492E-09	4.492E-09	4.492E-09	4.492E-09	4.492E-09	4.492E-09	4.492E-09
AM241	1.775E+02	2.676E+02	3.374E+02	3.913E+02	4.326E+02	4.879E+02	5.278E+02	5.402E+02	5.395E+02	5.295E+02
AM242M	1.207E+00	1.180E+00	1.153E+00	1.127E+00	1.102E+00	1.053E+00	9.830E-01	9.180E-01	8.573E-01	7.826E-01
AM242	1.201E+00	1.174E+00	1.147E+00	1.122E+00	1.096E+00	1.047E+00	9.781E-01	9.135E-01	8.531E-01	7.787E-01
AM243	1.023E+00	1.022E+00	1.022E+00	1.021E+00	1.021E+00	1.020E+00	1.018E+00	1.017E+00	1.015E+00	1.013E+00
CM242	1.485E+00	9.714E-01	9.493E-01	9.279E-01	9.070E-01	8.662E-01	8.089E-01	7.554E-01	7.055E-01	6.440E-01
CM243	1.123E-01	9.944E-02	8.805E-02	7.797E-02	6.904E-02	5.414E-02	3.759E-02	2.610E-02	1.812E-02	1.114E-02
CM244	3.320E+01	2.741E+01	2.264E+01	1.870E+01	1.544E+01	1.053E+01	5.930E+00	3.340E+00	1.881E+00	8.749E-01
CM245	1.982E-03	1.982E-03	1.981E-03	1.980E-03	1.979E-03	1.977E-03	1.975E-03	1.973E-03	1.970E-03	1.967E-03
CM246	2.010E-05	2.008E-05	2.007E-05	2.005E-05	2.004E-05	2.001E-05	1.996E-05	1.992E-05	1.988E-05	1.982E-05
CM247	1.442E-11	1.442E-11	1.442E-11	1.442E-11	1.442E-11	1.442E-11	1.442E-11	1.442E-11	1.442E-11	1.442E-11
SUBTOTAL**	1.427E+04	1.125E+04	9.043E+03	7.318E+03	5.961E+03	4.042E+03	2.413E+03	1.589E+03	1.163E+03	8.834E+02
TOTAL***	1.427E+04	1.126E+04	9.044E+03	7.319E+03	5.962E+03	4.043E+03	2.414E+03	1.591E+03	1.164E+03	8.844E+02

* Four decimal places of accuracy are as reported by ORIGEN2 output and are not significant for many radionuclides.

** Subtotal: total activity of the 145 isotopes listed in the table.

*** Total: total activity of the ORIGEN2 output isotopes.

Worst-Case Template 29

This analysis was focused on creating a bounding source term estimate. The hypothetical fuel template was created to try to maximize the source term for all radionuclides, but radionuclide production and decay is a complex multivariable process. It is impossible to maximize all radionuclides. Consequently, Template 29 was created by normalizing all the completed templates to the same basis (Ci per MWd per kg) and selecting the highest curie content for each radionuclide. This template, shown below, is used to conservatively estimate source terms when sufficient information is not known to select one of the other templates. It is expected to be extremely conservative for any credible fuel. This worst-case template was used in the analysis for spent fuels that didn't fit any of the other completed templates. The hypothetical template was not used in the analysis (other than to derive this Worst-Case Template 29).

	DECAY TIMES (years)									
	5	10	15	20	25	35	50	65	80	100
Ac-227	3.327E-05	5.466E-05	7.291E-05	8.848E-05	1.018E-04	1.228E-04	1.442E-04	1.575E-04	1.658E-04	1.723E-04
Ag-110	2.572E-03	1.622E-05	1.024E-07	6.458E-10	4.074E-12	1.621E-16	4.072E-23	0.000E+00	0.000E+00	0.000E+00
Ag-110m	1.933E-01	1.219E-03	7.699E-06	4.855E-08	3.063E-10	1.219E-14	3.062E-21	0.000E+00	0.000E+00	0.000E+00
Ag-111	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Am-241	1.775E+02	2.676E+02	3.374E+02	3.913E+02	4.326E+02	4.879E+02	5.278E+02	5.402E+02	5.395E+02	5.295E+02
Am-242	1.201E+00	1.174E+00	1.147E+00	1.122E+00	1.096E+00	1.047E+00	9.781E-01	9.135E-01	8.531E-01	7.787E-01
Am-242m	1.207E+00	1.180E+00	1.153E+00	1.127E+00	1.102E+00	1.053E+00	9.830E-01	9.180E-01	8.573E-01	7.826E-01
Am-243	1.023E+00	1.022E+00	1.022E+00	1.021E+00	1.021E+00	1.020E+00	1.018E+00	1.017E+00	1.015E+00	1.013E+00
Ba-136m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ba-137m	2.488E+03	2.216E+03	1.975E+03	1.759E+03	1.567E+03	1.245E+03	8.802E+02	6.226E+02	4.403E+02	2.774E+02
Ba-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Be-10	1.527E-05	1.527E-05	1.527E-05	1.527E-05	1.527E-05	1.527E-05	1.527E-05	1.527E-05	1.527E-05	1.527E-05
Bi-211	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
Bi-212	1.870E-02	1.912E-02	1.843E-02	1.760E-02	1.678E-02	1.524E-02	1.319E-02	1.141E-02	9.880E-03	8.157E-03
C-14	7.583E+00	7.577E+00	7.570E+00	7.570E+00	7.563E+00	7.556E+00	7.543E+00	7.529E+00	7.515E+00	7.495E+00
Cd-113	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cd-113m	2.758E-01	2.174E-01	1.715E-01	1.353E-01	1.067E-01	6.636E-02	3.255E-02	1.598E-02	7.834E-03	3.031E-03
Cd-115m	2.291E-11	1.099E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce-141	2.889E-12	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ce-142	1.276E-06	1.276E-06	1.276E-06	1.276E-06	1.276E-06	1.276E-06	1.276E-06	1.276E-06	1.276E-06	1.276E-06
Ce-144	8.500E+02	9.926E+00	1.159E-01	1.353E-03	1.581E-05	8.425E-07	3.430E-15	2.939E-18	1.679E-18	0.000E+00
Cl-36	1.429E-01	1.429E-01	1.429E-01	1.429E-01	1.428E-01	1.428E-01	1.428E-01	1.428E-01	1.428E-01	1.428E-01
Cm-242	1.485E+00	9.714E-01	9.493E-01	9.279E-01	9.070E-01	8.662E-01	8.089E-01	7.554E-01	7.055E-01	6.440E-01
Cm-243	1.123E-01	9.944E-02	8.805E-02	7.797E-02	6.904E-02	5.414E-02	3.759E-02	2.610E-02	1.812E-02	1.114E-02
Cm-244	3.320E+01	2.741E+01	2.264E+01	1.870E+01	1.544E+01	1.053E+01	5.930E+00	3.340E+00	1.881E+00	8.749E-01
Cm-245	1.982E-03	1.982E-03	1.981E-03	1.980E-03	1.979E-03	1.977E-03	1.975E-03	1.973E-03	1.970E-03	1.967E-03
Cm-246	1.915E-04	1.914E-04	1.912E-04	1.911E-04	1.909E-04	1.906E-04	1.902E-04	1.898E-04	1.893E-04	1.888E-04
Cm-247	6.671E-10	6.671E-10	6.671E-10	6.671E-10	6.671E-10	6.671E-10	6.671E-10	6.671E-10	6.671E-10	6.671E-10
Co-60	9.084E+04	4.704E+04	2.437E+04	1.262E+04	6.541E+03	1.755E+03	2.441E+02	3.393E+01	4.719E+00	3.399E-01
Cr-51	1.652E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs-134	5.083E+02	9.478E+01	1.767E+01	3.296E+00	6.143E-01	2.134E-02	1.384E-04	8.966E-07	1.838E-07	7.020E-12

	DECAY TIMES (years)									
	5	10	15	20	25	35	50	65	80	100
Cs-135	2.749E-02	2.749E-02	2.749E-02	2.749E-02	2.749E-02	2.749E-02	2.749E-02	2.749E-02	2.749E-02	2.749E-02
Cs-136	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Cs-137	2.629E+03	2.343E+03	2.088E+03	1.860E+03	1.658E+03	1.316E+03	9.305E+02	6.580E+02	4.654E+02	2.933E+02
Eu-152	5.555E+00	4.306E+00	3.338E+00	2.588E+00	2.006E+00	1.206E+00	5.615E-01	2.615E-01	1.219E-01	4.398E-02
Eu-154	8.753E+02	5.851E+02	3.912E+02	2.615E+02	1.748E+02	7.812E+01	2.334E+01	6.972E+00	2.083E+00	4.160E-01
Eu-155	2.847E+02	1.416E+02	7.045E+01	3.504E+01	1.743E+01	4.312E+00	5.306E-01	6.528E-02	8.035E-03	4.918E-04
Eu-156	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Fe-55	5.450E+04	1.437E+04	3.789E+03	9.991E+02	2.634E+02	1.832E+01	3.359E-01	6.159E-03	1.129E-04	5.460E-07
Fe-59	1.215E-08	7.372E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Fr-223	4.592E-07	7.543E-07	1.006E-06	1.221E-06	1.404E-06	1.695E-06	1.989E-06	2.173E-06	2.288E-06	2.378E-06
Gd-153	3.031E-02	1.622E-04	8.681E-07	4.644E-09	2.484E-11	7.113E-16	1.090E-22	0.000E+00	0.000E+00	0.000E+00
H-3	8.177E+01	6.180E+01	4.667E+01	3.526E+01	2.662E+01	1.519E+01	6.545E+00	2.820E+00	1.215E+00	3.953E-01
I-129	6.636E-04	6.636E-04	6.636E-04	6.636E-04	6.636E-04	6.636E-04	6.636E-04	6.636E-04	6.636E-04	6.636E-04
I-131	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
In-114	1.140E-11	8.988E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
In-114m	1.191E-11	9.391E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
In-115m	1.608E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Kr-85	2.601E+02	1.883E+02	1.363E+02	9.864E+01	7.141E+01	3.743E+01	1.420E+01	5.387E+00	2.044E+00	5.613E-01
La-140	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
MN-54	4.195E+01	7.304E-01	1.271E-02	2.213E-04	3.853E-06	3.147E-07	6.162E-15	1.229E-17	7.023E-18	0.000E+00
Mo-93	4.926E-02	4.921E-02	4.916E-02	4.912E-02	4.907E-02	4.897E-02	4.882E-02	4.868E-02	4.854E-02	4.834E-02
Nb-93m	2.169E-02	3.679E-02	4.849E-02	5.757E-02	6.460E-02	7.427E-02	8.204E-02	8.566E-02	8.736E-02	8.832E-02
Nb-94	6.799E-02	6.797E-02	6.797E-02	6.795E-02	6.794E-02	6.792E-02	6.788E-02	6.785E-02	6.782E-02	6.777E-02
Nb-95	1.113E-03	2.884E-12	7.473E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nb-95m	3.720E-06	9.638E-15	2.497E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Nd-144	3.807E-11	3.838E-11	3.839E-11	3.839E-11	3.839E-11	3.839E-11	3.839E-11	3.839E-11	3.839E-11	3.839E-11
Nd-147	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ni-59	2.130E+01	2.130E+01	2.130E+01	2.130E+01	2.130E+01	2.130E+01	2.129E+01	2.129E+01	2.128E+01	2.128E+01
Ni-63	3.064E+03	2.951E+03	2.842E+03	2.737E+03	2.636E+03	2.444E+03	2.183E+03	1.950E+03	1.742E+03	1.498E+03
Np-237	9.759E-03	9.760E-03	9.762E-03	9.766E-03	9.770E-03	9.779E-03	9.792E-03	1.025E-02	1.287E-02	1.634E-02
Pa-231	1.786E-04	1.786E-04	1.787E-04	1.788E-04	1.788E-04	1.789E-04	1.791E-04	1.793E-04	1.795E-04	1.797E-04

	DECAY TIMES (years)									
	5	10	15	20	25	35	50	65	80	100
Pa-233	9.759E-03	9.760E-03	9.762E-03	9.766E-03	9.770E-03	9.779E-03	9.792E-03	1.025E-02	1.287E-02	1.634E-02
Pa-234	9.541E-06	9.541E-06	9.541E-06	9.541E-06	9.541E-06	9.541E-06	9.541E-06	9.541E-06	9.541E-06	9.541E-06
Pa-234m	7.338E-03	7.338E-03	7.338E-03	7.338E-03	7.338E-03	7.338E-03	7.338E-03	7.338E-03	7.338E-03	7.338E-03
Pb-210	7.042E-09	1.980E-08	5.865E-08	1.278E-07	2.341E-07	5.798E-07	1.495E-06	2.957E-06	5.017E-06	8.743E-06
Pb-211	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
Pb-212	1.870E-02	1.912E-02	1.843E-02	1.760E-02	1.678E-02	1.524E-02	1.319E-02	1.141E-02	9.880E-03	8.157E-03
Pd-107	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03	1.013E-03
Pm-145	8.675E-01	7.207E-01	5.928E-01	4.875E-01	4.008E-01	2.710E-01	1.507E-01	8.378E-02	4.659E-02	2.130E-02
Pm-147	2.910E+03	7.770E+02	2.076E+02	5.544E+01	1.481E+01	1.056E+00	2.012E-02	3.835E-04	1.606E-05	3.718E-08
Pm-148	3.534E-12	1.757E-25	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pm-148m	6.275E-11	3.121E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Po-212	1.198E-02	1.225E-02	1.181E-02	1.128E-02	1.076E-02	9.757E-03	8.447E-03	7.310E-03	6.330E-03	5.226E-03
Po-215	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
Po-216	1.870E-02	1.912E-02	1.843E-02	1.760E-02	1.678E-02	1.524E-02	1.319E-02	1.141E-02	9.880E-03	8.157E-03
Pr-143	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pr-144	8.500E+02	9.926E+00	1.159E-01	1.353E-03	1.581E-05	8.425E-07	3.430E-15	2.939E-18	1.679E-18	0.000E+00
Pr-144m	1.020E+01	1.191E-01	1.391E-03	1.625E-05	1.896E-07	1.012E-08	4.117E-17	3.524E-20	2.014E-20	0.000E+00
Pu-236	9.558E-04	2.836E-04	8.417E-05	2.498E-05	7.422E-06	6.624E-07	2.676E-08	1.014E-08	9.710E-09	9.692E-09
Pu-237	4.701E-14	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Pu-238	2.358E+02	2.268E+02	2.180E+02	2.096E+02	2.015E+02	1.863E+02	1.656E+02	1.471E+02	1.308E+02	1.118E+02
Pu-239	2.605E+01	2.605E+01	2.604E+01	2.604E+01	2.604E+01	2.603E+01	2.602E+01	2.601E+01	2.600E+01	2.598E+01
Pu-240	1.828E+01	1.829E+01	1.829E+01	1.829E+01	1.829E+01	1.829E+01	1.827E+01	1.825E+01	1.822E+01	1.819E+01
Pu-241	1.290E+04	1.014E+04	7.971E+03	6.266E+03	4.926E+03	3.044E+03	1.478E+03	7.181E+02	3.488E+02	1.332E+02
Pu-242	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01	1.535E-01
Pu-244	5.307E-09	5.307E-09	5.307E-09	5.307E-09	5.307E-09	5.307E-09	5.307E-09	5.307E-09	5.307E-09	5.307E-09
Ra-223	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.

	DECAY TIMES (years)									
	5	10	15	20	25	35	50	65	80	100
Rh-106	2.298E+02	7.379E+00	2.371E-01	7.618E-03	2.446E-04	5.345E-05	8.368E-12	8.227E-14	4.701E-14	0.000E+00
Rn-219	3.329E-05	5.473E-05	7.302E-05	8.863E-05	1.019E-04	1.230E-04	1.443E-04	1.577E-04	1.660E-04	1.725E-04
Rn-220	1.870E-02	1.912E-02	1.843E-02	1.760E-02	1.678E-02	1.524E-02	1.319E-02	1.141E-02	9.880E-03	8.157E-03
Ru-103	1.184E-09	1.224E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Ru-106	2.298E+02	7.379E+00	2.371E-01	7.618E-03	2.446E-04	5.345E-05	8.368E-12	8.227E-14	4.701E-14	0.000E+00
Sb-124	2.081E-06	1.533E-15	1.129E-24	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sb-125	1.176E+02	3.366E+01	9.629E+00	2.756E+00	7.884E-01	6.457E-02	1.513E-03	3.545E-05	4.220E-06	5.569E-09
Sb-126	1.459E-03	1.459E-03	1.459E-03	1.459E-03	1.459E-03	1.459E-03	1.458E-03	1.458E-03	1.458E-03	1.458E-03
Sb-126M	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.041E-02	1.041E-02
Se-79	1.199E-02	1.199E-02	1.199E-02	1.199E-02	1.199E-02	1.199E-02	1.199E-02	1.199E-02	1.198E-02	1.198E-02
Sm-145	1.665E-01	4.034E-03	9.776E-05	2.369E-06	5.741E-08	3.371E-11	4.797E-16	6.826E-21	0.000E+00	0.000E+00
Sm-147	6.263E-06	6.287E-06	6.294E-06	6.295E-06	6.296E-06	6.296E-06	6.296E-06	6.296E-06	6.296E-06	6.296E-06
Sm-151	1.766E+02	1.700E+02	1.635E+02	1.573E+02	1.514E+02	1.402E+02	1.249E+02	1.113E+02	9.913E+01	8.499E+01
Sn-119m	8.272E+00	4.719E-02	2.692E-04	1.536E-06	8.763E-09	2.853E-13	5.300E-20	0.000E+00	0.000E+00	0.000E+00
Sn-121m	1.457E-01	1.360E-01	1.269E-01	1.184E-01	1.104E-01	9.616E-02	7.809E-02	6.341E-02	5.150E-02	3.902E-02
Sn-123	2.085E-02	1.156E-06	6.408E-11	3.553E-15	1.970E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sn-125	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sn-126	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.042E-02	1.041E-02	1.041E-02
Sr-89	2.098E-06	2.771E-17	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Sr-90	2.525E+03	2.243E+03	1.991E+03	1.768E+03	1.570E+03	1.237E+03	8.662E+02	6.063E+02	4.243E+02	2.637E+02
Tb-160	8.938E-06	2.254E-13	5.683E-21	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Tc-99	4.230E-01	4.230E-01	4.230E-01	4.230E-01	4.230E-01	4.230E-01	4.230E-01	4.228E-01	4.228E-01	4.228E-01
Te-123m	4.057E-04	1.035E-08	2.635E-13	6.717E-18	1.712E-22	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te-125m	2.870E+01	8.211E+00	2.350E+00	6.724E-01	1.924E-01	1.575E-02	3.691E-04	8.647E-06	1.028E-06	1.359E-09
Te-127	4.862E-03	4.435E-08	4.044E-13	3.690E-18	3.366E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	#VALUE!
Te-127m	4.965E-03	4.527E-08	4.130E-13	3.767E-18	3.435E-23	0.000E+00	0.000E+00	0.000E+00	0.000E+00	#VALUE!
Te-129	1.130E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Te-129m	1.736E-13	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Th-227	3.283E-05	5.397E-05	7.201E-05	8.741E-05	1.005E-04	1.213E-04	1.423E-04	1.555E-04	1.637E-04	1.701E-04
Th-228	1.869E-02	1.911E-02	1.842E-02	1.759E-02	1.677E-02	1.523E-02	1.319E-02	1.141E-02	9.880E-03	8.157E-03
Th-229	1.730E-05	2.623E-05	3.517E-05	4.558E-05	5.622E-05	7.749E-05	1.093E-04	1.412E-04	1.729E-04	2.152E-04

[illegible]

Appendix B

Index to DOE Spent Nuclear Fuels

Intentionally Blank

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
Hanford SNF						
AMERICIUM TARGETS	776	02. Pu/U Alloy SNF	Other	NOT INTACT	C-3	D-3
CALVERT CLIFFS 1	307	08. U Oxide SNF	Non-metals	INTACT	C-4	D-4
COOPER NUCLEAR	308	08. U Oxide SNF	Non-metals	INTACT	C-5	D-5
FFTF-DFA/TDFA	71	04. MOX SNF	Non-metals	INTACT	C-6	D-6
FFTF-DFA/TDFA PINS	323	04. MOX SNF	Non-metals	INTACT	C-7	D-7
FFTF-TFA PINS	320	04. MOX SNF	Non-metals	INTACT	C-8	D-8
FFTF-TFA PINS (AC-3)	1046	03. Pu/U Carbide SNF	Non-metals	INTACT	C-9	D-9
FFTF-TFA-AB-1	317	04. MOX SNF	Non-metals	INTACT	C-10	D-10
FFTF-TFA-ABA-1 THRU 6	318	08. U Oxide SNF	Non-metals	INTACT	C-11	D-11
FFTF-TFA-ACN-1 (MOX) PINS	321	04. MOX SNF	Non-metals	INTACT	C-12	D-12
FFTF-TFA-ACN-1 (PU/UC) PINS	865	03. Pu/U Carbide SNF	Non-metals	INTACT	C-13	D-13
FFTF-TFA-ACO-2, 4 THRU 16	329	04. MOX SNF	Non-metals	INTACT	C-14	D-14
FFTF-TFA-CRBR-3 & CRBR-5	322	04. MOX SNF	Non-metals	INTACT	C-15	D-15
FFTF-TFA-DEA-2	324	04. MOX SNF	Non-metals	INTACT	C-16	D-16
FFTF-TFA-FC-1	325	03. Pu/U Carbide SNF	Non-metals	INTACT	C-17	D-17
FFTF-TFA-MFF-1 & 1A (CDE)	330	04. MOX SNF	Non-metals	INTACT	C-18	D-18
FFTF-TFA-P0-2,4 & 5	333	04. MOX SNF	Non-metals	INTACT	C-19	D-19
FFTF-TFA-SRF-3&4	334	04. MOX SNF	Non-metals	INTACT	C-20	D-20
FFTF-TFA-UO-1	335	04. MOX SNF	Non-metals	INTACT	C-21	D-21
FFTF-TFA-WBO18 & WBO42	336	08. U Oxide SNF	Non-metals	INTACT	C-22	D-22
GE TEST	96	04. MOX SNF	Non-metals	NOT INTACT	C-23	D-23
LWR COMMERCIAL FUEL	130	08. U Oxide SNF	Non-metals	NOT INTACT	C-24	D-24
LWR SCRAP	309	08. U Oxide SNF	Non-metals	NOT INTACT	C-25	D-25
N REACTOR	991	07. U Metal SNF	Other	NOT INTACT	C-26	D-26
POINT BEACH	311	08. U Oxide SNF	Non-metals	INTACT	C-27	D-27
SHIPPINGPORT PWR C2 BLKT	193	08. U Oxide SNF	Non-metals	INTACT	C-28	D-28
SINGLE PASS REACTOR FUEL	198	07. U Metal SNF	Other	NOT INTACT	C-29	D-29
SINGLE PASS REACTOR FUEL	197	07. U Metal SNF	Other	NOT INTACT	C-30	D-30
SP-100 FUEL	777	08. U Oxide SNF	Non-metals	INTACT	C-31	D-31

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
TRIGA 8.5/20 FFCR (DORF)	315	11. U Zr H SNF	Non-metals	INTACT	C-32	D-32
TRIGA STD (ALUM) HANFORD	314	11. U Zr H SNF	Non-metals	INTACT	C-33	D-33
TRIGA STD 8.5/20	233	11. U Zr H SNF	Non-metals	INTACT	C-34	D-34
TRIGA STD 8.5/20 (HANFORD)	316	11. U Zr H SNF	Non-metals	INTACT	C-35	D-35
INEEL SNF						
ACRR (PULSED CORE)	757	08. U Oxide SNF	Non-metals	INTACT	C-36	D-36
ANP	451	08. U Oxide SNF	Non-metals	INTACT	C-37	D-37
APPR (AGE-2)	6	08. U Oxide SNF	Non-metals	INTACT	C-38	D-38
ARKANSAS	7	08. U Oxide SNF	Non-metals	NOT INTACT	C-39	D-39
ARMF (PLATES)	8	09. Alum Based SNF	Stable	INTACT	C-40	D-40
ARMF/CFRMF MARK I	9	09. Alum Based SNF	Stable	INTACT	C-41	D-41
ARMF/CFRMF MARK I LL	10	09. Alum Based SNF	Stable	INTACT	C-42	D-42
ARMF/CFRMF MARK II	11	09. Alum Based SNF	Stable	INTACT	C-43	D-43
ARMF/CFRMF MARK III	12	09. Alum Based SNF	Stable	INTACT	C-44	D-44
ATR	15	09. Alum Based SNF	Stable	INTACT	C-45	D-45
ATR	16	09. Alum Based SNF	Stable	INTACT	C-46	D-46
ATR	843	09. Alum Based SNF	Stable	INTACT	C-47	D-47
BCD B-17 (TURKEY POINT 3)	19	08. U Oxide SNF	Non-metals	INTACT	C-48	D-48
BER-II TRIGA (FLIP LEU 45/20) (GERMANY)	236	11. U Zr H SNF	Non-metals	INTACT	C-49	D-49
BMI (CPI-24)	774	08. U Oxide SNF	Non-metals	NOT INTACT	C-50	D-50
BMI (CPI-38)	20	08. U Oxide SNF	Non-metals	NOT INTACT	C-51	D-51
BORAX V (SUPERHEATER)	22	08. U Oxide SNF	Non-metals	INTACT	C-52	D-52
BR-3	927	08. U Oxide SNF	Non-metals	INTACT	C-53	D-53
BR-3 FUEL	340	08. U Oxide SNF	Non-metals	INTACT	C-54	D-54
BRP-B	23	08. U Oxide SNF	Non-metals	INTACT	C-55	D-55
BRP-C	24	08. U Oxide SNF	Non-metals	INTACT	C-56	D-56
BRP-D1	25	08. U Oxide SNF	Non-metals	INTACT	C-57	D-57
BRP-D2	26	08. U Oxide SNF	Non-metals	INTACT	C-58	D-58
BRP-E	27	08. U Oxide SNF	Non-metals	INTACT	C-59	D-59
BRP-EG	28	08. U Oxide SNF	Non-metals	INTACT	C-60	D-60
BRP-EG/F	1081	08. U Oxide SNF	Non-metals	INTACT	C-61	D-61

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
BRP-EP	29	04. MOX SNF	Non-metals	INTACT	C-62	D-62
BRP-F	30	08. U Oxide SNF	Non-metals	INTACT	C-63	D-63
BRP-F-PU	1082	08. U Oxide SNF	Non-metals	INTACT	C-64	D-64
CONNECTICUT YANKEE (S004)	34	08. U Oxide SNF	Non-metals	INTACT	C-65	D-65
CP-5 CONVERTER CYLINDERS	36	02. Pu/U Alloy SNF	Other	INTACT	C-66	D-66
DOE TEST & EXPERIMENTAL (ALUM)	42	10. Misc. SNF	Other	NOT INTACT	C-67	D-67
DOE TEST & EXPERIMENTAL (SST)	857	10. Misc. SNF	Other	NOT INTACT	C-68	D-68
DOE TEST & EXPERIMENTAL (ZIRC)	858	10. Misc. SNF	Other	NOT INTACT	C-69	D-69
DRCT	701	08. U Oxide SNF	Non-metals	INTACT	C-70	D-70
DRCT	756	08. U Oxide SNF	Non-metals	INTACT	C-71	D-71
DRESDEN I (E00161)	928	08. U Oxide SNF	Non-metals	INTACT	C-72	D-72
DRESDEN I (UN0064)	47	08. U Oxide SNF	Non-metals	INTACT	C-73	D-73
DRESII, HBR, BR-3, BRP, TMI	50	08. U Oxide SNF	Non-metals	NOT INTACT	C-74	D-74
EBR-II NITRIDE FUEL EXPER	363	10. Misc. SNF	Other	INTACT	C-75	D-75
EBR-II OXIDE FUEL EXPER	364	04. MOX SNF	Non-metals	INTACT	C-76	D-76
EBR-II OXIDE FUEL EXPER	345	04. MOX SNF	Non-metals	INTACT	C-77	D-77
FAST REACTOR FUEL	906	06. Th/U Oxide SNF	Non-metals	NOT INTACT	C-78	D-78
FAST REACTOR FUEL (U/PUC)	1029	03. Pu/U Carbide SNF	Non-metals	NOT INTACT	C-79	D-79
FERMI CORE I & 2 (CORE FOIL)	457	02. Pu/U Alloy SNF	Other	INTACT	C-80	D-80
FERMI CORE I & 2 (CORE SHIM)	69	02. Pu/U Alloy SNF	Other	INTACT	C-81	D-81
FERMI CORE I & 2 (DECLAD)	453	02. Pu/U Alloy SNF	Other	NOT INTACT	C-82	D-82
FERMI CORE I & 2 (SECTIONED)	454	02. Pu/U Alloy SNF	Other	INTACT	C-83	D-83
FERMI CORE I & 2 (SODIUM WORTH)	455	02. Pu/U Alloy SNF	Other	INTACT	C-84	D-84
FERMI CORE I & 2 (STD FUEL SUBASSEMBLY)	456	02. Pu/U Alloy SNF	Other	INTACT	C-85	D-85
FFTF CARBIDE FUEL EXPER.	347	03. Pu/U Carbide SNF	Non-metals	INTACT	C-86	D-86
FFTF OXIDE EXPERIMENTS	349	04. MOX SNF	Non-metals	INTACT	C-87	D-87
FSVR	86	05. Th/U Carbide SNF	Non-metals	INTACT	C-88	D-88
FSVR	85	05. Th/U Carbide SNF	Non-metals	INTACT	C-89	D-89
GA HTGR FUEL	89	05. Th/U Carbide SNF	Non-metals	NOT INTACT	C-90	D-90
GA RERTR	90	11. U Zr H SNF	Non-metals	NOT INTACT	C-91	D-91
GCRE CAN (1B-8T 1&2)	94	08. U Oxide SNF	Non-metals	NOT INTACT	C-92	D-92
GCRE PELLETS (1B-7T-1)	95	08. U Oxide SNF	Non-metals	NOT INTACT	C-93	D-93
GETR FILTERS	98	08. U Oxide SNF	Non-metals	NOT INTACT	C-94	D-94

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
H. B. ROBINSON (ASSEMBLY)	383	08. U Oxide SNF	Non-metals	INTACT	C-95	D-95
H. B. ROBINSON RODS	864	08. U Oxide SNF	Non-metals	NOT INTACT	C-96	D-96
HFBR	102	09. Alum Based SNF	Stable	INTACT	C-97	D-97
HFBR	961	09. Alum Based SNF	Stable	INTACT	C-98	D-98
HFEF FISSION CHAMBERS (U METAL)	894	07. U Metal SNF	Other	NOT INTACT	C-99	D-99
HTGR (PEACH BOTTOM SCRAP)	935	05. Th/U Carbide SNF	Non-metals	INTACT	C-100	D-100
KEMA	861	06. Th/U Oxide SNF	Non-metals	NOT INTACT	C-101	D-101
LOFT CENTER FUEL MODULE (A1,A2,A3,F1)	127	08. U Oxide SNF	Non-metals	INTACT	C-102	D-102
LOFT CENTER FUEL MODULE (FP-1)	1061	08. U Oxide SNF	Non-metals	INTACT	C-103	D-103
LOFT CENTER FUEL MODULE FP-2 REMAINS	923	08. U Oxide SNF	Non-metals	NOT INTACT	C-104	D-104
LOFT CORNER FUEL MODULE	128	08. U Oxide SNF	Non-metals	INTACT	C-105	D-105
LOFT FUEL RODS	924	08. U Oxide SNF	Non-metals	NOT INTACT	C-106	D-106
LOFT SQUARE FUEL MODULE	129	08. U Oxide SNF	Non-metals	INTACT	C-107	D-107
LOOSE FUEL ROD STORAGE BASKET (LFRSB)	126	08. U Oxide SNF	Non-metals	NOT INTACT	C-108	D-108
LWR SNF SCRAP (ZR/SST)	940	08. U Oxide SNF	Non-metals	NOT INTACT	C-109	D-109
MISCELLANEOUS RSWF FUEL	366	10. Misc. SNF	Other	INTACT	C-110	D-110
MISCELLANEOUS TREAT FUEL (MOX)	369	04. MOX SNF	Non-metals	NOT INTACT	C-111	D-111
MISCELLANEOUS TREAT FUEL (U-METAL)	905	07. U Metal SNF	Other	NOT INTACT	C-112	D-112
MTR CANAL SCRAP	1062	08. U Oxide SNF	Non-metals	NOT INTACT	C-113	D-113
MURR (UALX) COLUMBIA	142	09. Alum Based SNF	Stable	INTACT	C-114	D-114
MURR (UALX) COLUMBIA	962	09. Alum Based SNF	Stable	INTACT	C-115	D-115
OCONEE	156	08. U Oxide SNF	Non-metals	INTACT	C-116	D-116
ORR	461	09. Alum Based SNF	Stable	INTACT	C-117	D-117
PATHFINDER (SUPERHEATER)	166	08. U Oxide SNF	Non-metals	INTACT	C-118	D-118
PATHFINDER (SUPERHEATER)	814	08. U Oxide SNF	Non-metals	INTACT	C-119	D-119
PBF DRIVER CORE	167	08. U Oxide SNF	Non-metals	INTACT	C-120	D-120
PEACH BOTTOM (ASSEMBLY)	385	08. U Oxide SNF	Non-metals	INTACT	C-121	D-121
PEACH BOTTOM RODS	386	08. U Oxide SNF	Non-metals	NOT INTACT	C-122	D-122
PEACH BOTTOM UNIT I CORE I	169	05. Th/U Carbide SNF	Non-metals	INTACT	C-123	D-123
PEACH BOTTOM UNIT I CORE I	170	05. Th/U Carbide SNF	Non-metals	INTACT	C-124	D-124
PEACH BOTTOM UNIT I CORE II	171	05. Th/U Carbide SNF	Non-metals	INTACT	C-125	D-125
PEACH BOTTOM UNIT I CORE II (INTACT)	206	05. Th/U Carbide SNF	Non-metals	INTACT	C-126	D-126
PNL MIXED MATERIAL EXP.DCC-1	430	08. U Oxide SNF	Non-metals	NOT INTACT	C-127	D-127

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
PNL MIXED MATERIAL EXP.DCC-2	431	08. U Oxide SNF	Non-metals	NOT INTACT	C-128	D-128
PNL MIXED MATERIAL EXP.DCC-3	432	08. U Oxide SNF	Non-metals	NOT INTACT	C-129	D-129
PNL MOX FUEL	414	04. MOX SNF	Non-metals	NOT INTACT	C-130	D-130
PNL MOX FUEL	415	04. MOX SNF	Non-metals	NOT INTACT	C-131	D-131
PNL MOX FUEL 7055	416	04. MOX SNF	Non-metals	NOT INTACT	C-132	D-132
PNL MOX FUEL 7057	417	04. MOX SNF	Non-metals	NOT INTACT	C-133	D-133
PNL MOX PELLETS 7057	418	04. MOX SNF	Non-metals	NOT INTACT	C-134	D-134
PNL MOX PINS 7057	419	04. MOX SNF	Non-metals	NOT INTACT	C-135	D-135
PNL MOX STAR 3	433	04. MOX SNF	Non-metals	NOT INTACT	C-136	D-136
PNL MOX STAR 4	434	04. MOX SNF	Non-metals	NOT INTACT	C-137	D-137
PNL MOX STAR 5	435	04. MOX SNF	Non-metals	NOT INTACT	C-138	D-138
PNL MOX STAR 6	436	04. MOX SNF	Non-metals	NOT INTACT	C-139	D-139
PNL MOX STAR 7	422	04. MOX SNF	Non-metals	INTACT	C-140	D-140
PNL-3	420	04. MOX SNF	Non-metals	INTACT	C-141	D-141
PULSTAR - BUFFALO (6%RODS)	174	08. U Oxide SNF	Non-metals	INTACT	C-142	D-142
PULSTAR-N.C. STATE UNIV. (4% ASSEMBLIES)	175	08. U Oxide SNF	Non-metals	INTACT	C-143	D-143
PULSTAR-SUNY-BUFFALO (6% RODS)	176	08. U Oxide SNF	Non-metals	INTACT	C-144	D-144
RESIDUE FAILED PBF RODS	381	08. U Oxide SNF	Non-metals	NOT INTACT	C-145	D-145
ROBERT E. GINNA	182	08. U Oxide SNF	Non-metals	INTACT	C-146	D-146
ROVER (UBM)	840	03. Pu/U Carbide SNF	Non-metals	NOT INTACT	C-147	D-147
SHIPPINGPORT LWBR BLKT I	374	06. Th/U Oxide SNF	Non-metals	INTACT	C-148	D-148
SHIPPINGPORT LWBR BLKT II	375	06. Th/U Oxide SNF	Non-metals	INTACT	C-149	D-149
SHIPPINGPORT LWBR BLKT III	376	06. Th/U Oxide SNF	Non-metals	INTACT	C-150	D-150
SHIPPINGPORT LWBR REFLCT. IV	371	06. Th/U Oxide SNF	Non-metals	INTACT	C-151	D-151
SHIPPINGPORT LWBR REFLCT. V	372	06. Th/U Oxide SNF	Non-metals	INTACT	C-152	D-152
SHIPPINGPORT LWBR SCRAP	377	06. Th/U Oxide SNF	Non-metals	NOT INTACT	C-153	D-153
SHIPPINGPORT LWBR SCRAP (LINER 15718)	379	06. Th/U Oxide SNF	Non-metals	NOT INTACT	C-154	D-154
SHIPPINGPORT LWBR SEED	380	06. Th/U Oxide SNF	Non-metals	INTACT	C-155	D-155
SHIPPINGPORT PWR C1 BLKT	191	08. U Oxide SNF	Non-metals	INTACT	C-156	D-156
SHIPPINGPORT PWR C2 BLKT	192	08. U Oxide SNF	Non-metals	INTACT	C-157	D-157
SHIPPINGPORT PWR-C1-S4	194	02. Pu/U Alloy SNF	Other	INTACT	C-158	D-158
SHIPPINGPORT PWR-C2-S1	195	08. U Oxide SNF	Non-metals	INTACT	C-159	D-159
SHIPPINGPORT PWR-C2-S2	196	08. U Oxide SNF	Non-metals	INTACT	C-160	D-160

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
SM-1A	201	08. U Oxide SNF	Non-metals	NOT INTACT	C-161	D-161
SNAP	203	11. U Zr H SNF	Non-metals	NOT INTACT	C-162	D-162
SODIUM LOOP SAFETY FAC.	352	04. MOX SNF	Non-metals	NOT INTACT	C-163	D-163
SODIUM LOOP SAFETY FAC.	367	04. MOX SNF	Non-metals	NOT INTACT	C-164	D-164
SPEC (ORME)	208	02. Pu/U Alloy SNF	Other	NOT INTACT	C-165	D-165
SPSS (SPERT)	213	08. U Oxide SNF	Non-metals	NOT INTACT	C-166	D-166
TMI-2	228	08. U Oxide SNF	Non-metals	NOT INTACT	C-167	D-167
TMI-2 CORE DEBRIS	914	08. U Oxide SNF	Non-metals	NOT INTACT	C-168	D-168
TMI-2 CORE DEBRIS (D-153 & 388)	229	08. U Oxide SNF	Non-metals	NOT INTACT	C-169	D-169
TORY-IIA	230	08. U Oxide SNF	Non-metals	NOT INTACT	C-170	D-170
TORY-IIC	231	08. U Oxide SNF	Non-metals	NOT INTACT	C-171	D-171
TREAT DRIVER	232	08. U Oxide SNF	Non-metals	INTACT	C-172	D-172
TRIGA 8.5/20 FFCR OSU	1039	11. U Zr H SNF	Non-metals	INTACT	C-173	D-173
TRIGA 8.5/20 FFCR UNIV. OF CAL-IRVINE	1050	11. U Zr H SNF	Non-metals	INTACT	C-174	D-174
TRIGA 8.5/20 FFCR UNIV. OF CAL-IRVINE	1052	11. U Zr H SNF	Non-metals	INTACT	C-175	D-175
TRIGA (ACPR 12/20) JAPAN	480	11. U Zr H SNF	Non-metals	INTACT	C-176	D-176
TRIGA (ACPR 12/20) PENN. STATE UNIV.	1002	11. U Zr H SNF	Non-metals	INTACT	C-177	D-177
TRIGA (ACPR 12/20) SLOVENIA	932	11. U Zr H SNF	Non-metals	INTACT	C-178	D-178
TRIGA (ACPR) ROMANIA	1077	11. U Zr H SNF	Non-metals	INTACT	C-179	D-179
TRIGA (DEMOUNTABLE) U OF AZ	971	11. U Zr H SNF	Non-metals	INTACT	C-180	D-180
TRIGA (FLIP LEU 45/20) (DAMAGED) SO. KOREA	819	11. U Zr H SNF	Non-metals	INTACT	C-181	D-181
TRIGA (FLIP LEU-I 20/20) MALAYSIA	497	11. U Zr H SNF	Non-metals	INTACT	C-182	D-182
TRIGA (FLIP LEU-I 20/20) THAILAND	496	11. U Zr H SNF	Non-metals	INTACT	C-183	D-183
TRIGA (FLIP LEU-I) BANGLADESH	470	11. U Zr H SNF	Non-metals	INTACT	C-184	D-184
TRIGA (FLIP LEU-II 20/30) PHILIPPINES	499	11. U Zr H SNF	Non-metals	INTACT	C-185	D-185
TRIGA (FLIP LEU-II 20/30) TAIWAN	498	11. U Zr H SNF	Non-metals	INTACT	C-186	D-186
TRIGA (FLIP)	729	11. U Zr H SNF	Non-metals	INTACT	C-187	D-187
TRIGA (FLIP) ANL-W	354	11. U Zr H SNF	Non-metals	INTACT	C-188	D-188
TRIGA (FLIP) ANL-W (NRAD)	884	11. U Zr H SNF	Non-metals	INTACT	C-189	D-189
TRIGA (FLIP) AUSTRIA	492	11. U Zr H SNF	Non-metals	INTACT	C-190	D-190
TRIGA (FLIP) FFCR	996	11. U Zr H SNF	Non-metals	INTACT	C-191	D-191
TRIGA (FLIP) FFCR OSU	702	11. U Zr H SNF	Non-metals	INTACT	C-192	D-192
TRIGA (FLIP) FFCR SO. KOREA	733	11. U Zr H SNF	Non-metals	INTACT	C-193	D-193

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
TRIGA (FLIP) MEXICO	493	11. U Zr H SNF	Non-metals	INTACT	C-194	D-194
TRIGA (FLIP) OSU	240	11. U Zr H SNF	Non-metals	INTACT	C-195	D-195
TRIGA (FLIP) SLOVENIA	495	11. U Zr H SNF	Non-metals	INTACT	C-196	D-196
TRIGA (FLIP) SO. KOREA	494	11. U Zr H SNF	Non-metals	INTACT	C-197	D-197
TRIGA (FLIP) TEXAS A&M	239	11. U Zr H SNF	Non-metals	INTACT	C-198	D-198
TRIGA (FLIP) TEXAS A&M	241	11. U Zr H SNF	Non-metals	INTACT	C-199	D-199
TRIGA (FLIP) TEXAS A&M - DAMAGED	844	11. U Zr H SNF	Non-metals	INTACT	C-200	D-200
TRIGA (FLIP) U OF WI	1035	11. U Zr H SNF	Non-metals	INTACT	C-201	D-201
TRIGA (FLIP) UNIV OF WISCONSIN	242	11. U Zr H SNF	Non-metals	INTACT	C-202	D-202
TRIGA (FLIP) WSU	243	11. U Zr H SNF	Non-metals	INTACT	C-203	D-203
TRIGA (HIGH POWER) (HEU)	998	11. U Zr H SNF	Non-metals	INTACT	C-204	D-204
TRIGA (HIGH POWER) ROMANIA	302	11. U Zr H SNF	Non-metals	INTACT	C-205	D-205
TRIGA (HIGH POWER) ROMANIA	930	11. U Zr H SNF	Non-metals	INTACT	C-206	D-206
TRIGA 20/20 FFCR MNRC	737	11. U Zr H SNF	Non-metals	INTACT	C-207	D-207
TRIGA 30/20 FFCR MNRC	1055	11. U Zr H SNF	Non-metals	INTACT	C-208	D-208
TRIGA 8.5/20 FFCR	1003	11. U Zr H SNF	Non-metals	INTACT	C-209	D-209
TRIGA 8.5/20 FFCR AFRRI	969	11. U Zr H SNF	Non-metals	INTACT	C-210	D-210
TRIGA 8.5/20 FFCR ENGLAND	987	11. U Zr H SNF	Non-metals	INTACT	C-211	D-211
TRIGA 8.5/20 FFCR HEIDELBERG	1045	11. U Zr H SNF	Non-metals	INTACT	C-212	D-212
TRIGA 8.5/20 FFCR ITALY	730	11. U Zr H SNF	Non-metals	INTACT	C-213	D-213
TRIGA 8.5/20 FFCR MNRC	703	11. U Zr H SNF	Non-metals	INTACT	C-214	D-214
TRIGA 8.5/20 FFCR OSU	1041	11. U Zr H SNF	Non-metals	INTACT	C-215	D-215
TRIGA 8.5/20 FFCR PENN. STATE UNIV.	815	11. U Zr H SNF	Non-metals	INTACT	C-216	D-216
TRIGA 8.5/20 FFCR SLOVENIA	941	11. U Zr H SNF	Non-metals	INTACT	C-217	D-217
TRIGA 8.5/20 FFCR SO. KOREA	734	11. U Zr H SNF	Non-metals	INTACT	C-218	D-218
TRIGA 8.5/20 FFCR U OF AZ	974	11. U Zr H SNF	Non-metals	INTACT	C-219	D-219
TRIGA 8.5/20 FFCR U OF IL	448	11. U Zr H SNF	Non-metals	INTACT	C-220	D-220
TRIGA 8.5/20 FFCR U OF TX AUSTIN	825	11. U Zr H SNF	Non-metals	INTACT	C-221	D-221
TRIGA 8.5/20 FFCR ZAIRE	735	11. U Zr H SNF	Non-metals	INTACT	C-222	D-222
TRIGA STD (ACPR)	895	11. U Zr H SNF	Non-metals	INTACT	C-223	D-223
TRIGA STD (ALUM) ARRR	238	11. U Zr H SNF	Non-metals	INTACT	C-224	D-224
TRIGA STD (ALUM) AUSTRIA	462	11. U Zr H SNF	Non-metals	INTACT	C-225	D-225
TRIGA STD (ALUM) BRAZIL	471	11. U Zr H SNF	Non-metals	INTACT	C-226	D-226

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
TRIGA STD (ALUM) CORNELL	1047	11. U Zr H SNF	Non-metals	INTACT	C-227	D-227
TRIGA STD (ALUM) CORNELL UNIV.	235	11. U Zr H SNF	Non-metals	INTACT	C-228	D-228
TRIGA STD (ALUM) DOW	970	11. U Zr H SNF	Non-metals	INTACT	C-229	D-229
TRIGA STD (ALUM) FINLAND	463	11. U Zr H SNF	Non-metals	INTACT	C-230	D-230
TRIGA STD (ALUM) GA	728	11. U Zr H SNF	Non-metals	INTACT	C-231	D-231
TRIGA STD (ALUM) GA	870	11. U Zr H SNF	Non-metals	INTACT	C-232	D-232
TRIGA STD (ALUM) GERMANY	465	11. U Zr H SNF	Non-metals	INTACT	C-233	D-233
TRIGA STD (ALUM) HANFORD	876	11. U Zr H SNF	Non-metals	INTACT	C-234	D-234
TRIGA STD (ALUM) HANNOVER	303	11. U Zr H SNF	Non-metals	INTACT	C-235	D-235
TRIGA STD (ALUM) HEIDELBERG	464	11. U Zr H SNF	Non-metals	INTACT	C-236	D-236
TRIGA STD (ALUM) ITALY	466	11. U Zr H SNF	Non-metals	INTACT	C-237	D-237
TRIGA STD (ALUM) ITALY	467	11. U Zr H SNF	Non-metals	INTACT	C-238	D-238
TRIGA STD (ALUM) JAPAN	481	11. U Zr H SNF	Non-metals	INTACT	C-239	D-239
TRIGA STD (ALUM) KANSAS STATE UNIV	804	11. U Zr H SNF	Non-metals	INTACT	C-240	D-240
TRIGA STD (ALUM) KSU	871	11. U Zr H SNF	Non-metals	INTACT	C-241	D-241
TRIGA STD (ALUM) MSU	878	11. U Zr H SNF	Non-metals	INTACT	C-242	D-242
TRIGA STD (ALUM) REED COLLEGE	256	11. U Zr H SNF	Non-metals	INTACT	C-243	D-243
TRIGA STD (ALUM) SLOVENIA	468	11. U Zr H SNF	Non-metals	INTACT	C-244	D-244
TRIGA STD (ALUM) SO. KOREA	483	11. U Zr H SNF	Non-metals	INTACT	C-245	D-245
TRIGA STD (ALUM) U OF IL	447	11. U Zr H SNF	Non-metals	INTACT	C-246	D-246
TRIGA STD (ALUM) U OF IL	501	11. U Zr H SNF	Non-metals	INTACT	C-247	D-247
TRIGA STD (ALUM) U OF UTAH	699	11. U Zr H SNF	Non-metals	INTACT	C-248	D-248
TRIGA STD (ALUM) UNIV. OF TEXAS	877	11. U Zr H SNF	Non-metals	INTACT	C-249	D-249
TRIGA STD (ALUM) USGS	267	11. U Zr H SNF	Non-metals	INTACT	C-250	D-250
TRIGA STD (ALUM) ZAIRE	487	11. U Zr H SNF	Non-metals	INTACT	C-251	D-251
TRIGA STD 12/20 ROMANIA	1078	11. U Zr H SNF	Non-metals	INTACT	C-252	D-252
TRIGA STD 20/20 (IFE) ENGLAND	1043	11. U Zr H SNF	Non-metals	INTACT	C-253	D-253
TRIGA STD 20/20 ARRR	780	11. U Zr H SNF	Non-metals	INTACT	C-254	D-254
TRIGA STD 20/20 MNRC	1053	11. U Zr H SNF	Non-metals	INTACT	C-255	D-255
TRIGA STD 20/20 MNRC	1054	11. U Zr H SNF	Non-metals	INTACT	C-256	D-256
TRIGA STD 20/20 SOLVENIA	731	11. U Zr H SNF	Non-metals	INTACT	C-257	D-257
TRIGA STD 30/20	995	11. U Zr H SNF	Non-metals	INTACT	C-258	D-258
TRIGA STD 30/20 MNRC	704	11. U Zr H SNF	Non-metals	INTACT	C-259	D-259

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
TRIGA STD 8.5/20	252	11. U Zr H SNF	Non-metals	INTACT	C-260	D-260
TRIGA STD 8.5/20 (IFE) ITALY	929	11. U Zr H SNF	Non-metals	INTACT	C-261	D-261
TRIGA STD 8.5/20 (IFE) OSU	1040	11. U Zr H SNF	Non-metals	INTACT	C-262	D-262
TRIGA STD 8.5/20 (IFE) U OF AZ	972	11. U Zr H SNF	Non-metals	INTACT	C-263	D-263
TRIGA STD 8.5/20 (IFE) U OF AZ	973	11. U Zr H SNF	Non-metals	INTACT	C-264	D-264
TRIGA STD 8.5/20 (IFE) U OF IL	1048	11. U Zr H SNF	Non-metals	INTACT	C-265	D-265
TRIGA STD 8.5/20 (IFE) UNIV. OF CAL-IRVINE	824	11. U Zr H SNF	Non-metals	INTACT	C-266	D-266
TRIGA STD 8.5/20 (IFE) UNIV. OF CAL-IRVINE	1051	11. U Zr H SNF	Non-metals	INTACT	C-267	D-267
TRIGA STD 8.5/20 AFRI	250	11. U Zr H SNF	Non-metals	INTACT	C-268	D-268
TRIGA STD 8.5/20 ANL-W	353	11. U Zr H SNF	Non-metals	INTACT	C-269	D-269
TRIGA STD 8.5/20 ANL-W	370	11. U Zr H SNF	Non-metals	INTACT	C-270	D-270
TRIGA STD 8.5/20 AUSTRIA	469	11. U Zr H SNF	Non-metals	INTACT	C-271	D-271
TRIGA STD 8.5/20 BRAZIL	1063	11. U Zr H SNF	Non-metals	INTACT	C-272	D-272
TRIGA STD 8.5/20 CORNELL	246	11. U Zr H SNF	Non-metals	INTACT	C-273	D-273
TRIGA STD 8.5/20 DOW	251	11. U Zr H SNF	Non-metals	INTACT	C-274	D-274
TRIGA STD 8.5/20 ENGLAND	485	11. U Zr H SNF	Non-metals	INTACT	C-275	D-275
TRIGA STD 8.5/20 FINLAND	472	11. U Zr H SNF	Non-metals	INTACT	C-276	D-276
TRIGA STD 8.5/20 GA	244	11. U Zr H SNF	Non-metals	NOT INTACT	C-277	D-277
TRIGA STD 8.5/20 GERMANY	305	11. U Zr H SNF	Non-metals	INTACT	C-278	D-278
TRIGA STD 8.5/20 GERMANY	474	11. U Zr H SNF	Non-metals	INTACT	C-279	D-279
TRIGA STD 8.5/20 HANNOVER	473	11. U Zr H SNF	Non-metals	INTACT	C-280	D-280
TRIGA STD 8.5/20 HEIDELBERG	1044	11. U Zr H SNF	Non-metals	INTACT	C-281	D-281
TRIGA STD 8.5/20 INDONESIA	475	11. U Zr H SNF	Non-metals	INTACT	C-282	D-282
TRIGA STD 8.5/20 INDONESIA	476	11. U Zr H SNF	Non-metals	INTACT	C-283	D-283
TRIGA STD 8.5/20 ITALY	477	11. U Zr H SNF	Non-metals	INTACT	C-284	D-284
TRIGA STD 8.5/20 ITALY	478	11. U Zr H SNF	Non-metals	INTACT	C-285	D-285
TRIGA STD 8.5/20 ITALY	1080	11. U Zr H SNF	Non-metals	INTACT	C-286	D-286
TRIGA STD 8.5/20 JAPAN	479	11. U Zr H SNF	Non-metals	INTACT	C-287	D-287
TRIGA STD 8.5/20 KANSAS STATE UNIV	253	11. U Zr H SNF	Non-metals	INTACT	C-288	D-288
TRIGA STD 8.5/20 MEXICO	482	11. U Zr H SNF	Non-metals	INTACT	C-289	D-289
TRIGA STD 8.5/20 MNRC	254	11. U Zr H SNF	Non-metals	INTACT	C-290	D-290
TRIGA STD 8.5/20 MSU	873	11. U Zr H SNF	Non-metals	NOT INTACT	C-291	D-291
TRIGA STD 8.5/20 PENN. STATE UNIV.	237	11. U Zr H SNF	Non-metals	INTACT	C-292	D-292

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
TRIGA STD 8.5/20 REED COLLEGE	775	11. U Zr H SNF	Non-metals	INTACT	C-293	D-293
TRIGA STD 8.5/20 SLOVENIA	488	11. U Zr H SNF	Non-metals	INTACT	C-294	D-294
TRIGA STD 8.5/20 SLOVENIA	1079	11. U Zr H SNF	Non-metals	INTACT	C-295	D-295
TRIGA STD 8.5/20 SO. KOREA	484	11. U Zr H SNF	Non-metals	INTACT	C-296	D-296
TRIGA STD 8.5/20 TEXAS A&M	258	11. U Zr H SNF	Non-metals	INTACT	C-297	D-297
TRIGA STD 8.5/20 THAILAND	489	11. U Zr H SNF	Non-metals	INTACT	C-298	D-298
TRIGA STD 8.5/20 TURKEY	490	11. U Zr H SNF	Non-metals	INTACT	C-299	D-299
TRIGA STD 8.5/20 U OF AZ	59	11. U Zr H SNF	Non-metals	INTACT	C-300	D-300
TRIGA STD 8.5/20 U OF AZ	975	11. U Zr H SNF	Non-metals	INTACT	C-301	D-301
TRIGA STD 8.5/20 U OF IL	449	11. U Zr H SNF	Non-metals	INTACT	C-302	D-302
TRIGA STD 8.5/20 U OF TX AUSTIN	265	11. U Zr H SNF	Non-metals	INTACT	C-303	D-303
TRIGA STD 8.5/20 U OF UTAH	261	11. U Zr H SNF	Non-metals	INTACT	C-304	D-304
TRIGA STD 8.5/20 UC @ Berkeley	874	11. U Zr H SNF	Non-metals	NOT INTACT	C-305	D-305
TRIGA STD 8.5/20 UNIV OF MARYLAND	260	11. U Zr H SNF	Non-metals	INTACT	C-306	D-306
TRIGA STD 8.5/20 UNIV. OF CAL-IRVINE	264	11. U Zr H SNF	Non-metals	INTACT	C-307	D-307
TRIGA STD 8.5/20 UNIV. OF WISCONSIN	262	11. U Zr H SNF	Non-metals	INTACT	C-308	D-308
TRIGA STD 8.5/20 USGS	964	11. U Zr H SNF	Non-metals	INTACT	C-309	D-309
TRIGA STD 8.5/20 WSU	268	11. U Zr H SNF	Non-metals	INTACT	C-310	D-310
TRIGA STD 8.5/20 ZAIRE	486	11. U Zr H SNF	Non-metals	INTACT	C-311	D-311
TRU SCRAP SNF (MOX)	368	04. MOX SNF	Non-metals	NOT INTACT	C-312	D-312
TRU SCRAP SNF (U METAL)	904	07. U Metal SNF	Other	NOT INTACT	C-313	D-313
TURKEY POINT	271	08. U Oxide SNF	Non-metals	INTACT	C-314	D-314
US/UK FUEL PINS	356	04. MOX SNF	Non-metals	NOT INTACT	C-315	D-315
VBWR (GENEVA)	285	08. U Oxide SNF	Non-metals	INTACT	C-316	D-316
VEPCO	286	08. U Oxide SNF	Non-metals	INTACT	C-317	D-317
VEPCO	700	08. U Oxide SNF	Non-metals	INTACT	C-318	D-318
VEPCO (T-11 ASSEMBLY)	993	08. U Oxide SNF	Non-metals	INTACT	C-319	D-319
VEPCO (T-11 RODS)	1049	08. U Oxide SNF	Non-metals	INTACT	C-320	D-320
VEPCO T-11	994	08. U Oxide SNF	Non-metals	INTACT	C-321	D-321
Savannah River SNF						
ANLJ	5	09. Alum Based SNF	Stable	INTACT	C-322	D-322
ASTRA-(AUSTRIA)(LEU U308)	1058	09. Alum Based SNF	Stable	INTACT	C-323	D-323
ASTRA-(AUSTRIA)(LEU U3SI2)	712	09. Alum Based SNF	Stable	INTACT	C-324	D-324

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
ASTRA-AUSTRIA (UALX-HEU)	646	09. Alum Based SNF	Stable	INTACT	C-325	D-325
ASTRA-AUSTRIA (UALX-MEU)	566	09. Alum Based SNF	Stable	INTACT	C-326	D-326
ATSR	17	09. Alum Based SNF	Stable	INTACT	C-327	D-327
BABCOCK & WILCOX SCRAP	18	04. MOX SNF	Non-metals	NOT INTACT	C-328	D-328
BER-II [HMI] (END BOXES) GERMANY	892	09. Alum Based SNF	Stable	INTACT	C-329	D-329
BER-II [HMI] (UALX HEU) GERMANY	758	09. Alum Based SNF	Stable	INTACT	C-330	D-330
BNL MEDICAL RX (BMRR)	21	09. Alum Based SNF	Stable	INTACT	C-331	D-331
BSR	31	09. Alum Based SNF	Stable	INTACT	C-332	D-332
CANDU	979	08. U Oxide SNF	Non-metals	INTACT	C-333	D-333
CVTR FUEL	37	08. U Oxide SNF	Non-metals	INTACT	C-334	D-334
DR-3 (U3O8 LEU)(DENMARK)	1059	09. Alum Based SNF	Stable	INTACT	C-335	D-335
DR-3 (U3SI2 LEU)(DENMARK)	759	09. Alum Based SNF	Stable	INTACT	C-336	D-336
DR-3 (UALX HEU)(DENMARK)	714	09. Alum Based SNF	Stable	INTACT	C-337	D-337
DRESDEN I THO2/UO2 (LEU)	44	06. Th/U Oxide SNF	Non-metals	INTACT	C-338	D-338
DRESDEN UO2 (LEU)	49	08. U Oxide SNF	Non-metals	INTACT	C-339	D-339
EBWR (6% UO2) LEU	65	08. U Oxide SNF	Non-metals	INTACT	C-340	D-340
EBWR (FUEL FOLLOWER) HEU	740	08. U Oxide SNF	Non-metals	NOT INTACT	C-341	D-341
EBWR (MOX)	63	04. MOX SNF	Non-metals	INTACT	C-342	D-342
EBWR (NORMAL UO2)	60	08. U Oxide SNF	Non-metals	INTACT	C-343	D-343
EBWR (SPIKES)	891	08. U Oxide SNF	Non-metals	INTACT	C-344	D-344
EBWR (U METAL) ENRICHED HEAVY	64	07. U Metal SNF	Other	INTACT	C-345	D-345
EBWR (U METAL) ENRICHED THIN	887	07. U Metal SNF	Other	INTACT	C-346	D-346
EBWR (U METAL) ET-11	888	07. U Metal SNF	Other	INTACT	C-347	D-347
EBWR (U METAL) NORMAL HEAVY	889	07. U Metal SNF	Other	INTACT	C-348	D-348
EBWR (U METAL) NORMAL THIN	890	07. U Metal SNF	Other	INTACT	C-349	D-349
ENEA (LEU UALX) SALUGGIA ITALY	760	09. Alum Based SNF	Stable	INTACT	C-350	D-350
ENEA (UALX HEU) SALUGGIA ITALY	574	09. Alum Based SNF	Stable	INTACT	C-351	D-351
EPRI	67	04. MOX SNF	Non-metals	NOT INTACT	C-352	D-352
ERR (ASSEMBLIES)	68	06. Th/U Oxide SNF	Non-metals	INTACT	C-353	D-353
ERR (RODS)	1057	06. Th/U Oxide SNF	Non-metals	INTACT	C-354	D-354
ESSOR (UALX-HEU) ITALY	762	09. Alum Based SNF	Stable	INTACT	C-355	D-355
FMRB (GERMANY)	577	09. Alum Based SNF	Stable	INTACT	C-356	D-356
FRG-1 (U3O8 LEU) GERMANY	581	09. Alum Based SNF	Stable	INTACT	C-357	D-357

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
FRG-1 (U3SI2 LEU) GERMANY	741	09. Alum Based SNF	Stable	INTACT	C-358	D-358
FRG-1 (UALX HEU) GERMANY	742	09. Alum Based SNF	Stable	INTACT	C-359	D-359
FRJ (UALX-HEU) GERMANY	933	09. Alum Based SNF	Stable	INTACT	C-360	D-360
FRJ (UALX-MEU) GERMANY	1000	09. Alum Based SNF	Stable	INTACT	C-361	D-361
FRJ TUBES (U3O8 LEU) GERMANY	999	09. Alum Based SNF	Stable	INTACT	C-362	D-362
FRM (UALX HEU 45%) GERMANY	805	09. Alum Based SNF	Stable	INTACT	C-363	D-363
FRM (UALX HEU) GERMANY	806	09. Alum Based SNF	Stable	INTACT	C-364	D-364
FRR ASTRA (U3O8-LEU) AUSTRIA	556	09. Alum Based SNF	Stable	INTACT	C-365	D-365
FRR ASTRA (U3SI2 LEU) AUSTRIA	515	09. Alum Based SNF	Stable	INTACT	C-366	D-366
FRR ASTRA (UALX-HEU) AUSTRIA	654	09. Alum Based SNF	Stable	INTACT	C-367	D-367
FRR ASTRA (UALX-HEU) AUSTRIA	738	09. Alum Based SNF	Stable	INTACT	C-368	D-368
FRR FMRB (GERMANY)	1066	09. Alum Based SNF	Stable	INTACT	C-369	D-369
FRR MTR (UALX HEU) AUSTRALIA	649	09. Alum Based SNF	Stable	INTACT	C-370	D-370
FRR MTR (UALX-HEU) JAPAN	603	09. Alum Based SNF	Stable	INTACT	C-371	D-371
FRR MTR (UALX-HEU) JAPAN	605	09. Alum Based SNF	Stable	INTACT	C-372	D-372
FRR MTR (UALX-HEU) NETHERLANDS	609	09. Alum Based SNF	Stable	INTACT	C-373	D-373
FRR MTR (UALX-HEU) TAIWAN	628	09. Alum Based SNF	Stable	INTACT	C-374	D-374
FRR MTR (UALX-LEU) ARGENTINA	547	09. Alum Based SNF	Stable	INTACT	C-375	D-375
FRR MTR (UALX-LEU) JAPAN	551	09. Alum Based SNF	Stable	INTACT	C-376	D-376
FRR MTR (UALX-LEU) TAIWAN	555	09. Alum Based SNF	Stable	INTACT	C-377	D-377
FRR MTR (UALX-LEU) VENEZUELA	559	09. Alum Based SNF	Stable	INTACT	C-378	D-378
FRR MTR (UALX-MEU) JAPAN	565	09. Alum Based SNF	Stable	INTACT	C-379	D-379
FRR MTR UALX HEU CANADA	294	09. Alum Based SNF	Stable	INTACT	C-380	D-380
FRR MTR-C (U3O8-LEU) PERU	503	09. Alum Based SNF	Stable	INTACT	C-381	D-381
FRR MTR-C (U3SI2 LEU) CANADA	512	09. Alum Based SNF	Stable	INTACT	C-382	D-382
FRR MTR-C (U3SI2 LEU) GERMANY	517	09. Alum Based SNF	Stable	INTACT	C-383	D-383
FRR MTR-C (U3SI2 LEU) GREECE	531	09. Alum Based SNF	Stable	INTACT	C-384	D-384
FRR MTR-C (U3SI2 LEU) JAPAN	289	09. Alum Based SNF	Stable	INTACT	C-385	D-385
FRR MTR-C (U3SI2 LEU) NETHERLANDS	509	09. Alum Based SNF	Stable	INTACT	C-386	D-386
FRR MTR-C (UALX LEU) SWEDEN	523	09. Alum Based SNF	Stable	INTACT	C-387	D-387
FRR MTR-C (UALX-HEU) ARGENTINA	635	09. Alum Based SNF	Stable	INTACT	C-388	D-388
FRR MTR-C (UALX-HEU) CANADA	612	09. Alum Based SNF	Stable	INTACT	C-389	D-389
FRR MTR-C (UALX-HEU) GERMANY	579	09. Alum Based SNF	Stable	INTACT	C-390	D-390

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
FRR MTR-C (UALX-HEU) JAPAN	600	09. Alum Based SNF	Stable	INTACT	C-391	D-391
FRR MTR-C (UALX-HEU) PORTUGAL	631	09. Alum Based SNF	Stable	INTACT	C-392	D-392
FRR MTR-C (UALX-HEU) TURKEY	643	09. Alum Based SNF	Stable	INTACT	C-393	D-393
FRR MTR-C (UALX-LEU) JAPAN	552	09. Alum Based SNF	Stable	INTACT	C-394	D-394
FRR MTR-C (UALX-LEU) PORTUGAL	540	09. Alum Based SNF	Stable	INTACT	C-395	D-395
FRR MTR-C1 (UALX-HEU) SWITZERLAND	656	09. Alum Based SNF	Stable	INTACT	C-396	D-396
FRR MTR-C2 (U3SI2 LEU) TURKEY	527	09. Alum Based SNF	Stable	INTACT	C-397	D-397
FRR MTR-C2 (UALX-HEU) SWITZERLAND	657	09. Alum Based SNF	Stable	INTACT	C-398	D-398
FRR MTR-O (UALX-HEU) TURKEY	642	09. Alum Based SNF	Stable	INTACT	C-399	D-399
FRR MTR-O (UALX-LEU) PORTUGAL	541	09. Alum Based SNF	Stable	INTACT	C-400	D-400
FRR MTR-S (U308-LEU) INDONESIA	502	09. Alum Based SNF	Stable	INTACT	C-401	D-401
FRR MTR-S (U308-LEU) PERU	504	09. Alum Based SNF	Stable	INTACT	C-402	D-402
FRR MTR-S (U3SI2 LEU) CANADA	513	09. Alum Based SNF	Stable	INTACT	C-403	D-403
FRR MTR-S (U3SI2 LEU) GERMANY	519	09. Alum Based SNF	Stable	INTACT	C-404	D-404
FRR MTR-S (U3SI2 LEU) GERMANY	1067	09. Alum Based SNF	Stable	INTACT	C-405	D-405
FRR MTR-S (U3SI2 LEU) GREECE	532	09. Alum Based SNF	Stable	INTACT	C-406	D-406
FRR MTR-S (U3SI2 LEU) JAPAN	506	09. Alum Based SNF	Stable	INTACT	C-407	D-407
FRR MTR-S (U3SI2 LEU) JAPAN	508	09. Alum Based SNF	Stable	INTACT	C-408	D-408
FRR MTR-S (U3SI2 LEU) NETHERLANDS	510	09. Alum Based SNF	Stable	INTACT	C-409	D-409
FRR MTR-S (U3SI2 LEU) TURKEY	528	09. Alum Based SNF	Stable	INTACT	C-410	D-410
FRR MTR-S (UALX-HEU) CANADA	720	09. Alum Based SNF	Stable	INTACT	C-411	D-411
FRR MTR-S (UALX-HEU) GERMANY	582	09. Alum Based SNF	Stable	INTACT	C-412	D-412
FRR MTR-S (UALX-HEU) GERMANY	584	09. Alum Based SNF	Stable	INTACT	C-413	D-413
FRR MTR-S (UALX-HEU) GERMANY	585	09. Alum Based SNF	Stable	INTACT	C-414	D-414
FRR MTR-S (UALX-HEU) GERMANY	588	09. Alum Based SNF	Stable	INTACT	C-415	D-415
FRR MTR-S (UALX-HEU) JAPAN	602	09. Alum Based SNF	Stable	INTACT	C-416	D-416
FRR MTR-S (UALX-HEU) NETHERLANDS	607	09. Alum Based SNF	Stable	INTACT	C-417	D-417
FRR MTR-S (UALX-HEU) NETHERLANDS	608	09. Alum Based SNF	Stable	INTACT	C-418	D-418
FRR MTR-S (UALX-HEU) PORTUGAL	632	09. Alum Based SNF	Stable	INTACT	C-419	D-419
FRR MTR-S (UALX-HEU) SWITZERLAND	658	09. Alum Based SNF	Stable	INTACT	C-420	D-420
FRR MTR-S (UALX-HEU) TURKEY	644	09. Alum Based SNF	Stable	INTACT	C-421	D-421
FRR MTR-S (UALX-LEU) JAPAN	553	09. Alum Based SNF	Stable	INTACT	C-422	D-422
FRR MTR-S (UALX-LEU) PORTUGAL	542	09. Alum Based SNF	Stable	INTACT	C-423	D-423

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
FRR MTR-S (UALX-MEU) GERMANY	1068	09. Alum Based SNF	Stable	INTACT	C-424	D-424
FRR PIN CLUSTER U3SI2-LEU CANADA	660	09. Alum Based SNF	Stable	INTACT	C-425	D-425
FRR PIN CLUSTER U3SI2-LEU SO. KOREA	293	09. Alum Based SNF	Stable	INTACT	C-426	D-426
FRR PIN CLUSTER U3SI2-LEU SO. KOREA	659	09. Alum Based SNF	Stable	INTACT	C-427	D-427
FRR PIN CLUSTER UALX HEU CANADA	661	09. Alum Based SNF	Stable	INTACT	C-428	D-428
FRR PIN CLUSTER UALX HEU CANADA	662	09. Alum Based SNF	Stable	INTACT	C-429	D-429
FRR PIN CLUSTER UALX HEU CANADA	663	09. Alum Based SNF	Stable	INTACT	C-430	D-430
FRR SLOWPOKE (HEU) CANADA	665	09. Alum Based SNF	Stable	INTACT	C-431	D-431
FRR SLOWPOKE (HEU) CANADA	666	09. Alum Based SNF	Stable	INTACT	C-432	D-432
FRR SLOWPOKE (HEU) CANADA	668	09. Alum Based SNF	Stable	INTACT	C-433	D-433
FRR SLOWPOKE (HEU) CANADA	669	09. Alum Based SNF	Stable	INTACT	C-434	D-434
FRR SLOWPOKE (HEU) MONTREAL	667	09. Alum Based SNF	Stable	INTACT	C-435	D-435
FRR TARGET ARGENTINA	297	08. U Oxide SNF	Non-metals	INTACT	C-436	D-436
FRR TARGET CANADA	671	08. U Oxide SNF	Non-metals	NOT INTACT	C-437	D-437
FRR TARGET INDONESIA	672	08. U Oxide SNF	Non-metals	NOT INTACT	C-438	D-438
FRR TUBES (U3SI2 LEU) DENMARK	298	09. Alum Based SNF	Stable	INTACT	C-439	D-439
FRR TUBES (U3SI2 LEU) GERMANY	673	09. Alum Based SNF	Stable	INTACT	C-440	D-440
FRR TUBES (U3SI2 LEU) GERMANY	674	09. Alum Based SNF	Stable	INTACT	C-441	D-441
FRR TUBES (U3SI2 LEU) GERMANY	675	09. Alum Based SNF	Stable	INTACT	C-442	D-442
FRR TUBES (UALX LEU) AUSTRALIA	299	09. Alum Based SNF	Stable	INTACT	C-443	D-443
FRR TUBES (UALX-HEU) AUSTRALIA	300	09. Alum Based SNF	Stable	INTACT	C-444	D-444
FRR TUBES (UALX-HEU) AUSTRALIA	684	09. Alum Based SNF	Stable	INTACT	C-445	D-445
FRR TUBES (UALX-HEU) DENMARK	676	09. Alum Based SNF	Stable	INTACT	C-446	D-446
FRR TUBES (UALX-HEU) DENMARK	678	09. Alum Based SNF	Stable	INTACT	C-447	D-447
FRR TUBES (UALX-HEU) GERMANY	683	09. Alum Based SNF	Stable	INTACT	C-448	D-448
FRR TUBES (UALX-HEU) GERMANY	685	09. Alum Based SNF	Stable	INTACT	C-449	D-449
GCRE (1B SERIES)	745	08. U Oxide SNF	Non-metals	INTACT	C-450	D-450
GCRE (1Z SERIES)	916	08. U Oxide SNF	Non-metals	INTACT	C-451	D-451
GENTR	97	09. Alum Based SNF	Stable	INTACT	C-452	D-452
GRR (UALX HEU) GREECE	440	09. Alum Based SNF	Stable	INTACT	C-453	D-453
GRR (UALX HEU) GREECE	1069	09. Alum Based SNF	Stable	INTACT	C-454	D-454
GTRR	87	09. Alum Based SNF	Stable	INTACT	C-455	D-455
H. B. ROBINSON	99	04. MOX SNF	Non-metals	NOT INTACT	C-456	D-456

Fuel Name	SNF ID	TSPA Category	DBE Category		Source Term Est.	
					Page #	
					2010	2030
HFBR	706	09. Alum Based SNF	Stable	INTACT	C-457	D-457
HFIR (INNER)	103	09. Alum Based SNF	Stable	INTACT	C-458	D-458
HFIR (INNER)	1083	09. Alum Based SNF	Stable	INTACT	C-459	D-459
HFIR (OUTER)	707	09. Alum Based SNF	Stable	INTACT	C-460	D-460
HFIR (OUTER)	1084	09. Alum Based SNF	Stable	INTACT	C-461	D-461
HIFAR (UALX-HEU) AUSTRALIA	680	09. Alum Based SNF	Stable	INTACT	C-462	D-462
HOR (NETHERLANDS)	713	09. Alum Based SNF	Stable	INTACT	C-463	D-463
HTRE (ANP)	105	08. U Oxide SNF	Non-metals	NOT INTACT	C-464	D-464
HWCTR 3EMT-2 (UMO)	118	02. Pu/U Alloy SNF	Other	INTACT	C-465	D-465
HWCTR DRIVER (U-ZR) HEU	117	02. Pu/U Alloy SNF	Other	INTACT	C-466	D-466
HWCTR ETWO (U METAL) LEU	867	07. U Metal SNF	Other	INTACT	C-467	D-467
HWCTR IMT (U METAL-SST) DU	113	07. U Metal SNF	Other	INTACT	C-468	D-468
HWCTR IRO (UO2) LEU	976	08. U Oxide SNF	Non-metals	INTACT	C-469	D-469
HWCTR IS (U-ZR) LEU	977	02. Pu/U Alloy SNF	Other	INTACT	C-470	D-470
HWCTR OT (UO2) LEU	283	08. U Oxide SNF	Non-metals	INTACT	C-471	D-471
HWCTR RMT & SMT (U METAL) LEU	790	07. U Metal SNF	Other	INTACT	C-472	D-472
HWCTR SOT (UO2) LEU	120	08. U Oxide SNF	Non-metals	INTACT	C-473	D-473
HWCTR SPR (U-ZR) LEU	783	02. Pu/U Alloy SNF	Other	INTACT	C-474	D-474
HWCTR SPRO (UO2) ALUM LEU	115	09. Alum Based SNF	Non-metals	INTACT	C-475	D-475
HWCTR SPRO (UO2) SST LEU	978	08. U Oxide SNF	Non-metals	INTACT	C-476	D-476
HWCTR SPRO (UO2) ZR LEU	772	08. U Oxide SNF	Non-metals	INTACT	C-477	D-477
HWCTR TFEN (U-ZR) LEU	880	02. Pu/U Alloy SNF	Other	INTACT	C-478	D-478
HWCTR TMT-1-2 & 1-3 (U/TH)	112	02. Pu/U Alloy SNF	Stable	INTACT	C-479	D-479
HWCTR TWNT (U METAL) LEU	791	07. U Metal SNF	Other	INTACT	C-480	D-480
IAN-R1 (COLUMBIA)	596	09. Alum Based SNF	Stable	INTACT	C-481	D-481
IAN-R1 (COLUMBIA)	803	09. Alum Based SNF	Stable	INTACT	C-482	D-482
IEA-R1 (UALX HEU) BRAZIL	954	09. Alum Based SNF	Stable	INTACT	C-483	D-483
IEA-R1 (UALX LEU) BRAZIL	545	09. Alum Based SNF	Stable	INTACT	C-484	D-484
IEA-R1 (UALX LEU) BRAZIL	1076	09. Alum Based SNF	Stable	INTACT	C-485	D-485
IOWA ST. UNIV. (HEU UALX)	792	09. Alum Based SNF	Stable	INTACT	C-486	D-486
IOWA STATE UNIVERSITY (U3Si2 LEU)	953	09. Alum Based SNF	Stable	INTACT	C-487	D-487
JEN-1 (HEU UALX) SPAIN	795	09. Alum Based SNF	Stable	INTACT	C-488	D-488
JEN-1 (UALX LEU) SPAIN	749	09. Alum Based SNF	Stable	INTACT	C-489	D-489

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
JMTR	507	09. Alum Based SNF	Stable	INTACT	C-490	D-490
JMTR (UALX 45% MEU) JAPAN	886	09. Alum Based SNF	Stable	INTACT	C-491	D-491
JMTR (UALX HEU) JAPAN	123	09. Alum Based SNF	Stable	INTACT	C-492	D-492
JRR-2 (UALX-HEU 45%) JAPAN	885	09. Alum Based SNF	Stable	INTACT	C-493	D-493
JRR-2 (UALX-HEU) JAPAN	606	09. Alum Based SNF	Stable	INTACT	C-494	D-494
JRR-3M (ULAX LEU)	1056	09. Alum Based SNF	Stable	INTACT	C-495	D-495
JRR-4 (U3SI2 LEU)	1071	09. Alum Based SNF	Stable	INTACT	C-496	D-496
JRR-4 (UALX HEU)	505	09. Alum Based SNF	Stable	INTACT	C-497	D-497
JRR-4 (UALX HEU)	1070	09. Alum Based SNF	Stable	INTACT	C-498	D-498
KURR (UALX-HEU) JAPAN	601	09. Alum Based SNF	Stable	INTACT	C-499	D-499
LWR SAMPLES	134	04. MOX SNF	Non-metals	NOT INTACT	C-500	D-500
MIT	135	09. Alum Based SNF	Stable	INTACT	C-501	D-501
MIT	136	09. Alum Based SNF	Stable	INTACT	C-502	D-502
ML-1 (GCRE)	137	08. U Oxide SNF	Non-metals	INTACT	C-503	D-503
MNR (UALX-HEU) CANADA	614	09. Alum Based SNF	Stable	INTACT	C-504	D-504
MNR (UALX-HEU) CANADA	1064	09. Alum Based SNF	Stable	INTACT	C-505	D-505
MURR (UALX) COLUMBIA	144	09. Alum Based SNF	Stable	INTACT	C-506	D-506
MURR (ULAX HEU) COLUMBIA	143	09. Alum Based SNF	Stable	INTACT	C-507	D-507
N.S. SAVANNAH (UO2)	854	08. U Oxide SNF	Non-metals	INTACT	C-508	D-508
NEREIDE (FRANCE)	751	09. Alum Based SNF	Stable	INTACT	C-509	D-509
NIST	154	09. Alum Based SNF	Stable	INTACT	C-510	D-510
NIST (U308 HEU)	752	09. Alum Based SNF	Stable	INTACT	C-511	D-511
OHIO STATE (HEU)	157	09. Alum Based SNF	Stable	INTACT	C-512	D-512
OHIO STATE (LEU)	158	09. Alum Based SNF	Stable	INTACT	C-513	D-513
OMEGA WEST (204)	406	09. Alum Based SNF	Stable	INTACT	C-514	D-514
OMEGA WEST (236)	407	09. Alum Based SNF	Stable	INTACT	C-515	D-515
OMEGA WEST (250)	408	09. Alum Based SNF	Stable	INTACT	C-516	D-516
ORR (U308 HEU)	903	09. Alum Based SNF	Stable	INTACT	C-517	D-517
ORR (U308 HEU)	753	09. Alum Based SNF	Stable	INTACT	C-518	D-518
ORR (U3SI2 LEU)	165	09. Alum Based SNF	Stable	INTACT	C-519	D-519
ORR (U3SI2 LEU)	850	09. Alum Based SNF	Stable	INTACT	C-520	D-520
ORR (U3SI2 LEU)	944	09. Alum Based SNF	Stable	INTACT	C-521	D-521
ORR SPECIAL	163	09. Alum Based SNF	Stable	INTACT	C-522	D-522

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
ORR-BW-1 (MOX)	160	04. MOX SNF	Non-metals	INTACT	C-523	D-523
PRR-1 (UALX-HEU) PHILIPPINES	638	09. Alum Based SNF	Stable	INTACT	C-524	D-524
PRR-1 (UALX-LEU) PHILLIPPINES	558	09. Alum Based SNF	Stable	INTACT	C-525	D-525
PURDUE UNIVERSITY (U-ALX HEU)	177	09. Alum Based SNF	Stable	INTACT	C-526	D-526
PURDUE UNIVERSITY-MTR-SI	178	09. Alum Based SNF	Stable	INTACT	C-527	D-527
R-2 SVTR (U3SI2 LEU) SWEDEN	942	09. Alum Based SNF	Stable	INTACT	C-528	D-528
R-2 SVTR (UALX HEU) SWEDEN	801	09. Alum Based SNF	Stable	INTACT	C-529	D-529
RA-3 (UALX-HEU) (ARGENTINA)	634	09. Alum Based SNF	Stable	INTACT	C-530	D-530
RA-3 (UALX-HEU) (ARGENTINA)	636	09. Alum Based SNF	Stable	INTACT	C-531	D-531
RECH-1 (CHILE)	708	09. Alum Based SNF	Stable	INTACT	C-532	D-532
RHF (FRANCE)	179	09. Alum Based SNF	Stable	INTACT	C-533	D-533
RINSC	181	09. Alum Based SNF	Stable	INTACT	C-534	D-534
RINSC	180	09. Alum Based SNF	Stable	INTACT	C-535	D-535
RPI (UALX-LEU) PORTUGAL	943	09. Alum Based SNF	Stable	INTACT	C-536	D-536
RSG-GAS (U308-LEU) INDONESIA	288	09. Alum Based SNF	Stable	INTACT	C-537	D-537
RU-1 (UALX LEU) URAGUAY	557	09. Alum Based SNF	Stable	INTACT	C-538	D-538
RU-1 (UALX LEU) URAGUAY	1073	09. Alum Based SNF	Stable	INTACT	C-539	D-539
RV-1 (UALX LEU) VENEZUELA	816	09. Alum Based SNF	Stable	INTACT	C-540	D-540
SAPHIR U3SI2-LEU (SWITZERLAND)	443	09. Alum Based SNF	Stable	INTACT	C-541	D-541
SAPHIR UALX-HEU (SWITZERLAND)	444	09. Alum Based SNF	Stable	INTACT	C-542	D-542
SAPHIR ULAX MEU (SWITZERLAND)	945	09. Alum Based SNF	Stable	INTACT	C-543	D-543
SAXTON (MOX SST)	883	04. MOX SNF	Non-metals	NOT INTACT	C-544	D-544
SAXTON (MOX ZR)	787	04. MOX SNF	Non-metals	NOT INTACT	C-545	D-545
SAXTON (UO2 SST)	882	08. U Oxide SNF	Non-metals	INTACT	C-546	D-546
SAXTON (UO2 ZR)	788	08. U Oxide SNF	Non-metals	INTACT	C-547	D-547
SHIPPINGPORT PWR C1 BLKT (RODS)	189	08. U Oxide SNF	Non-metals	INTACT	C-548	D-548
SLOWPOKE (HEU) CANADA	296	09. Alum Based SNF	Stable	INTACT	C-549	D-549
SLOWPOKE (HEU) CANADA	1065	09. Alum Based SNF	Stable	INTACT	C-550	D-550
SPERT-III	209	08. U Oxide SNF	Non-metals	INTACT	C-551	D-551
THOR (UALX-HEU) TAIWAN	629	09. Alum Based SNF	Stable	INTACT	C-552	D-552
TRR-1 (UALX-HEU) THAILAND	633	09. Alum Based SNF	Stable	INTACT	C-553	D-553
UMRR (HEU) ROLLA	881	09. Alum Based SNF	Stable	INTACT	C-554	D-554
UMRR (LEU) ROLLA	146	09. Alum Based SNF	Stable	INTACT	C-555	D-555

					Source Term Est.	
					Page #	
Fuel Name	SNF ID	TSPA Category	DBE Category		2010	2030
UNIV OF FLORIDA (ARGONAUT) HEU	272	09. Alum Based SNF	Stable	INTACT	C-556	D-556
UNIV OF FLORIDA (ARGONAUT) LEU	273	09. Alum Based SNF	Stable	INTACT	C-557	D-557
UNIV OF MASS-LOWELL (HEU)	274	09. Alum Based SNF	Stable	INTACT	C-558	D-558
UNIV OF MASS-LOWELL (LEU)	275	09. Alum Based SNF	Stable	INTACT	C-559	D-559
UNIV OF MICHIGAN	276	09. Alum Based SNF	Stable	INTACT	C-560	D-560
UNIV OF MICHIGAN (CONTROL)	1005	09. Alum Based SNF	Stable	INTACT	C-561	D-561
UNIV OF MICHIGAN (REG)	277	09. Alum Based SNF	Stable	INTACT	C-562	D-562
UNIV OF VIRGINIA (U3SI2 LEU)	952	09. Alum Based SNF	Stable	INTACT	C-563	D-563
UNIV OF VIRGINIA (ULAX HEU)	279	09. Alum Based SNF	Stable	INTACT	C-564	D-564
VBWR (UO2)	855	08. U Oxide SNF	Non-metals	INTACT	C-565	D-565
WORCESTER POLY INSTITUTE	287	09. Alum Based SNF	Stable	INTACT	C-566	D-566
ZPRL (UALX-LEU) TAIWAN	554	09. Alum Based SNF	Stable	INTACT	C-567	D-567