RZ Geometry Models of 1000 MWt ABR Core Concepts

Reference 1000 MWt Advanced Burner Reactor (ABR) core concepts were developed at ANL in FY 2007 with ternary metal and mixed oxide fuels. Two core concepts were developed for both metal and oxide cores: startup and TRU recycled equilibrium cores. Weapons-grade plutonium was used as the TRU feed of the startup core without recycling the ABR spent fuel. For the recycled core, the TRU recovered from the ABR spent fuel was used as the primary TRU feed and the TRU from LWR spent fuel was used as the makeup feed. Compact core concepts of medium TRU conversion ratio (~0.8 for the startup core and ~0.7 for the recycled equilibrium core) were developed by trade-off between the burnup reactivity loss and the TRU conversion ratio.

The planar layouts of the ABR oxide and metal core concepts are shown in Figures 1 and 2, respectively. Both the cores consist of 180 drivers, 114 reflectors, 66 radial shields, and 15 primary and four secondary control assemblies. Three enrichment zones are used for the oxide core, whereas two enrichment zones are used for the metal core. The primary control system consists of three control assemblies in the fourth row and 12 control assemblies in the seventh row, and the secondary system contains four control assemblies located at the core center and in the fourth row. The primary control assemblies are axially moved to maintain criticality, while the secondary control assemblies are positioned at the top of the active core all the time.

Figures 3 and 4 respectively show the RZ geometry models of the ABR oxide and metal core concepts. All the dimensions represent the values at the operating conditions, accounting for the thermal expansions of fuel and structural materials. In these R-Z models, the primary control assemblies in the fourth row are homogenized together with the secondary control assemblies in the fourth row and positioned at the top of the active core. In the oxide core, the axial position of the primary control assemblies in the seventh row is 68.6 cm from the bottom of the active core for the startup core and 79.5 cm and for the recycled core. For the metal core, the primary control assembly positions of the startup and recycled cores are 57.9 cm and 63.3 cm, respectively.

Region-wise, homogenized nuclide densities at the beginning of equilibrium cycle (BOEC) of the startup oxide core, startup metal core, and recycled oxide core are provided in Appendices A, B, and C, respectively. The fuel compositions are prepared separately for five axial burn regions of each of inner, middle (oxide core only), and outer core zones. Fission products are modeled five lumped fission products, depending on fissionable isotopes. Average material temperatures for multi-group cross section preparation are provided in Appendix D.

As noted above, fission products are modeled with five lumped fission products. In order to simplify the proposed cross section adjustment exercise, it is suggested to replace these lumped fission products by a single element (e.g., Mo) or remove the lumped fission products.

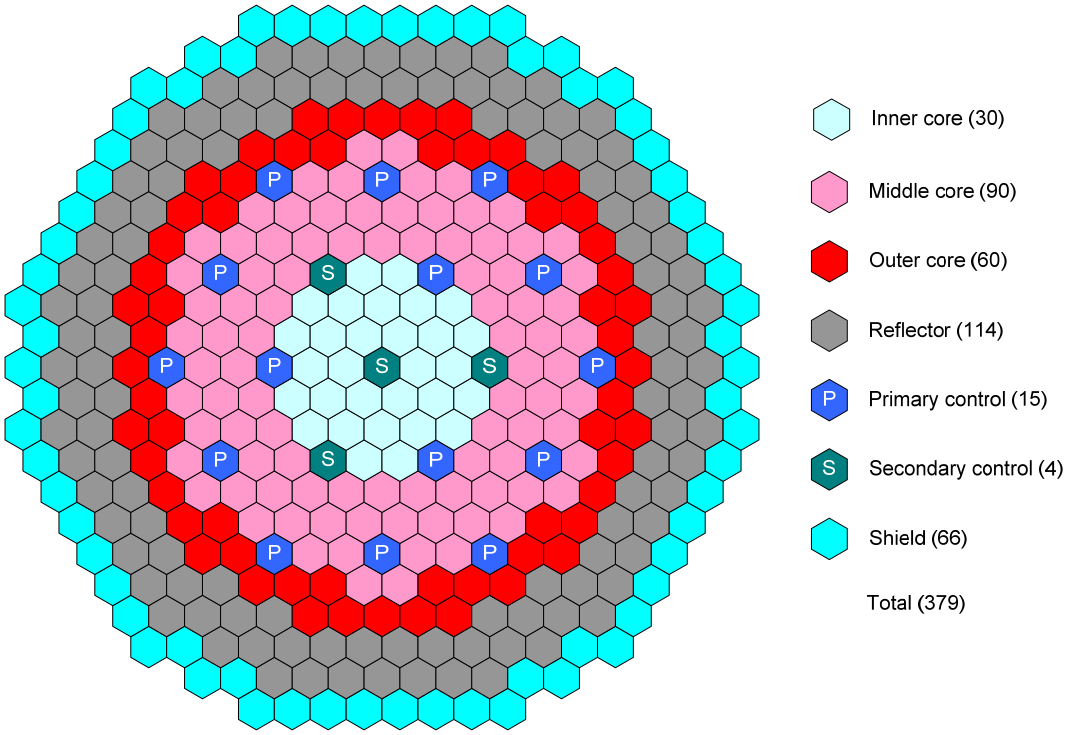

Figure 1. Planar Layout of Reference 1000 MWt ABR Oxide Core Concept

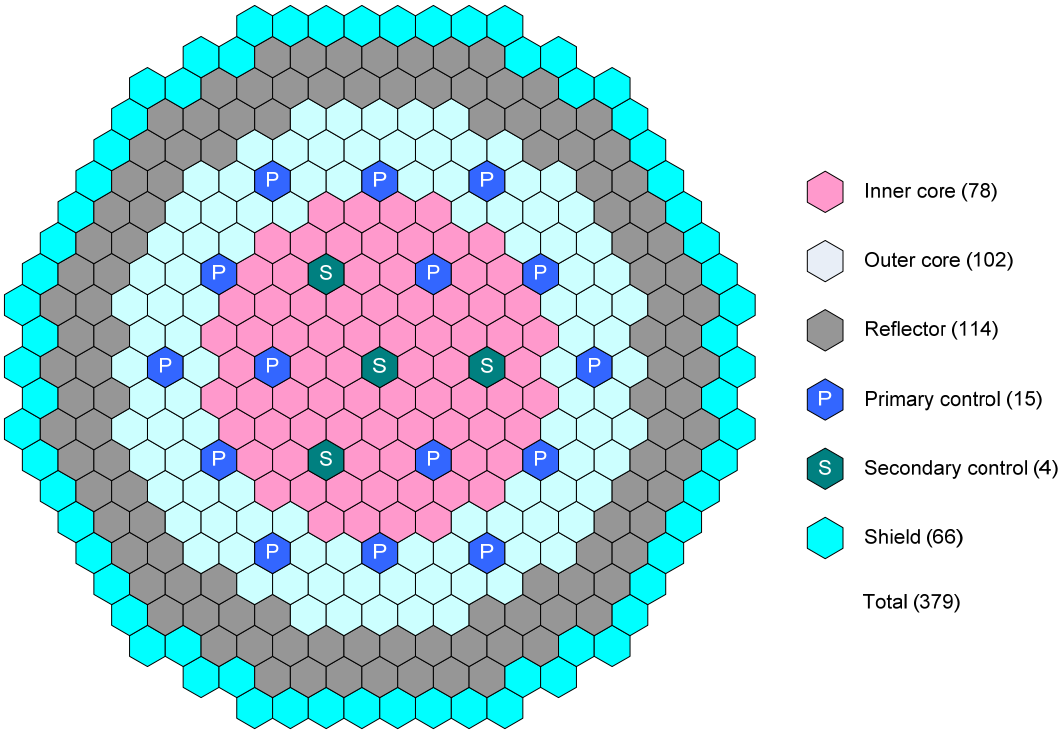

Figure 2. Planar Layout of Reference 1000 MWt ABR Metal Core Concept

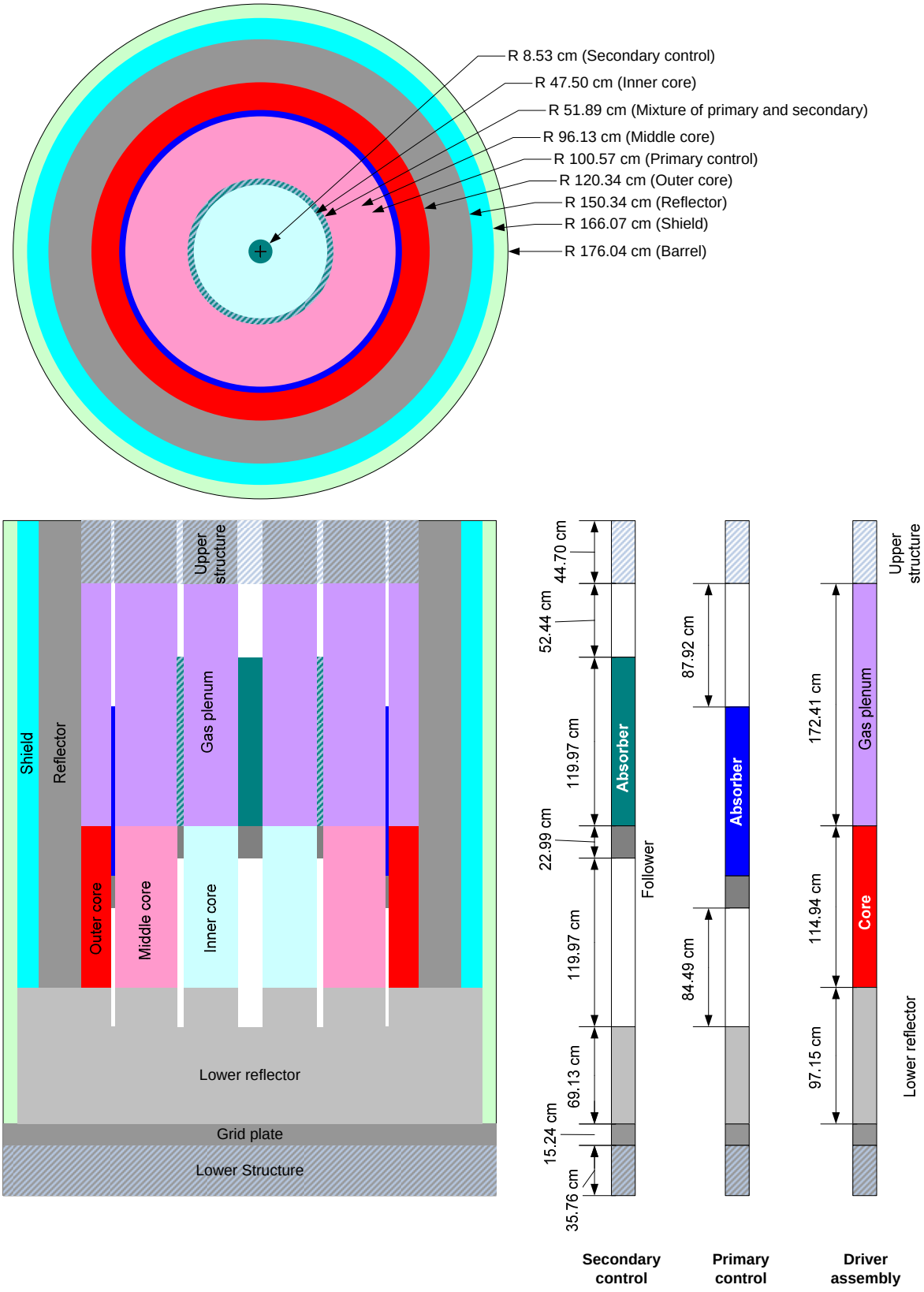

Figure 3. RZ Geometry Model of 1000 MWt ABR Oxide Core

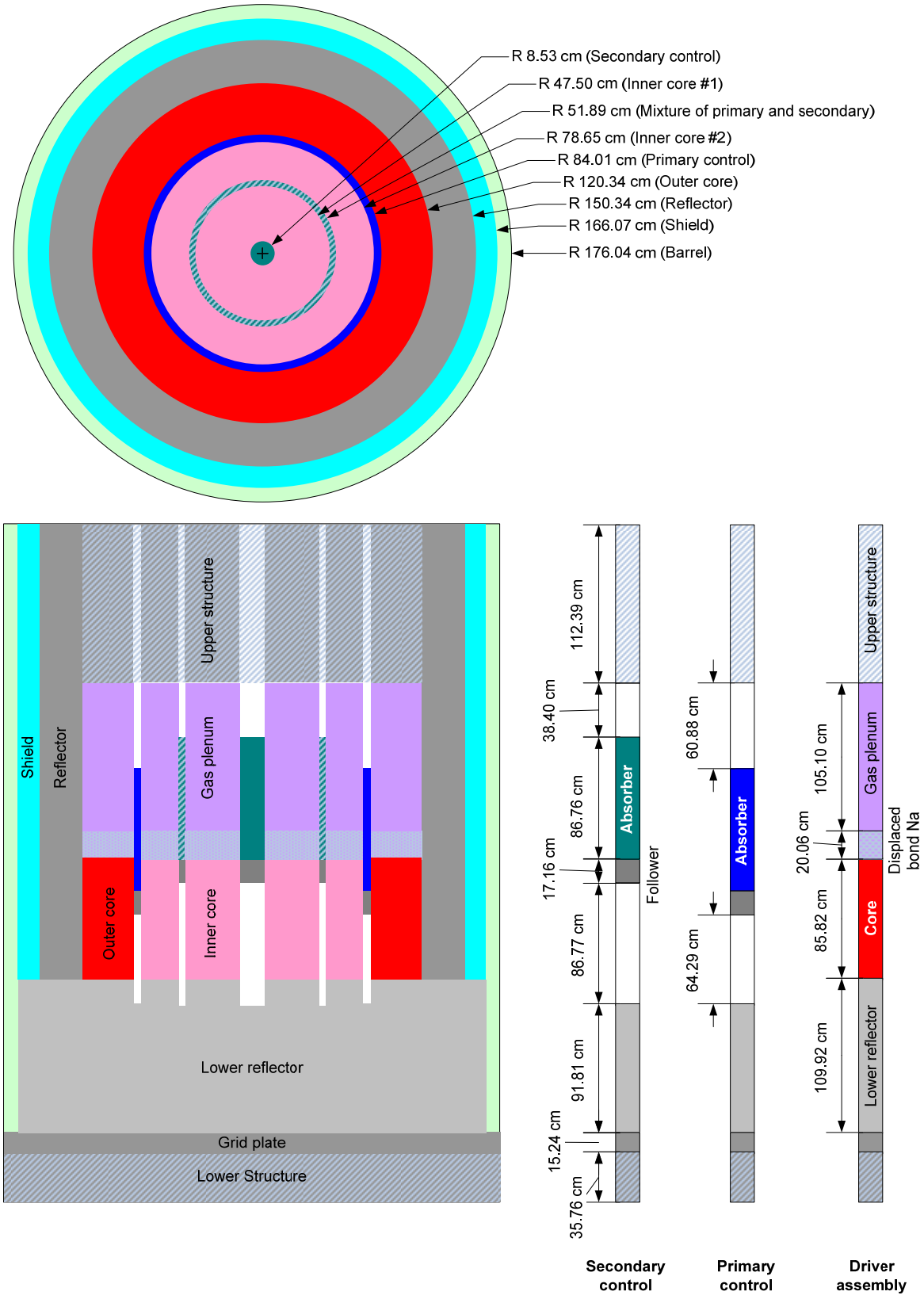

Figure 4. RZ Geometry Model of 1000 MWt ABR Metal Core

Appendix A. BOEC Nuclide Number Densities (#/barn-cm) of Startup Oxide Core

1. Inner Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	Na23	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03
Structure	Fe	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02
	Cr	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03
	Mn55	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04
	Ni	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04
	Mo	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04
Fuel	U234	6.7199E-09	8.7656E-09	9.3294E-09	8.2960E-09	5.5856E-09
	U235	7.8935E-06	7.1198E-06	6.8689E-06	7.3348E-06	8.6984E-06
	U236	1.1065E-06	1.1929E-06	1.2288E-06	1.1584E-06	9.3539E-07
	U238	5.9477E-03	5.8233E-03	5.7834E-03	5.8556E-03	6.0360E-03
	Np237	1.2447E-06	1.6289E-06	1.6950E-06	1.5731E-06	1.1060E-06
	Pu236	5.1177E-12	9.2945E-12	1.0236E-11	8.5477E-12	3.9005E-12
	Pu238	5.3775E-07	7.3123E-07	7.9225E-07	6.8063E-07	4.1150E-07
	Pu239	9.9775E-04	9.6991E-04	9.6103E-04	9.7696E-04	1.0209E-03
	Pu240	1.6777E-04	1.7662E-04	1.8188E-04	1.7159E-04	1.4630E-04
	Pu241	1.5038E-05	1.6764E-05	1.7800E-05	1.5826E-05	1.1514E-05
	Pu242	1.4192E-06	1.8015E-06	2.0053E-06	1.6345E-06	9.5614E-07
	Am241	9.5142E-07	1.0019E-06	1.0408E-06	9.6439E-07	7.8872E-07
	Am242m	3.1938E-08	3.7965E-08	4.1053E-08	3.5258E-08	2.2559E-08
	Am243	8.7649E-08	1.2259E-07	1.4307E-07	1.0660E-07	4.8201E-08
	Cm242	5.3289E-08	6.8596E-08	7.6420E-08	6.2100E-08	3.4313E-08
	Cm243	2.0926E-09	2.7000E-09	3.1449E-09	2.3319E-09	1.0166E-09
	Cm244	1.3752E-08	2.1979E-08	2.7036E-08	1.8235E-08	6.1530E-09
	Cm245	1.0189E-09	1.8547E-09	2.3896E-09	1.4763E-09	3.7794E-10
	Cm246	2.8954E-11	6.5570E-11	9.0122E-11	4.9397E-11	8.6709E-12
	O	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02
Fission product	LFP35 [a)]	3.7928E-06	4.4393E-06	4.6357E-06	4.2740E-06	3.2024E-06
	LFP38 [b)]	4.7811E-05	6.7659E-05	7.2170E-05	6.4110E-05	4.0575E-05
	LFP39 [c)]	3.9350E-04	5.0622E-04	5.4083E-04	4.7907E-04	3.2044E-04
	LFP40 [d)]	1.0504E-05	1.5766E-05	1.7459E-05	1.4457E-05	7.7439E-06
	LFP41 [e)]	6.6157E-06	9.3915E-06	1.0702E-05	8.3608E-06	4.0945E-06

a) LFP35: lumped fission product from U234, U235, U236, and Pu236 fissions
b) LFP38: lumped fission product from U238, Np237, and Pu238 fissions
c) LFP39: lumped fission product from Pu239 fission
d) LFP40: lumped fission product from Pu240 fission
e) LFP41: lumped fission products from Pu241 and higher actinides fissions

2. Middle Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	Na23	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03
Structure	Fe	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02
	Cr	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03
	Mn55	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04
	Ni	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04
	Mo	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04
Fuel	U234	6.2284E-09	8.0473E-09	8.5465E-09	7.6313E-09	5.2326E-09
	U235	8.2850E-06	7.5198E-06	7.2752E-06	7.7300E-06	9.0710E-06
	U236	9.7752E-07	1.0754E-06	1.1140E-06	1.0388E-06	8.0344E-07
	U238	5.8987E-03	5.7887E-03	5.7539E-03	5.8171E-03	5.9784E-03
	Np237	1.1634E-06	1.5429E-06	1.6106E-06	1.4863E-06	1.0229E-06
	Pu236	4.4663E-12	8.2636E-12	9.1383E-12	7.5738E-12	3.3416E-12
	Pu238	4.7301E-07	6.4144E-07	6.9441E-07	5.9743E-07	3.6440E-07
	Pu239	1.0819E-03	1.0467E-03	1.0360E-03	1.0553E-03	1.1104E-03
	Pu240	1.6604E-04	1.7486E-04	1.7987E-04	1.6998E-04	1.4462E-04
	Pu241	1.3782E-05	1.5448E-05	1.6381E-05	1.4593E-05	1.0577E-05
	Pu242	1.1998E-06	1.5219E-06	1.6855E-06	1.3862E-06	8.2383E-07
	Am241	9.2034E-07	9.7417E-07	1.0111E-06	9.3833E-07	7.6743E-07
	Am242m	2.7876E-08	3.3703E-08	3.6504E-08	3.1236E-08	1.9403E-08
	Am243	6.6615E-08	9.3630E-08	1.0881E-07	8.1615E-08	3.6670E-08
	Cm242	4.3862E-08	5.7277E-08	6.3812E-08	5.1798E-08	2.7875E-08
	Cm243	1.4926E-09	1.9814E-09	2.3133E-09	1.7037E-09	6.9840E-10
	Cm244	9.2702E-09	1.5025E-08	1.8422E-08	1.2472E-08	4.0706E-09
	Cm245	6.1835E-10	1.1545E-09	1.4857E-09	9.1710E-10	2.2067E-10
	Cm246	1.5554E-11	3.6406E-11	5.0048E-11	2.7314E-11	4.4006E-12
	O	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02
Fission product	LFP35	3.3289E-06	3.9624E-06	4.1536E-06	3.8009E-06	2.7506E-06
	LFP38	4.3115E-05	6.1322E-05	6.5452E-05	5.8072E-05	3.6341E-05
	LFP39	3.6847E-04	4.7685E-04	5.0941E-04	4.5115E-04	2.9705E-04
	LFP40	9.4816E-06	1.4286E-05	1.5800E-05	1.3109E-05	6.9493E-06
	LFP41	5.3210E-06	7.6435E-06	8.6948E-06	6.8082E-06	3.2720E-06

3. Outer Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	NA23	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03
Structure	Fe	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02
	Cr	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03
	Mn55	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04
	Ni	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04
	Mo	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04
Fuel	U234	5.4966E-09	6.6707E-09	6.9923E-09	6.4207E-09	4.9543E-09
	U235	8.8784E-06	8.2480E-06	8.0441E-06	8.4113E-06	9.3916E-06
	U236	6.9547E-07	7.9526E-07	8.3352E-07	7.6266E-07	5.7594E-07
	U238	5.6236E-03	5.5524E-03	5.5299E-03	5.5698E-03	5.6686E-03
	Np237	8.7117E-07	1.1780E-06	1.2372E-06	1.1317E-06	7.6202E-07
	Pu236	2.6168E-12	4.9541E-12	5.5197E-12	4.5355E-12	1.9594E-12
	Pu238	3.7229E-07	4.7528E-07	5.0821E-07	4.4977E-07	3.1591E-07
	Pu239	1.4136E-03	1.3602E-03	1.3442E-03	1.3725E-03	1.4497E-03
	Pu240	1.7878E-04	1.8850E-04	1.9341E-04	1.8410E-04	1.6240E-04
	Pu241	1.2844E-05	1.4332E-05	1.5119E-05	1.3668E-05	1.0708E-05
	Pu242	9.4921E-07	1.1586E-06	1.2606E-06	1.0791E-06	7.4824E-07
	Am241	9.6838E-07	1.0249E-06	1.0600E-06	9.9424E-07	8.6038E-07
	Am242m	2.2054E-08	2.7242E-08	2.9584E-08	2.5343E-08	1.6421E-08
	Am243	4.1117E-08	5.5381E-08	6.3328E-08	4.9362E-08	2.6364E-08
	Cm242	3.0421E-08	4.0013E-08	4.4473E-08	3.6517E-08	2.1246E-08
	Cm243	7.5621E-10	1.0475E-09	1.2275E-09	9.0732E-10	4.0606E-10
	Cm244	4.1154E-09	6.4717E-09	7.8335E-09	5.4874E-09	2.1215E-09
	Cm245	2.0007E-10	3.6963E-10	4.7252E-10	2.9879E-10	8.3317E-11
	Cm246	3.3776E-12	7.9080E-12	1.0835E-11	6.0286E-12	1.1087E-12
	O	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02
Fission product	LFP35	2.2522E-06	2.7642E-06	2.9222E-06	2.6394E-06	1.8722E-06
	LFP38	2.9434E-05	4.1915E-05	4.4744E-05	3.9791E-05	2.5041E-05
	LFP39	3.1740E-04	4.1258E-04	4.4057E-04	3.9149E-04	2.6247E-04
	LFP40	7.2373E-06	1.0892E-05	1.1994E-05	1.0077E-05	5.5871E-06
	LFP41	3.4230E-06	4.8913E-06	5.5242E-06	4.4159E-06	2.3413E-06

4. Lower Structure, Grid Plate, and Lower Reflector

Nuclide	Lower structure	Grid plate	Lower reflector
Na23	1.5591E-02	1.5591E-02	8.1322E-03
Fe	1.5878E-02	1.5878E-02	4.4260E-02
Cr	3.2355E-03	3.2355E-03	6.5809E-03
Mn55	5.0846E-04	5.0846E-04	2.9155E-04
Ni	3.2604E-03	3.2604E-03	2.7289E-04
Mo	4.3524E-04	4.3524E-04	3.1113E-04

5. Fission Gas Plenum and Upper Structure

Nuclide	Gas plenum	Upper structure
Na23	8.1322E-03	8.1322E-03
Fe	1.8573E-02	4.4260E-02
Cr	2.7616E-03	6.5809E-03
Mn55	1.2234E-04	2.9155E-04
Ni	1.1452E-04	2.7289E-04
Mo	1.3056E-04	3.1113E-04

6. Radial Reflector, Shield, and Barrel

Nuclide	Radial reflector	Shield	Barrel
Na23	3.45173E-03	3.80767E-03	1.23563E-02
Fe	5.89102E-02	2.06903E-02	1.83018E-02
Cr	8.75918E-03	3.07638E-03	3.72938E-03
Mn55	3.88047E-04	1.36289E-04	5.86069E-04
Ni	3.63219E-04	1.27569E-04	3.75801E-03
Mo	4.14113E-04	1.45444E-04	5.01672E-04
C12		1.67189E-03	
B10		7.05028E-03	
B11		2.83782E-02	

7. Control Assemblies

Nuclide	Under follower	Follower	Absorber		Above absorber	Upper structure
			Secondary	Primary		
Na23	2.02091E-02	1.64105E-02	6.42006E-03	6.42006E-03	6.42006E-02	7.87124E-03
Fe	6.45825E-03	1.83482E-02	1.44809E-02	1.44809E-02	1.44809E-03	4.50768E-02
Cr	9.60257E-04	2.72814E-03	2.15312E-03	2.15312E-03	2.15312E-04	6.70233E-03
Mn55	4.25411E-05	1.20862E-04	9.53870E-05	9.53870E-05	9.53870E-03	2.77927E-04
Ni	3.98192E-05	1.13129E-04	8.92839E-05	8.92839E-05	8.92839E-04	2.96925E-04
Mo	4.53987E-05	1.28980E-04	1.01794E-04	1.01794E-04	1.01794E-04	3.16870E-04
C12			1.05367E-02	1.05367E-02		
B10			8.38725E-03	2.70650E-02		
B11			3.37598E-02	1.64104E-02		

Appendix B. BOEC Nuclide Number Densities (#/barn-cm) of Startup Metal Core

1. Inner Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	Na23	7.8712E-03	7.8712E-03	7.8712E-03	7.8712E-03	7.8712E-03
Structure	Fe	1.7889E-02	1.7889E-02	1.7889E-02	1.7889E-02	1.7889E-02
	Cr	2.6599E-03	2.6599E-03	2.6599E-03	2.6599E-03	2.6599E-03
	Mn55	1.1784E-04	1.1784E-04	1.1784E-04	1.1784E-04	1.1784E-04
	Ni	1.1030E-04	1.1030E-04	1.1030E-04	1.1030E-04	1.1030E-04
	Mo	1.2575E-04	1.2575E-04	1.2575E-04	1.2575E-04	1.2575E-04
Fuel	U234	4.0295E-09	4.8981E-09	5.0728E-09	4.5923E-09	3.4048E-09
	U235	1.2393E-05	1.1988E-05	1.1839E-05	1.2291E-05	1.3307E-05
	U236	9.8706E-07	9.8735E-07	1.0036E-06	9.3054E-07	7.8523E-07
	U238	8.1520E-03	8.0962E-03	8.0799E-03	8.1281E-03	8.2317E-03
	Np237	1.4157E-06	1.8799E-06	1.9589E-06	1.7810E-06	1.2277E-06
	Pu236	5.4725E-12	9.7820E-12	1.0659E-11	8.6882E-12	4.0093E-12
	Pu238	3.9039E-07	4.7112E-07	4.9178E-07	4.2932E-07	3.0052E-07
	Pu239	1.1108E-03	1.0924E-03	1.0874E-03	1.0969E-03	1.1219E-03
	Pu240	1.2913E-04	1.2427E-04	1.2470E-04	1.2009E-04	1.1365E-04
	Pu241	9.3163E-06	8.8364E-06	8.9178E-06	8.3205E-06	7.4811E-06
	Pu242	7.1302E-07	7.0395E-07	7.2058E-07	6.4547E-07	5.3337E-07
	Am241	4.1883E-07	3.9418E-07	3.9476E-07	3.7992E-07	3.6305E-07
	Am242m	1.0928E-08	1.0767E-08	1.1026E-08	9.8067E-09	7.7424E-09
	Am243	3.1810E-08	3.0351E-08	3.1577E-08	2.6027E-08	1.8201E-08
	Cm242	2.1105E-08	2.1178E-08	2.1910E-08	1.8819E-08	1.3863E-08
	Cm243	4.7419E-10	3.8391E-10	3.9521E-10	3.1263E-10	2.1534E-10
	Cm244	3.4723E-09	3.3275E-09	3.5334E-09	2.6614E-09	1.5403E-09
	Cm245	1.8458E-10	1.8191E-10	1.9751E-10	1.3633E-10	6.4641E-11
	Cm246	3.5803E-12	3.8485E-12	4.3143E-12	2.6645E-12	9.6769E-13
	Zr	2.8392E-03	2.8392E-03	2.8392E-03	2.8392E-03	2.8392E-03
Fission product	LFP35 [a)]	3.6820E-06	4.0818E-06	4.2105E-06	3.8449E-06	2.9973E-06
	LFP38 [b)]	4.8050E-05	6.5436E-05	6.8846E-05	6.1089E-05	4.0355E-05
	LFP39 [c)]	3.0782E-04	3.6706E-04	3.8367E-04	3.4122E-04	2.4548E-04
	LFP40 [d)]	6.8704E-06	8.9595E-06	9.5115E-06	8.0912E-06	5.0941E-06
	LFP41 [e)]	4.8050E-05	6.5436E-05	6.8846E-05	6.1089E-05	4.0355E-05

2. Outer Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	NA23	7.8712E-03	7.8712E-03	7.8712E-03	7.8712E-03	7.8712E-03
Structure	Fe	1.7889E-02	1.7889E-02	1.7889E-02	1.7889E-02	1.7889E-02
	Cr	2.6599E-03	2.6599E-03	2.6599E-03	2.6599E-03	2.6599E-03
	Mn55	1.1784E-04	1.1784E-04	1.1784E-04	1.1784E-04	1.1784E-04
	Ni	1.1030E-04	1.1030E-04	1.1030E-04	1.1030E-04	1.1030E-04
	Mo	1.2575E-04	1.2575E-04	1.2575E-04	1.2575E-04	1.2575E-04
Fuel	U234	3.7347E-09	4.4002E-09	4.5345E-09	4.1995E-09	3.3348E-09
	U235	1.2928E-05	1.2558E-05	1.2432E-05	1.2785E-05	1.3566E-05
	U236	7.0220E-07	7.2116E-07	7.3772E-07	6.7631E-07	5.5745E-07
	U238	7.8153E-03	7.7737E-03	7.7618E-03	7.7944E-03	7.8661E-03
	Np237	1.1259E-06	1.5091E-06	1.5777E-06	1.4302E-06	9.7366E-07
	Pu236	3.6853E-12	6.6851E-12	7.3254E-12	5.9596E-12	2.7010E-12
	Pu238	3.3575E-07	3.9160E-07	4.0583E-07	3.6651E-07	2.8369E-07
	Pu239	1.4658E-03	1.4368E-03	1.4287E-03	1.4466E-03	1.4905E-03
	Pu240	1.5013E-04	1.4713E-04	1.4774E-04	1.4342E-04	1.3723E-04
	Pu241	1.0007E-05	9.7125E-06	9.8037E-06	9.2864E-06	8.5695E-06
	Pu242	6.9407E-07	7.0081E-07	7.1532E-07	6.5908E-07	5.7201E-07
	Am241	4.9508E-07	4.7588E-07	4.7698E-07	4.6354E-07	4.4946E-07
	Am242m	9.7697E-09	9.9724E-09	1.0267E-08	9.1338E-09	7.1585E-09
	Am243	2.5393E-08	2.3845E-08	2.4720E-08	2.0848E-08	1.5695E-08
	Cm242	1.7193E-08	1.7852E-08	1.8538E-08	1.6043E-08	1.1901E-08
	Cm243	2.8688E-10	2.5150E-10	2.6173E-10	2.0701E-10	1.4114E-10
	Cm244	2.0635E-09	1.9589E-09	2.0797E-09	1.5890E-09	9.7082E-10
	Cm245	8.2083E-11	8.1361E-11	8.8703E-11	6.1436E-11	2.9703E-11
	Cm246	1.1356E-12	1.2379E-12	1.3971E-12	8.5922E-13	3.0684E-13
	Zr	2.8392E-03	2.8392E-03	2.8392E-03	2.8392E-03	2.8392E-03
Fission product	LFP35	2.5541E-06	2.9001E-06	3.0075E-06	2.7234E-06	2.0735E-06
	LFP38	3.5709E-05	4.8878E-05	5.1517E-05	4.5820E-05	3.0166E-05
	LFP39	2.8078E-04	3.3873E-04	3.5464E-04	3.1656E-04	2.2767E-04
	LFP40	6.0384E-06	8.0535E-06	8.5656E-06	7.3565E-06	4.6505E-06
	LFP41	3.5709E-05	4.8878E-05	5.1517E-05	4.5820E-05	3.0166E-05

3. Lower Structure, Grid Plate, and Lower Reflector

Nuclide	Lower structure	Grid plate	Lower reflector
Na23	1.5591E-02	1.5591E-02	7.8712E-03
Fe	1.5878E-02	1.5878E-02	4.5077E-02
Cr	3.2355E-03	3.2355E-03	6.7023E-03
Mn55	5.0846E-04	5.0846E-04	2.9693E-04
Ni	3.2604E-03	3.2604E-03	2.7793E-04
Mo	4.3524E-04	4.3524E-04	3.1687E-04

4. Fission Gas Plenum and Upper Structure

Nuclide	Gas Plenum with displaced bond Na	Gas plenum	Upper structure
Na23	1.6557E-02	7.8712E-03	7.8712E-03
Fe	1.7889E-02	1.7889E-02	4.5077E-02
Cr	2.6599E-03	2.6599E-03	6.7023E-03
Mn55	1.1784E-04	1.1784E-04	2.9693E-04
Ni	1.1030E-04	1.1030E-04	2.7793E-04
Mo	1.2575E-04	1.2575E-04	3.1687E-04

5. Radial Reflector, Shield, and Barrel

Nuclide	Radial reflector	Shield	Barrel
Na23	3.4517E-03	3.8077E-03	1.2356E-02
Fe	5.8910E-02	2.0690E-02	1.8302E-02
Cr	8.7592E-03	3.0764E-03	3.7294E-03
Mn55	3.8805E-04	1.3629E-04	5.8607E-04
Ni	3.6322E-04	1.2757E-04	3.7580E-03
Mo	4.1411E-04	1.4544E-04	
C12		1.0858E-02	
B10		2.2744E-02	
B11		2.0686E-02	

6. Control Assemblies

Nuclide	Under follower	Follower	Absorber		Above absorber	Upper structure
			Secondary	Primary		
Na23	2.0209E-02	1.6411E-02	6.4201E-03	6.4201E-03	6.4201E-03	7.8712E-03
Fe	6.45823-03	1.8348E-02	1.4481E-02	1.4481E-02	1.4481E-02	4.5077E-02
Cr	9.6026E-04	2.7281E-03	2.1531E-03	2.1531E-03	2.1531E-03	6.7023E-03
Mn55	4.2541E-05	1.2086E-04	9.5387E-05	9.5387E-05	9.5387E-05	2.9693E-04
Ni	3.9819E-05	1.1313E-04	8.9284E-05	8.9284E-05	8.9284E-05	2.7793E-04
Mo	4.5399E-05	1.2898E-04	1.0179E-04	1.0179E-04	1.0179E-04	3.1687E-04
C12			1.0537E-02	1.0869E-02		
B10			8.3873E-03	2.7065E-02		
B11			3.3760E-02	1.6410E-02		

Appendix C. BOEC Nuclide Number Densities (#/barn-cm) of Recycled Oxide Core

1. Inner Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	Na23	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03
Structure	Fe	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02
	Cr	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03
	Mn55	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04
	Ni	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04
	Mo	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04
Fuel	U234	6.4319E-07	6.0429E-07	5.9246E-07	6.1463E-07	6.6954E-07
	U235	8.2377E-06	7.5720E-06	7.3559E-06	7.7711E-06	8.8939E-06
	U236	9.0366E-07	9.9269E-07	1.0280E-06	9.5752E-07	7.5727E-07
	U238	5.5788E-03	5.4894E-03	5.4608E-03	5.5146E-03	5.6426E-03
	Np237	1.3251E-05	1.2756E-05	1.2532E-05	1.2966E-05	1.4022E-05
	Pu236	1.1814E-10	1.3241E-10	1.3410E-10	1.3073E-10	1.1558E-10
	Pu238	5.0045E-05	4.8018E-05	4.7474E-05	4.8468E-05	5.0863E-05
	Pu239	7.0883E-04	7.0714E-04	7.0646E-04	7.0745E-04	7.0825E-04
	Pu240	5.3934E-04	5.2951E-04	5.2752E-04	5.3103E-04	5.4112E-04
	Pu241	8.9976E-05	8.8296E-05	8.8408E-05	8.8026E-05	8.7409E-05
	Pu242	1.3138E-04	1.2931E-04	1.2871E-04	1.2982E-04	1.3262E-04
	Am241	4.7040E-05	4.3767E-05	4.2701E-05	4.4746E-05	5.0108E-05
	Am242m	4.0083E-06	3.8425E-06	3.7845E-06	3.8921E-06	4.1120E-06
	Am243	4.4696E-05	4.3813E-05	4.3637E-05	4.3958E-05	4.4794E-05
	Cm242	2.4461E-06	2.7751E-06	2.8955E-06	2.6591E-06	2.0095E-06
	Cm243	3.0981E-07	3.1436E-07	3.2302E-07	3.0570E-07	2.7710E-07
	Cm244	3.4300E-05	3.4309E-05	3.4478E-05	3.4126E-05	3.3355E-05
	Cm245	1.0142E-05	9.9622E-06	9.9750E-06	9.9395E-06	9.9578E-06
	Cm246	6.1911E-06	6.1773E-06	6.1804E-06	6.1746E-06	6.1733E-06
	O	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02
Fission product	LFP35	2.7919E-06	3.3563E-06	3.5303E-06	3.1979E-06	2.2933E-06
	LFP38	4.1564E-05	5.9267E-05	6.3578E-05	5.5523E-05	3.4233E-05
	LFP39	1.9748E-04	2.6283E-04	2.8346E-04	2.4526E-04	1.5538E-04
	LFP40	2.8395E-05	4.0454E-05	4.3542E-05	3.7849E-05	2.3346E-05
	LFP41	5.4126E-05	7.0362E-05	7.5814E-05	6.5582E-05	4.1719E-05

2. Middle Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	Na23	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03
Structure	Fe	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02
	Cr	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03
	Mn55	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04
	Ni	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04
	Mo	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04
Fuel	U234	7.2436E-07	6.8348E-07	6.7144E-07	6.9355E-07	7.4990E-07
	U235	8.4243E-06	7.7788E-06	7.5734E-06	7.9608E-06	9.0285E-06
	U236	7.9339E-07	8.8688E-07	9.2208E-07	8.5334E-07	6.5603E-07
	U238	5.4589E-03	5.3797E-03	5.3547E-03	5.4010E-03	5.5148E-03
	Np237	1.5088E-05	1.4514E-05	1.4274E-05	1.4733E-05	1.5892E-05
	Pu236	1.3171E-10	1.4811E-10	1.5031E-10	1.4608E-10	1.2822E-10
	Pu238	5.5515E-05	5.3452E-05	5.2914E-05	5.3877E-05	5.6260E-05
	Pu239	7.5244E-04	7.4540E-04	7.4334E-04	7.4687E-04	7.5519E-04
	Pu240	5.9181E-04	5.8062E-04	5.7817E-04	5.8246E-04	5.9441E-04
	Pu241	9.6761E-05	9.5219E-05	9.5311E-05	9.4966E-05	9.4289E-05
	Pu242	1.4508E-04	1.4290E-04	1.4227E-04	1.4341E-04	1.4635E-04
	Am241	5.3951E-05	5.0420E-05	4.9293E-05	5.1418E-05	5.7114E-05
	Am242m	4.4755E-06	4.3196E-06	4.2663E-06	4.3629E-06	4.5560E-06
	Am243	4.9278E-05	4.8383E-05	4.8202E-05	4.8525E-05	4.9392E-05
	Cm242	2.3574E-06	2.7301E-06	2.8625E-06	2.6077E-06	1.8962E-06
	Cm243	3.1564E-07	3.1937E-07	3.2647E-07	3.1252E-07	2.9142E-07
	Cm244	3.6933E-05	3.6974E-05	3.7139E-05	3.6798E-05	3.6021E-05
	Cm245	1.0983E-05	1.0786E-05	1.0788E-05	1.0773E-05	1.0833E-05
	Cm246	6.7801E-06	6.7589E-06	6.7595E-06	6.7581E-06	6.7658E-06
	O	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02
Fission product	LFP35	2.4015E-06	2.9471E-06	3.1133E-06	2.8019E-06	1.9394E-06
	LFP38	3.8540E-05	5.5371E-05	5.9480E-05	5.1951E-05	3.1654E-05
	LFP39	1.8253E-04	2.4497E-04	2.6422E-04	2.2909E-04	1.4304E-04
	LFP40	2.8576E-05	4.1006E-05	4.4171E-05	3.8441E-05	2.3447E-05
	LFP41	5.0892E-05	6.7355E-05	7.2694E-05	6.2840E-05	3.9027E-05

3. Outer Core

Material	Nuclide	Axial node from core bottom				
		1	2	3	4	5
Coolant	NA23	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03	8.1322E-03
Structure	Fe	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02	1.8573E-02
	Cr	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03	2.7616E-03
	Mn55	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04	1.2234E-04
	Ni	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04	1.1452E-04
	Mo	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04	1.3056E-04
Fuel	U234	1.1303E-06	1.0941E-06	1.0847E-06	1.1009E-06	1.1421E-06
	U235	7.6389E-06	7.1780E-06	7.0335E-06	7.2933E-06	7.9544E-06
	U236	5.6786E-07	6.4334E-07	6.7063E-07	6.2053E-07	4.9571E-07
	U238	4.5422E-03	4.4948E-03	4.4800E-03	4.5063E-03	4.5693E-03
	Np237	4.8957E-05	4.6780E-05	4.6027E-05	4.7391E-05	5.0686E-05
	Pu236	2.5009E-10	3.0342E-10	3.1247E-10	2.9597E-10	2.3346E-10
	Pu238	8.5618E-05	8.4378E-05	8.4173E-05	8.4481E-05	8.5296E-05
	Pu239	1.1142E-03	1.0788E-03	1.0686E-03	1.0867E-03	1.1339E-03
	Pu240	8.4812E-04	8.3515E-04	8.3211E-04	8.3729E-04	8.5140E-04
	Pu241	1.6073E-04	1.5773E-04	1.5740E-04	1.5787E-04	1.6002E-04
	Pu242	2.1785E-04	2.1556E-04	2.1492E-04	2.1604E-04	2.1888E-04
	Am241	1.0593E-04	1.0042E-04	9.8670E-05	1.0181E-04	1.0968E-04
	Am242m	6.1910E-06	6.2158E-06	6.2220E-06	6.2046E-06	6.0838E-06
	Am243	6.8657E-05	6.7880E-05	6.7768E-05	6.7954E-05	6.8611E-05
	Cm242	3.0806E-06	3.6982E-06	3.9138E-06	3.5211E-06	2.5457E-06
	Cm243	3.8842E-07	3.9839E-07	4.0717E-07	3.9129E-07	3.7072E-07
	Cm244	4.4791E-05	4.5091E-05	4.5338E-05	4.4876E-05	4.4011E-05
	Cm245	1.2811E-05	1.2667E-05	1.2679E-05	1.2651E-05	1.2709E-05
	Cm246	7.6435E-06	7.6202E-06	7.6200E-06	7.6203E-06	7.6370E-06
	O	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02	1.5205E-02
Fission product	LFP35	1.4560E-06	1.8497E-06	1.9689E-06	1.7556E-06	1.2064E-06
	LFP38	3.0330E-05	4.3537E-05	4.6793E-05	4.1048E-05	2.5399E-05
	LFP39	1.9033E-04	2.5417E-04	2.7287E-04	2.3990E-04	1.5705E-04
	LFP40	3.0958E-05	4.4616E-05	4.8030E-05	4.2051E-05	2.5981E-05
	LFP41	5.6459E-05	7.5735E-05	8.1708E-05	7.1125E-05	4.5652E-05

4. Lower Structure, Grid Plate, and Lower Reflector

Nuclide	Lower structure	Grid plate	Lower reflector
Na23	1.5591E-02	1.5591E-02	8.1322E-03
Fe	1.5878E-02	1.5878E-02	4.4260E-02
Cr	3.2355E-03	3.2355E-03	6.5809E-03
Mn55	5.0846E-04	5.0846E-04	2.9155E-04
Ni	3.2604E-03	3.2604E-03	2.7289E-04
Mo	4.3524E-04	4.3524E-04	3.1113E-04

5. Fission Gas Plenum and Upper Structure

Nuclide	Gas plenum	Upper structure
Na23	8.1322E-03	8.1322E-03
Fe	1.8573E-02	4.4260E-02
Cr	2.7616E-03	6.5809E-03
Mn55	1.2234E-04	2.9155E-04
Ni	1.1452E-04	2.7289E-04
Mo	1.3056E-04	3.1113E-04

6. Radial Reflector, Shield, and Barrel

Nuclide	Radial reflector	Shield	Barrel
Na23	3.45173E-03	3.80767E-03	1.23563E-02
Fe	5.89102E-02	2.06903E-02	1.83018E-02
Cr	8.75918E-03	3.07638E-03	3.72938E-03
Mn55	3.88047E-04	1.36289E-04	5.86069E-04
Ni	3.63219E-04	1.27569E-04	3.75801E-03
Mo	4.14113E-04	1.45444E-04	5.01672E-04
C12		1.67189E-03	
B10		7.05028E-03	
B11		2.83782E-02	

7. Control Assemblies

Nuclide	Under follower	Follower	Absorber		Above absorber	Upper structure
			Secondary	Primary		
Na23	2.02091E-02	1.64105E-02	6.42006E-03	6.42006E-03	6.42006E-02	7.87124E-03
Fe	6.45825E-03	1.83482E-02	1.44809E-02	1.44809E-02	1.44809E-03	4.50768E-02
Cr	9.60257E-04	2.72814E-03	2.15312E-03	2.15312E-03	2.15312E-04	6.70233E-03
Mn55	4.25411E-05	1.20862E-04	9.53870E-05	9.53870E-05	9.53870E-03	2.77927E-04
Ni	3.98192E-05	1.13129E-04	8.92839E-05	8.92839E-05	8.92839E-04	2.96925E-04
Mo	4.53987E-05	1.28980E-04	1.01794E-04	1.01794E-04	1.01794E-04	3.16870E-04
C12			1.05367E-02	1.05367E-02		
B10			8.38725E-03	2.70650E-02		
B11			3.37598E-02	1.64104E-02		

Appendix D. Average Temperatures (°C)

	Metal Core	Oxide core
Lower structure	355	355
Grid place	355	355
Lower reflector	355	355
Active core		
- Fuel	581	1056
- Structure	450	445
- Coolant	433	433
Upper gas plenum	510	510
Upper structure	510	510
Radial reflector	355	355
Radial shield	355	355
Barrel	355	355