Enclosure 2

MFN 14-079

GEH Response to RAI 12.02-1

ABWR DCD DRAFT Revision 6 Markups

12.2.1.2.1.1.4 Gamma Ray Source Energy Spectra

Table 12.2-3 presents average gamma ray energy spectra thermal per watt of reactor power in both core and non-core regions. In Table 12.2-3, part A, the energy spectra in the core are presented. The energy spectra in the core represent the average gamma ray energy released by energy group in ~~J/cm^3/s/MW thermal~~pJ/cm^3/sec/MWt. The energy spectra~~ in J/s/MW thermal/cm^3~~ can be used with the total core power and power distributions to obtain the source in any part of the core.

The gamma ray energy spectra include the fission gamma rays, the fission product gamma ray and the gamma rays resulting from inelastic neutron scattering and thermal neutron capture. The total gamma ray energy released in the core is estimated to be accurate to within ±10%. The energy release rate above 0.96 ~~pico J~~picojoule may be in error by as much as a factor of ±2.

Table 12.2-3, part B, gives a gamma ray energy spectrum in ~~J/s/W~~pJ/W-sec in spent fuel as a function of time after operation. The data were prepared from tables of fission product decay gamma fitted to integral measurements for operation times of 10^8 s, or approximately 3.2 years. To obtain shutdown sources in the core the gamma ray energy spectra are combined with the core thermal power and power distributions. Shutdown sources in a single fuel element can be obtained by using the gamma ray energy spectra and the thermal power the element contained during operation.

Table 12.2-3, part C, gives the gamma ray energy spectra in the cylindrical regions of the reactor from the core through the vessel. The energy spectra are given in terms of ~~J/cm^3/ s/W~~ pJ/cm^3/sec/MWt at the inside surface and outside surfaces of the region. This energy spectrum, multiplied by the core thermal power, is the gamma ray source. The point on the inside surface of the region is the maximum point within the region. In the radial direction, the variation in source intensity may be approximated by an exponential fit to the data on the inside and outside surfaces of the region. The axial variation in a region can be estimated by using the core axial variation. The uncertainty in the gamma ray energy spectra is due primarily to the uncertainty in the neutron flux in these regions. The uncertainty in the neutron flux is estimated to vary from approximately ±50% at the core boundary to a factor of ±3 at the outside of the vessel. The calculations were carried out with voids beyond the vessel.

12.2.1.2.1.1.5 Gamma Ray and Neutron Fluxes Outside the Vessel

Table 12.2-4 presents the maximum axial neutron and gamma ray fluxes outside the vessel. The maximum axial flux occurs on the vessel opposite the elevation of the core with the maximum outer bundle power level. This elevation can be located using the data from Table 12.2-1. The fluxes at this elevation are based on a mean radius core and do not show azimuth angle variations. The calculational model for these fluxes assumed no shield materials beyond the vessel wall. The presence of shield materials will significantly alter the neutron fluxes in the lower end of the neutron energy spectrum. The gamma ray calculations include gamma ray sources from all of the cylindrical regions between the center of the core and the edge of the

12.2.1.2.7 Radioactive Sources in Piping and Main Steam Systems

12.2.1.2.7.1 Radioactive Sources in Main Steam System

All radioactive material in the Main Steam System result from radioactive sources carried over from the reactor during plant operation. In most of the components carrying live steam, the source is dominated by N-16. In components where N-16 has decayed, the other activities carried by the steam become significant.

12.2.1.2.7.2 Radioactive Crud in Piping and Steam Systems

The inside surfaces of the piping and all reactor and power systems components become coated with activated corrosion products, commonly called crud. The quantity of crud on the components is dependent on a number of factors, including power history, water quality and fuel experience. The piping and components carrying reactor water are coated with higher levels of crud than piping and components carrying steam.

12.2.1.2.8 Radioactive Sources in the Spent Fuel

The radiation source for spent fuel is given in Subsection 12.2.1.2.1.1.4 (Table 12.2-3)~~ in terms of J/s/W~~. The design calculation is carried out for a mean element and appropriate decay time.

12.2.1.2.9 Other Radioactive Sources

12.2.1.2.9.1 Reactor Startup Source

The reactor startup source is shipped to the site in a special cask designed with shielding. The source is transferred under water while in the cask and loaded into beryllium containers. This is then loaded into the reactor while remaining under water. The source remains within the reactor for its lifetime. Thus, no unique shielding requirements are required after reactor operation.

12.2.1.2.9.2 Radioactive Sources in the Control Rod Drive System

The control rod drive (CRD) source term data are provided in Table 12.2-18. The CRD System is described in Subsection 3.9.4.

12.2.1.2.9.3 Radioactivity in the Transverse In-Core Probe

The Traversing Incore Probe (TIP) System consists of a probe and a stainless steel cable which is run into and out of the core such that the probe and up to 3.7 m of cable are activated. The probe is described in Subsection 7.7.1.6.1 and is automatically controlled and indexed to its incore position. For maintenance, the probe is manually withdrawn into a shielded assembly area in which a shielded container is used to hold the probe. Both automatic logic control and mechanical stops prevent the probe and activated sections of the cable from withdrawal beyond the shielded room and container. Table 12.2-24 describes the levels of radioactivity expected

Table 12.2-3a Gamma Ray Source Energy Spectra—Gamma Ray Sources in the Core During Operation

Energy (E) Bounds (pJ)	Gamma Ray Source pJ/cm^3/s/MWt
E > 1.6E+00	3.7E+02
1.3E+00 < E < 1.6E+00	2.7E+06
9.6E-01 < E < 1.3E+00	3.5E+07
6.4E-01 < E < 9.6E-01	1.8E+08
3.2E-01 < E < 6.4E-01	8.5E+08
1.6E-01 < E < 3.2E-01	9.5E+08
8.2E-02 < E < 1.6E-01	5.0E+08
3.2E-02 < E < 8.2E-02	1.9E+08
E < 3.2E-02	5.3E+07

~~Table 12.2-3b Gamma Ray Source Energy Spectra—Post-Operation Gamma Sources in the Core* (pJ/W.s)~~

~~Energy Bounds (pJ)~~	~~Time after Shutdown~~			
	~~0 s~~	~~1 day~~	~~1 week~~	~~1 month~~
~~9.6E-01~~				
	~~1.3E+03~~	~~1.6E-01~~	~~1.6E+00~~	~~1.6E-01~~
~~6.4E-01~~				
	~~2.9E+03~~	~~1.1E+00~~	~~7.4E-01~~	~~1.6E-01~~
~~4.8E-01~~				
	~~1.7E+03~~	~~9.1E-01~~	~~5.9E-01~~	~~1.6E-01~~
~~4.2E-01~~				
	~~2.7E+03~~	~~4.6E+01~~	~~2.7E+01~~	~~1.6E-01~~
~~3.5E-01~~				
	~~3.4E+03~~	~~7.2E+01~~	~~6.4E+00~~	~~8.0E-02~~
~~2.9E-01~~				
	~~5.3E+03~~	~~5.0E+02~~	~~3.4E+02~~	~~1.0E+02~~
~~2.2E-01~~				
	~~5.9E+03~~	~~3.7E+02~~	~~2.6E+02~~	~~1.8E+02~~
~~1.4E-01~~				
	~~8.2E+03~~	~~1.2E+03~~	~~6.1E+02~~	~~3.4E+02~~
~~6.4E-02~~				
	~~1.9E+03~~	~~2.9E-03~~	~~1.4E+02~~	~~5.8E+01~~
~~1.6E-02~~				

* ~~Operating history of 3.2 years.~~

Table 12.2-3b Gamma Ray Source Energy Spectra— Post-Operation Gamma Sources in the Core* (pJ/W-sec)

Energy Bounds (pJ)	Time after Shutdown			
	0 s	1 day	1 week	1 month
0.96 < E < 0.64	1.3E+09	1.6E+05	1.6E+06	1.6E+05
0.64 < E < 0.48	2.9E+09	1.1E+06	7.4E+05	1.6E+05
0.48 < E < 0.42	1.8E+09	9.1E+05	5.9E+05	1.6E+05
0.42 < E < 0.35	2.7E+09	4.6E+07	2.7E+07	1.6E+05
0.35 < E < 0.29	3.4E+09	7.2E+07	6.4E+06	8.3E+05
0.29 < E < 0.22	5.3E+09	5.0E+08	3.4E+08	1.0E+08
0.22 < E < 0.14	5.9E+09	3.7E+08	2.6E+08	1.8E+08
0.140 < E < 0.064	8.2E+09	1.2E+09	6.1E+08	3.4E+08
0.064 < E < 0.016	1.9E+09	2.9E+08	1.4E+08	5.8E+07

* Operating history of 3.2 years.

~~Table 12.2-3c Gamma Ray Source Energy Spectra—Gamma Ray Source External to the Core During Operation~~

~~Energy Bounds (pJ)~~	~~Zone H~~	~~Gamma Ray Source pJ/cm^3/s/MWt~~ Shroud	~~Zone I~~	~~Vessel~~
~~E > 1.60~~	~~1.9E-07~~	~~2.7E-03~~	~~4.3E-09~~	~~3.0E-07~~
~~1.28 < E < 1.60~~	~~5.3E-04~~	~~41.7~~	~~1.2E-05~~	~~3.0E-04~~
~~0.96 < E < 1.28~~	~~0.14~~	~~76.9~~	~~2.4E-03~~	~~3.0E-03~~
~~0.64 < E < 0.96~~	~~8.3E-04~~	~~24.0~~	~~1.6E-05~~	~~8.2E-04~~
~~0.32 < E < 0.64~~	~~35.2~~	~~17.6~~	~~4.6E-02~~	~~8.3E-04~~
~~0.16 < E < 0.32~~	~~4.5E-03~~	~~7.7~~	~~6.1E-05~~	~~3.8E-04~~
~~8.2E-02 < E < 0.16~~	~~3.7E-03~~	~~4.6~~	~~5.0E-05~~	~~3.3E-04~~
~~3.2E-02 < E < 8.2E-02~~	~~1.1E-02~~	~~1.3~~	~~1.9E-04~~	~~3.3E-05~~
~~E < 3.2E-02~~	~~1.3E-04~~	~~0.30~~	~~2.6E-06~~	~~1.5E-05~~

Table 12.2-3c Gamma Ray Source Energy Spectra—Gamma Ray Source External to the Core During Operation

Energy Bounds (pJ)	Zone H	Gamma Ray Source pJ/cm^3/sec/MWt Shroud	Zone I	Vessel
E > 1.60	1.9E-01	2.7E+03	4.3E-03	3.0E-01
1.28 < E < 1.60	5.3E+02	4.2E+07	1.2E+01	3.0E+02
0.96 < E < 1.28	1.4E+05	7.7E+07	2.4E+03	3.0E+03
0.64 < E < 0.96	8.3E+02	2.4E+07	1.6E+01	8.2E+02
0.32 < E < 0.64	3.5E+07	1.8E+07	4.6E+05	8.3E+02
0.16 < E < 0.32	4.5E+03	7.7E+06	6.1E+01	3.8E+02
0.082 < E < 0.16	3.7E+03	4.6E+06	5.0E+01	3.4E+02
0.032 < E < 0.082	1.1E+04	1.3E+06	1.9E+02	3.4E+01
E < 0.032	1.3E+02	3.0E+05	2.6E+00	1.5E+01