WASHINGTON STATE UNIVERSITY

Nuclear Radiation Center

March 23, 2011

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Reference: Washington State University
Docket No. 50-27, License No. R-76

Subject: Response to: WASHINGTON STATE UNIVERSITY – REQUEST FOR ADDITIONAL INFORMATION REGARDING THE WASHINGTON STATE UNIVERSITY TRIGA REACTOR LICENSE RENEWAL (TAC NO. ME1589)

Washington State University (WSU) has applied to renew operating License Number R-76 (Docket number 50-27). As part of the license renewal process, the U.S. Nuclear Regulatory Commission has submitted a Request for Additional Information (RAI) to Washington State University in a letter dated February 23, 2011. This letter provides a response to the Request for Additional Information.

I declare under penalty of perjury that to the best of my knowledge the foregoing is true and correct.

Date Executed 3/23/2011

Respectfully Submitted

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Attachments

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Response to Request for Additional Information dated February 23, 2011

This response provides a dose assessment for the maximally exposed individual member of the public in the unrestricted area of the Dodgen Research Facility for the Maximum Hypothetical Accident—the loss of cladding integrity of a single TRIGA fuel element in air.

In order to calculate the dose rate for an individual member of the public in an unrestricted area within the Dodgen Research Facility, the following conservative assumptions were made:

1. The barometric air pressure in Room 201 is lower than the surrounding area.
2. A five minute time period is allowed for evacuation of the Dodgen Research Facility.
3. No credit is taken for attenuation due to gamma-ray absorption by air or the door to Room 201.
4. The maximally exposed person remains stationary for five minutes immediately outside the door leading into Room 201.
5. All airborne radioactive material is approximated as a point source in the geometric center of Room 201.
6. An instantaneous loss of pool water is accompanied by the immediate failure the cladding of a single fuel rod in air.
7. A power density of 30 kW is assumed for the defective fuel rod.
8. Volatile fission product inventory was calculated for an infinite irradiation time for the defective fuel rod prior to shutdown.

Assumption Justification

Assumption 1.
It is assumed that the barometric air pressure within the reactor pool room (Room 201) is lower than the air pressure in surrounding areas, thus restricting movement of airborne radioactive materials such that there is no leakage of radioactive materials from the pool room into public areas. As a result, there is no inhalation hazard in public areas or exposure due to immersion in radioactive gaseous or airborne particulate material. Maintenance of barometric pressure within Room 201 assures that, in the event of release of airborne fission products, there would be no leakage of airborne particles or gaseous effluent into the unrestricted area of the Dodgen Research Facility. As a result, radiation exposure due to beta particles in the unrestricted area is ruled out because beta particles are unable to penetrate through the concrete walls or doors leading from Room 201 into unrestricted areas. The radiation exposure rate, and concomitant dose rate is due only to penetration of gamma rays through the door and concrete wall. Bremmstrahlung radiation is not considered in the present analysis due to the limited range of beta-particles in air and the concomitant low bremmstrahlung intensity, as well as the existence of a relatively high linear attenuation coefficient for absorption of low-energy bremmstrahlung radiation.

Assumption 2.
Building evacuation drills are conducted on a regular basis. A five minute evacuation time is conservative because building evacuations have been observed to be executed more rapidly than five minutes.

Assumption 3
Beta particles emitted by airborne radionuclides cannot pass through the walls or door leading to Room 201. The concrete wall separating Room 201 from the public areas of the Dodgen Research Facility provides considerable shielding due to its thickness, therefore, it was decided to calculate the radiation exposure rate in the area outside the double doors leading into Room 201, assuming no attenuation of gamma rays due to shielding by the doors. Furthermore, the attenuation by air is sufficiently small that it can be reasonably neglected—a conservative assumption.

Assumption 4
It was assumed that a member of the public (the maximally exposed individual) remains outside the door leading into Room 201 for the five minute period of evacuation. The exposure rate was calculated for a person standing at the double doors for the entire five minutes.

Assumption 5
It was assumed that all of the airborne radioactive release forms a point source in the geometric center of Room 201. A point source in the geometric center of Room 201 was chosen as a reasonable approximation, rather than using a uniform distribution of airborne radioactive materials throughout Room 201. A point source in the geometric center of Room 201 provides greater exposure to the door under consideration than would be the case if a uniform distribution was used as the basis for the calculation.

Assumption 6
The MHA for the WSU reactor is the failure of the cladding of a single fuel rod in air. In order to be exposed to air there must be a loss of pool water based upon a hypothetical catastrophic failure of a beam port. There is no credit taken for pool drain time with regard to radioactive decay, i.e. pool drain time is assumed to be instantaneous upon shut down of the reactor. As a result, no decay corrections are used in the calculations.

Assumption 7
The power density in Core 35A (the core analyzed for the HEU to LEU conversion and in current operation) is such that the hot rod position (D4NE) produces approximately 22.5 kW of power. Thus, assuming 30 kW for the sake of the present calculation is considerably conservative, and will encompass power densities that may accompany future core changes. A power density of 30 kW was used in the present calculations because the volatile radioactive material inventory, as presented in the WSU Safety Analysis Report of 2002, was used as a baseline.

Assumption 8
An infinite irradiation time was assumed in order to assure that radioactive isotopes of the volatile fission products, Br, Kr, I, and Xe have reached steady-state concentrations.

Calculation of Dose Rate

The dose rate was calculated using the following volatile fission products: Br-82, 83, 84, 85, 87; Kr-83m, 85m, 87, 88, 89; I-131, 132, 133, 134, 135, 136; Xe-131m, 133m, 133, 135m, 135, 137, 138. The quantity of fission products released from the hypothetical failed fuel rod is described in Table 13.2 in the WSU Safety Analysis Report of 2002. The amount of activity released for each isotope is reproduced in the following table.

Volatile Fission Products and Quantities

Isotope	Activity released (mCi)	Isotope	Activity released (mCi)
Br-82	4.8	Kr-83m	15.7
Br-83	15.8	Kr-85m	39.6
Br-84	25.8	Kr-85	8.0
Br-85	7.0	Kr-87	71.2
Br-87	0.1	Kr-88	106
I-131	88.1	Kr-89	26
I-132	129	Xe-131m	0.8
I-133	201	Xe-133m	4.8
I-134	221	Xe133	201
I-135	186	Xe-135m	28
I-136	2.5	Xe-135	195
		Xe-137	49
		Xe-138	103

The gamma-rays due to the decay of each radionuclide were compiled to determine the exposure rate due to each gamma-ray. All of the radionuclides under consideration are beta-particle emitters accompanied by a suite of gamma-rays of varying intensities (i.e. yields) and energies. The gamma-ray energies which were chosen for the compilation all have yields greater than 1%, relative to each beta-particle emission, i.e. no gamma-rays with yields less than 1% were used in the calculations. The 1% cutoff was chosen to assure that the highest intensity gamma-rays would be properly accounted for, while those with yields less than 1% make negligible contributions to the exposure rates. The exposure rate was calculated with the following equation (1):

$$\mathrm{mR/hr} = \frac{6\mathrm{AEn}}{1000\mathrm{d}^2} \tag{1}$$

Where exposure is given in milliröntgens per hour, A is the activity in millicuries, E is the energy of the gamma ray in keV, n is the number of gamma-rays emitted per decay event, and d is the distance from the source in feet. The distance from the geometric center of the room to the geometric center of the door under consideration is 20.04 feet. For gamma-rays in the present case, the exposure in milliröntgens is approximately equal to the dose in millirads, and using a relative biological effectiveness factor of 1 for conversion of millirads to millirem one obtains the dose rate in millirem per hour. The dose rate due to each gamma-ray of greater than 1% yield for each radionuclide was calculated, and then the dose rates of all the gamma-rays were summed to determine a total dose rate. The gamma-ray energies, percent yields, and dose rates due to each gamma-ray are compiled in tables in Appendix A. The total dose rate due to the sum of all the gamma rays listed is 26 mrem/hr. Therefore, given a five minute exposure time, the dose to a person standing outside the door leading into Room 201 would be 2 mrem.

Appendix A

Gamma-ray energies, percent abundances and dose rates in millirem per hour are compiled for each gamma-ray with greater than 1% abundance. Dose rates were calculated using equation (1).

Br-82

Energy (keV)	% abundance	dose rate (mrem/hr)
221	2.3	3.66E-04
554	70.6	2.82E-02
619	43	1.92E-02
698	28	1.41E-02
776	83	4.64E-02
828	24	1.43E-02
1044	28	2.10E-02
1317	27	2.56E-02
1475	16.6	1.76E-02
	total	1.87E-01

Br-83

Energy (keV)	% abundance	dose rate (mrem/hr)
0.009	5	1.07E-07
530	1.3	1.63E-03
	total	1.63E-03

Br-84

Energy (keV)	% abundance	dose rate (mrem/hr)
605	1.75	4.10E-03
736	1.3	3.70E-03
802	6	1.86E-02
882	41.6	1.42E-01
1877	1.1	7.99E-03
1898	14.7	1.08E-01
2824	1.1	1.20E-02
3045	2.5	2.95E-02
3235	2	2.50E-02
3366	2.9	3.78E-02
3928	6.8	1.03E-01
	total	4.92E-01

Br-85

Energy (keV)	% abundance	dose rate (mrem/hr)
802	1.3	1.09E-03
832	5.3	4.63E-03
925	1.1	1.07E-03
	total	6.79E-03

Br-87

Energy (keV)	% abundance	dose rate (mrem/hr)
327	1.8	8.83E-06
345	2.6	1.35E-05
424	7.7	4.90E-05
434	5.5	3.58E-05
465	1	6.98E-06
604	50	4.53E-04
908	2.9	3.95E-05
947	4.1	5.82E-05
1032	2.5	3.87E-05
1062	5.6	8.92E-05
1374	2.4	4.95E-05
1419	100	2.13E-03
1465	37.2	8.17E-04
1476	32.8	7.26E-04
1578	7.4	1.75E-04
2005	9.1	2.74E-04
2073	4.2	1.31E-04
2561	10.6	4.07E-04
3021	4.3	1.95E-04
3941	3.7	2.19E-04
4136	18.6	1.15E-03
4367	4.7	3.08E-04
4777	2.2	1.58E-04
4956	2.3	1.71E-04
	total	7.70E-03

Kr-83m

Energy (keV)	% abundance	dose rate (mrem/hr)
9	5.4	1.14E-04
13	13.5	4.13E-04
14	2.3	7.58E-05
	total	6.04E-04

Kr-85m

Energy (keV)	% abundance	dose rate (mrem/hr)
13	1.1	8.49E-05
13	2.2	1.70E-04
151	75.5	6.77E-02
304	14	2.53E-02
	total	9.33E-02

Kr-87

Energy (keV)	% abundance	dose rate (mrem/hr)
403	48	2.32E-02
674	1.8	1.46E-03
846	7.25	7.36E-03
1176	1.1	1.55E-03
1740	2	4.18E-03
2012	2.9	7.00E-03
2554	8.6	2.64E-02
2558	4.3	1.32E-02
	total	8.43E-02

Kr-88

Energy (keV)	% abundance	dose rate (mrem/hr)
28	2	8.90E-04
166	3.1	8.18E-03
196	26	8.10E-02
362	2.3	1.32E-02
835	13	1.73E-01
986	1.3	2.04E-02
1141	1.3	2.36E-02
1179	1	1.87E-02
1251	1.1	2.19E-02
1370	1.5	3.27E-02
1518	2.2	5.31E-02
1530	11	2.68E-01
2030	4.6	1.48E-01
2035	3.8	1.23E-01
2196	13	4.54E-01
2232	3.4	1.21E-01
2392	35	1.33E+00
	total	2.89E+00

Kr-89

Energy (keV)	% abundance	dose rate (mrem/hr)
198	1.86	1.44E-03
221	20.4	1.76E-02
345	1.2	1.61E-03
356	4.2	5.83E-03
369	1.4	2.01E-03
411	2.61	4.18E-03
498	6.8	1.32E-02
499	1.16	2.26E-03
577	5.75	1.29E-02
586	16.9	3.86E-02
738	4.3	1.24E-02
777	1.14	3.45E-03
836	1.1	3.59E-03
867	6	2.03E-02
904	7.32	2.58E-02
1108	2.98	1.29E-02
1117	1.69	7.36E-03
1274	1.4	6.96E-03
1324	3.1	1.60E-02
1473	7	4.02E-02
1500	1.3	7.61E-03
1530	3.4	2.03E-02
1533	5.2	3.11E-02
1694	4.5	2.97E-02
1903	1.1	8.16E-03
2012	1.6	1.26E-02
2866	1.8	2.01E-02
3140	1.1	1.35E-02
3362	1.1	1.44E-02
3533	1.4	1.93E-02
	total	4.25E-01

I-131

Energy (keV)	% abundance	dose rate (mrem/hr)
29	1.4	5.37E-04
30	2.6	1.03E-03
80	2.6	2.75E-03
284	6	2.25E-02
364	81	3.90E-01
637	7.3	6.15E-02
723	1.8	1.72E-02
	total	4.95E-01

I-132

Energy (keV)	% abundance	dose rate (mrem/hr)
262	1.4	7.10E-03
506	5	4.90E-02
523	16	1.62E-01
547	1.3	1.38E-02
621	1.6	1.92E-02
630	13.7	1.67E-01
651	2.7	3.40E-02
668	98.7	1.28E+00
670	5	6.48E-02
672	5	6.50E-02
727	2.2	3.09E-02
727	3.2	4.50E-02
728	2.2	3.10E-02
773	76	1.14E+00
780	1.2	1.81E-02
810	2.9	4.55E-02
812	5.6	8.80E-02
877	1.1	1.87E-02
955	18.1	3.34E-01
1136	3	6.59E-02
1143	1.4	3.10E-02
1173	1.1	2.50E-02
1291	1.1	2.75E-02
1295	2	5.01E-02
1372	2.5	6.64E-02
1399	7.1	1.92E-01
1443	1.4	3.91E-02
1921	1.2	4.46E-02
2002	1.1	4.26E-02
	total	4.19E+00

I-133

Energy (keV)	% abundance	dose rate (mrem/hr)
510	1.5	2.31E-02
529	88	1.40E+00
707	1.6	3.41E-02
856	1.2	3.10E-02
875	4.6	1.21E-01
1237	1.6	5.97E-02
1299	2.2	8.62E-02
	total	1.76E+00

I-134

Energy (keV)	% abundance	dose rate (mrem/hr)
30	1.2	1.19E-03
135	3.3	1.48E-02
235	1.7	1.32E-02
405	7.4	9.94E-02
433	4.4	6.32E-02
459	1.4	2.13E-02
489	1.6	2.59E-02
514	2.4	4.09E-02
541	8.6	1.54E-01
566	1.2	2.25E-02
595	11	2.17E-01
613	10.9	2.21E-01
628	2.3	4.79E-02
677	8.2	1.84E-01
731	2.2	5.33E-02
767	3.8	9.66E-02
847	96	2.70E+00
857	6.6	1.88E-01
884	66	1.93E+00
948	4	1.26E-01
975	4.9	1.58E-01
1040	2	6.90E-02
1072	14	4.98E-01
1136	9.2	3.46E-01
1456	3	1.45E-01
1614	4	2.14E-01
1741	3	1.73E-01
1807	5.6	3.35E-01
	total	8.16E+00

I-135

Energy (keV)	% abundance	dose rate (mrem/hr)
221	1.7	1.05E-02
288	3.1	2.49E-02
418	3.5	4.08E-02
527	13	1.91E-01
546	7.1	1.08E-01
837	6.7	1.56E-01
973	1.2	3.26E-02
1039	7.9	2.29E-01
1101	1.6	4.91E-02
1124	3.6	1.13E-01
1132	22	6.95E-01
1260	28.6	1.01E+00
1457	8.6	3.50E-01
1503	1	4.19E-02
1566	1.3	5.68E-02
1678	9.5	4.45E-01
1706	4.1	1.95E-01
1791	7.7	3.85E-01
	total	4.13E+00

Xe-131m

Energy (keV)	% abundance	dose rate (mrem/hr)
29	16	5.57E-05
30	29	1.04E-04
34	8.5	3.47E-05
34	1.7	6.94E-06
164	2	3.94E-05
	total	2.41E-04

Xe-133

Energy (keV)	% abundance	dose rate (mrem/hr)
31	13	1.22E-02
31	25	2.34E-02
35	7.2	7.60E-03
36	1.6	1.74E-03
81	37	9.04E-02
	total	1.35E-01

Xe-133m

Energy (keV)	% abundance	dose rate (mrem/hr)
29	15.9	3.32E-04
30	30.6	6.61E-04
34	8.6	2.11E-04
34	1.5	3.67E-05
233	10	1.68E-03
	total	2.92E-03

Xe-135

Energy (keV)	% abundance	dose rate (mrem/hr)
31	1.3	1.18E-03
31	2.4	2.18E-03
250	90	6.58E-01
608	2.9	5.16E-02
	total	7.13E-01

Xe-135m

Energy (keV)	% abundance	dose rate (mrem/hr)
29	4	4.87E-04
30	8	1.01E-03
34	2	2.86E-04
527	80	1.77E-01
	total	1.79E-01

Xe-137

Energy (keV)	% abundance	dose rate (mrem/hr)
456	30	1.01E-01
	total	1.01E-01

Xe-138

Energy (keV)	% abundance	dose rate (mrem/hr)
31	1	4.79E-04
31	2	9.58E-04
154	5.9	1.40E-02
242	3.5	1.31E-02
258	81	3.23E-01
396	6.3	3.85E-02
401	2	1.24E-02
434	20	1.34E-01
1114	1.5	2.58E-02
1768	16.7	4.56E-01
1851	1.4	4.00E-02
2005	5.4	1.67E-01
2016	12	3.74E-01
2252	2.3	8.00E-02
	total	1.68E+00