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April 14, 2014

Mr. Alexander Adams
U. S. Nuclear Regulatory Commission
Research and Test Reactors Branch A
Office of Nuclear Reactor Regulation
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Rockville, MD 20852-2738

Reference: Oregon State University TRIGA Reactor (OSTR)
Docket No. 50-243, License No. R-106
License Ammendment Letter dated April 13, 2012
Affidavit Letter dated April 14, 2014
USNRC RAI Letter dated February 7, 2014

Subject: Answers to Request for Additional Inforamtion request by USNRC with respect to a license amendment application for the purpose of demonstrating ^{99}Mo production capability in the OSTR

Mr. Adams:

This letter serves as a reply to the Request for Additional Information (RAI) letter dated February 7, 2014, pertaining to a license amendment application for the purpose of allowing a fueled experiment. Consistent with the affidafid letter of April 14, 2014, some of the information in the answers to the RAI letter will be proprietary in nature and we request that the information be withheld from public disclosure. There are two enclosures with this letter. Enclosure 1 is a proprietary version of the answers to the RAI letter. Information which is **BOLDED** denotes proprietary information. Enclosure 2 is a public version of the answers to the RAI letter. Information which is redacted is denoted in **[....]**. I hereby affirm, state, and declare under penalty of perjury that the foregoing is true and correct.

Executed on: 4/14/14.

If you have any questions, please do not hesitate to contact me.

Sincerely,

Steve Reese
Director

cc: Document Control, NRC
Craig Bassett, NRC w/o attachements
Rick Spinrad, OSU w/o attachements
Rich Holdren, OSU w/o attachements
Andy Klein, OSU w/o attachements

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By letter dated February 7, 2014, the USNRC requested the following additional information. Enclosure 1 is a non-public version of the request for additional information. Information which is **BOLDED** denotes proprietary information. Enclosure 2 is a public version of the request for additional information. Information which is redacted is denoted in **[ ]**.

1. Safety Analysis Report (SAR) Section III. The amendment SAR evaluated excess reactivity of the reactor core based upon the normal core configuration under the beginning of life (BOL) conditions. The OSU Conversion SAR indicates that BOL is not the most limiting condition for the core. Provide either: 1) additional analysis at most limiting configurations(s) and condition(s) over core life; or, 2) wording for an additional technical specification (TS) to ensure that excess reactivity limits are not exceeded; or, 3) provide justification as to why an additional TS is not needed.

   An additional TS is not needed. The BOL core was analyzed because, of the three points used to define the core lifetime in the OSU Conversion SAR, it is closest to the actual core condition likely to be utilized. As of June 2013 annual report, the current core had a cumulative value of 261.8 MWD of operation with between 50-70 MWD added annually. The middle of life (MOL) value was estimated in the OSU Conversion SAR as 1600 MWD. Because the value for MOL is much farther away than BOL, it was felt that the BOL core value is most representative of our current condition (i.e., there is a need to perform the demonstration in the near future, not in the timeframe MOL). However, it is understood that all TS values apply (i.e., core excess and shutdown margin) and, as stated in the OSU Conversion SAR, the anticipated reactivity swing observed during the MOL core condition can be operationally accounted for by fuel management over time. This was the case for the FLIP fuel cores used by the OSTR from 1976-2008 and is also true for the current 30/20 fuel.

2. Response dated August 23, 2013. The accident analysis used **[...]**. The supplied reference documents **[...]**. As calculated accident doses are directly proportional to the **[...]**; the doses provided in the RAI response may underestimate offsite and facility worker doses. Provide an updated accident analysis using more conservative values for **[...]** or provide additional justification of the RAI response analysis.

   A sensitivity study was conducted on the influence of thermal conductivity (*k*) within the fueled region of a target on the element's temperature distribution. Six calculations were performed using the RELAP5-3D model developed for the safety analysis of this target. In all calculational cases, only thermal conductivity was varied within the fueled region. Additionally, of all the cases considered, the fueled region thermal conductivity was held constant (i.e. not considered to be dependent upon temperature). The outcome of this sensitivity study is presented in Table 2-1.

Table 2-1 – Summary of sensitivity study from target fueled region thermal conductivity

Thermal Conductivity [W/m-K]	Temperature [°C]			
	[...]	[...]	Maximum Fueled Region	Average Fueled Region
0.30	116.10	104.45	401.31	314.78
0.32	116.08	104.47	384.19	302.75
0.50	115.94	104.70	284.96	232.97
1.00	115.57	105.26	197.77	171.68
3.00	114.43	106.77	139.68	130.93
5.00	113.66	107.62	128.09	122.81

Empirically measured thermal conductivity values acquired from **[...]** infer that a thermal conductivity representative of **[...]** target composition may be of the approximate value 0.32 W/m-K. This assumes a relative comparison between the measured thermal conductivity in **[...]**. Given an assumed, constant thermal conductivity of 0.32, the maximum fueled region temperature is found to be 384.19 °C, while the average fueled region temperature is found to be approximately 80% of the maximum fuel temperature.

From Table 2-1, it is seen that while the maximum fueled region temperature is significantly influenced by the fueled region's thermal conductivity, the **[...]** remains relatively constant at ~116 °C or less for all cases considered. As a result of this analysis, revised values for **[...]** are provided below (Table 2-2) using data given in **[...]**. This temperature was chosen because best approximates value on the table for the average fueled region temperature for the target containing an **[...]**.

In cases where data was unavailable for a given isotope, the average value of **[...]** for the isotopes that were available was used. All other values and methodology remaining the same, the occupational and general public doses are provided in Tables 2-2 through 2-6 below. Because the values of **[...]** are higher, the resulting doses are proportionally (or nearly so) higher as well. Only in Scenarios A (i.e., no building) and B (i.e., ventilation on) at 10 m distance in air produced calculated values that were slightly greater than 100 mrem TEDE. However, given the uncertainty in the calculation and the unrealism (i.e., vanishing building and water instantaneously vanishing), these values are likely conservatively high. Regardless, no other scenario produced calculated values in excess of the 100 mrem TEDE annual limit to the general public.

Table 2-2 – Airborne Radioactive Source Term (Note: replaces Table 5 in the license amendment)

Isotope	Isotope Half-life (s)	Isotope Decay Constant (1/s)	U-235 Fission Product Yield	Target Activity (mCi)	[...]	No Water Reactor Bay Air Activity (mCi)	Water Reactor Bay Air Activity (mCi)
Br-82	127080	5.45E-06	6.10E-07	[...]	[...]	0.00	0.00
Br-83	8640	8.02E-05	5.38E-03	[...]	[...]	17.60	0.88
Br-84m	360	1.93E-03	3.18E-04	[...]	[...]	1.04	0.05
Br-84	1908	3.63E-04	1.00E-02	[...]	[...]	32.81	1.64
Br-85	172.2	4.03E-03	1.26E-02	[...]	[...]	41.33	2.07
Br-86	55.5	1.25E-02	1.82E-02	[...]	[...]	59.42	2.97
Br-87	55.9	1.24E-02	2.02E-02	[...]	[...]	66.02	3.30
I-131	692928	1.00E-06	2.88E-02	[...]	[...]	94.36	4.72
I-132	8208	8.44E-05	4.30E-02	[...]	[...]	140.63	7.03
I-133	74880	9.26E-06	6.70E-02	[...]	[...]	219.16	10.96
I-134	3156	2.20E-04	7.74E-02	[...]	[...]	253.07	12.65
I-135	23652	2.93E-05	6.29E-02	[...]	[...]	205.76	10.29
I-136	83.4	8.31E-03	2.47E-02	[...]	[...]	80.87	4.04
Kr-83m	6696	1.04E-04	5.38E-03	[...]	[...]	70.41	70.41
Kr-85m	16128	4.30E-05	1.26E-02	[...]	[...]	222.10	222.10
Kr-85	3.39E+08	2.04E-09	2.74E-03	[...]	[...]	2.24	2.24
Kr-87	4572	1.52E-04	2.51E-02	[...]	[...]	432.39	432.39
Kr-88	10224	6.78E-05	3.57E-02	[...]	[...]	499.33	499.33
Kr-89	189	3.67E-03	4.61E-02	[...]	[...]	395.06	395.06
Xe-131m	1028160	6.74E-07	3.17E-04	[...]	[...]	4.15	4.15
Xe-133m	189216	3.66E-06	1.95E-03	[...]	[...]	25.50	25.50
Xe-133	452736	1.53E-06	6.70E-02	[...]	[...]	991.56	991.56
Xe-135m	918	7.55E-04	1.21E-02	[...]	[...]	140.69	140.69
Xe-135	32760	2.12E-05	6.53E-02	[...]	[...]	790.06	790.06
Xe-137	229.2	3.02E-03	6.11E-02	[...]	[...]	812.49	812.49
Xe-138	846	8.19E-04	6.37E-02	[...]	[...]	550.45	550.45

Table 2-3 – Occupational Radiation Doses in the Reactor Room Following a Single Target Failure at End of Bombardment (Note: replaces Table 7 from license amendment)

Scenario	Release Environment	Occupancy (minutes)	$CDE_{Thyroid}$ + $DDE_{Thyroid}$ (mrem)	TEDE (mrem)
A	Water	2	13	3
A	Water	5	13	3
A	Air	2	219	10
A	Air	5	219	10
B	Water	2	89	18
B	Water	5	198	37
B	Air	2	1464	66
B	Air	5	3313	146
C	Water	2	95	19
C	Water	5	233	44
C	Air	2	1565	71
C	Air	5	3904	172

Table 2-4 –Radiation Doses to Members of the General Public Following a Single Target Failure at End of Bombardment – Scenario A (Note: replaces Table 8 in the license amendment)

Distance (m)	With Primary Water $CDE_{Thyroid}$ + $DDE_{Thyroid}$ (mrem)	With Primary Water TEDE (mrem)	No Primary Water $CDE_{Thyroid}$ + $DDE_{Thyroid}$ (mrem)	No Primary Water TEDE (mrem)
10	183	37	3004	137
50	83	16	1370	62
100	28	5	469	21
150	12	2	202	9
200	7	1	118	5
250	5	1	79	3
267	4	1	70	3

Table 2-5 –Radiation Doses to Members of the General Public Following a Single Target Failure at End of Bombardment – Scenario B (Note: replaces Table 9 in the license amendment)

Distance (m)	With Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	With Primary Water TEDE (mrem)	No Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	No Primary Water TEDE (mrem)
10	174	29	2986	126
50	79	13	1362	57
100	27	4	466	20
150	12	2	201	8
200	7	1	118	5
250	4	1	79	3
267	4	1	70	3

Table 2-6 –Radiation Doses to Members of the General Public Following a Single Target Failure at End of Bombardment – Scenario C (Note: replaces Table 10 in the license amendment)

Distance (m)	With Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	With Primary Water TEDE (mrem)	No Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	No Primary Water TEDE (mrem)
10	109	5	2158	66
50	50	2	395	30
100	17	1	337	10
150	7	<1	145	4
200	4	<1	85	3
250	3	<1	57	2
267	3	<1	51	2

3. SAR Section V. In reviewing the accident scenarios, the suggested bounding conditions of a release in air and irradiation time of one year are more conservative than the anticipated conditions for this fueled experiment. In consideration with the response provided to question number two above:
   a. Fueled experiments accident scenarios commonly involved a release in water. Provide an updated accident analysis for a release in water at the end of irradiation.
   b. It is assumed there will be a cool down period before the target is removed from the pool. Provide an updated accident analysis for a release in air upon removal from the pool. Also, please propose and justify a TS for the proposed cool down time or explain why a TS is not needed.

Below you will find an updated accident analysis using the **[...]** values given in the response to Question 2 above, an irradiation time of 6.5 days, and no decay time or cool down period. All other values and methodology remain the same. Values for the source term, occupational doses, and doses to the general public are provided in Tables 3-1 through 3-5 below.

Only Scenario A (i.e., no building) at 10 m with no water produced calculated value slightly greater than 100 mrem. However, given the uncertainty in the calculation and the unrealism (i.e., vanishing building and water instantaneously vanishing), this value is conservatively high. No other scenario projected a TEDE general public dose exceed the annual TEDE limit to the general public for either air or water release. As such, no TS for decay time or cool down period is needed.

Table 3-1 – Airborne Radioactive Source Term (Note: replaces Table 5 in the license amendment)

Isotope	Isotope Half-life (s)	Isotope Decay Constant (1/s)	U-235 Fission Product Yield	Target Activity (mCi)	[...]	No Water Reactor Bay Air Activity (mCi)	Water Reactor Bay Air Activity (mCi)
Br-82	127080	5.45E-06	6.10E-07	[...]	[...]	0.00	0.00
Br-83	8640	8.02E-05	5.38E-03	[...]	[...]	17.60	0.88
Br-84m	360	1.93E-03	3.18E-04	[...]	[...]	1.04	0.05
Br-84	1908	3.63E-04	1.00E-02	[...]	[...]	32.81	1.64
Br-85	172.2	4.03E-03	1.26E-02	[...]	[...]	41.33	2.07
Br-86	55.5	1.25E-02	1.82E-02	[...]	[...]	59.42	2.97
Br-87	55.9	1.24E-02	2.02E-02	[...]	[...]	66.02	3.30
I-131	692928	1.00E-06	2.88E-02	[...]	[...]	40.56	2.03
I-132	8208	8.44E-05	4.30E-02	[...]	[...]	140.63	7.03
I-133	74880	9.26E-06	6.70E-02	[...]	[...]	217.95	10.90
I-134	3156	2.20E-04	7.74E-02	[...]	[...]	253.07	12.65
I-135	23652	2.93E-05	6.29E-02	[...]	[...]	205.76	10.29
I-136	83.4	8.31E-03	2.47E-02	[...]	[...]	80.87	4.04
Kr-83m	6696	1.04E-04	5.38E-03	[...]	[...]	70.41	70.41
Kr-85m	16128	4.30E-05	1.26E-02	[...]	[...]	222.10	222.10
Kr-85	3.39E+08	2.04E-09	2.74E-03	[...]	[...]	0.04	0.04
Kr-87	4572	1.52E-04	2.51E-02	[...]	[...]	432.39	432.39
Kr-88	10224	6.78E-05	3.57E-02	[...]	[...]	499.33	499.33
Kr-89	189	3.67E-03	4.61E-02	[...]	[...]	395.06	395.06
Xe-131m	1028160	6.74E-07	3.17E-04	[...]	[...]	1.31	1.31
Xe-133m	189216	3.66E-06	1.95E-03	[...]	[...]	22.25	22.25
Xe-133	452736	1.53E-06	6.70E-02	[...]	[...]	571.89	571.89
Xe-135m	918	7.55E-04	1.21E-02	[...]	[...]	140.69	140.69
Xe-135	32760	2.12E-05	6.53E-02	[...]	[...]	790.05	790.05
Xe-137	229.2	3.02E-03	6.11E-02	[...]	[...]	812.49	812.49
Xe-138	846	8.19E-04	6.37E-02	[...]	[...]	550.45	550.45

Table 3-2 – Occupational Radiation Doses in the Reactor Room Following a Single Target Failure at End of Bombardment (Note: replaces Table 7 from license amendment)

Scenario	Release Environment	Occupancy (minutes)	$CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	TEDE (mrem)
A	Water	2	9	3
A	Water	5	9	3
A	Air	2	134	8
A	Air	5	134	8
B	Water	2	60	17
B	Water	5	133	35
B	Air	2	897	33
B	Air	5	2028	109
C	Water	2	64	18
C	Water	5	157	41
C	Air	2	958	53
C	Air	5	2389	128

Table 3-3 –Radiation Doses to Members of the General Public Following a Single Target Failure at End of Bombardment – Scenario A (Note: replaces Table 8 in the license amendment)

Distance (m)	With Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	With Primary Water TEDE (mrem)	No Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	No Primary Water TEDE (mrem)
10	125	36	1841	103
50	56	16	839	46
100	19	5	287	15
150	8	2	124	7
200	5	1	72	4
250	3	1	48	2
267	3	1	43	2

Table 3-4 –Radiation Doses to Members of the General Public Following a Single Target Failure at End of Bombardment – Scenario B (Note: replaces Table 9 in the license amendment)

Distance (m)	With Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	With Primary Water TEDE (mrem)	No Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	No Primary Water TEDE (mrem)
10	115	27	1824	92
50	52	12	832	42
100	18	4	285	14
150	8	2	123	6
200	4	1	72	4
250	3	1	48	2
267	3	1	43	2

Table 3-5 –Radiation Doses to Members of the General Public Following a Single Target Failure at End of Bombardment – Scenario C (Note: replaces Table 10 in the license amendment)

Distance (m)	With Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	With Primary Water TEDE (mrem)	No Primary Water $CDE_{Thyroid} + DDE_{Thyroid}$ (mrem)	No Primary Water TEDE (mrem)
10	58	3	1121	36
50	26	1	511	16
100	9	<1	175	6
150	4	<1	76	2
200	2	<1	44	1
250	2	<1	30	1
267	1	<1	26	1

4. SAR Section III page 14 and Response dated August 23, 2013. The response to Question 4 states that the "amendment is specifically written to allow use of no more than three targets…" However, in the response to Question 14, the proposed licensed possession limit of "1.0 kilograms of contained uranium-235" would permit possession of more than three targets. The amendment SAR analyzed in-pool storage of three unirradiated targets. Provide revised analysis for target storage in-tank based on the new possession limit or explain why additional analysis is not needed.

We propose to replace "1.0 kilograms of contained uranium-235" with "0.5 kilograms of contained uranium-235". At a **[…]** per target and an enrichment of 19.75% (the highest LEU enrichment available), three targets would combine to total **[…]** of uranium-235. The proposed possession limit would still allow for the storage of three targets, would be consistent with the analysis, and would accommodate for any uncertainty in the nominal values for the mass of uranium in each target.