NIOWAVE, INC.
1012 North Walnut Street
Lansing, MI 48906
Phone: (517) 999-3475

March 5th, 2015

U.S. Nuclear Regulatory Commission
Region III Office
2443 Warrenville Road, Suite 210
Lisle, IL 60532-4352

Attn: Mr. Kevin Null
Subj: Clarifications to the Combined Application for a License to Produce and Possess Accelerator Produced Radionuclides for Research and Development (NRC Control No. 584728)

Mr. Null:
Below you will find our clarifications to the estimates of the incidentally produced radionuclides.

Incidentally produced radionuclides

Radionuclides incidentally produced from stable targets

While producing radioisotopes from the stable targets a number of short lived ($T_{1/2}$ <120 days) isotopes will be produced. The total activity of all the short-lived incidentally produced radioisotopes possessed by Niowave will not exceed 15 mCi.

In addition, several long-lived ($T_{1/2}$ >120 days) isotopes can be produced while irradiating natural gold, holmium, iridium, manganese, molybdenum, scandium, selenium, strontium, titanium, zinc, and yttrium targets (see Table 1).

Table1. Possible incidentally produced long-lived ($T_{1/2}$ >120 days) isotopes, their half-lives, and exempt activities.

Isotope	Half-life	Exempt activity, μCi (10 CFR § 30.71 Schedule B)
Gold-195	183 d	10
Holmium-166m	1,200 y	0.1
Iridium-192m	242 y	0.1
Iridium-194m	171 d	0.1
Manganese-54	312 d	10
Molybdenum-93	4,000 y	0.1
Molybdenum-97	$3x10^6$ y	0.1
Niobium-91	680 y	0.1
Niobium-93m	16 y	10
Technicium-99	$2x10^5$ y	10

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To estimate the activity of incidentally produced long-lived isotopes let's consider Ir-192 production as an example. Whenever Ir-192 is produced (either via $^{193}Ir(\gamma,n)^{192}Ir$ or $^{191}Ir(n,\gamma)^{192}$ route), it is accompanied by Ir-192m. The Ir-192m yield was estimated using a 1 hour irradiation of a natural yttrium target with a 40 MeV electron beam. Our calculations show that production of 1 mCi of Ir-192 will result in less than 0.1 μCi of Ir-192m, which is below the exempt threshold. Similar calculations were done for all of the above long-lived radionuclides and we are certain that the activity of each of the radioisotopes from Table 1 possessed by Niowave will not exceed the exempt quantities.

Radionuclides incidentally produced from natural, depleted, and low-enriched uranium

While producing radioisotopes from natural, depleted, or low-enriched uranium, a number of fission products will be produced, many of them being long-lived ($T_{1/2}$ >120 days). However, due to short irradiation periods we are planning to perform (not to exceed few hours), the activity of these long-lived species will be negligible. As an example, we consider one of the most common fission products, Cs-137 ($T_{1/2}$=30.1 years) and calculate its yield from a 1 hour irradiation of uranium. To produce 1 mCi of Mo-99 in one hour, its production rate should be

$$\left(\frac{dN}{dt}\right)_{Mo-99} = 3.7\times10^{9}\,s^{-1}$$

The Cs-137 production rate is comparable to the Mo-99 production rate (7% vs. 6% of fissions) and the activity of the Cs-137 after 1 hour irradiation will be:

$$Y = \left(\frac{dN}{dt}\right)_{Cs-137}\left(1-e^{-\lambda t}\right) = 4\times10^{9}\,s^{-1}\times\left(1-e^{-\frac{\ln(2)\times 1h}{30.1y}}\right) = 10^{4}\,s^{-1} = 10kBq \approx 280nCi$$

This activity is so low that is barely increases the R-value. In fact, we calculated the maximum activity of Cs-137 that would require Niowave to increase our financial assurance value and found it to be about 0.2 mCi (see Table 2). This is about 1,000 higher than the amount of Cs-137 we would generate in the above example to produce 1 mCi of Mo-99. We understand that other long-lived isotopes will contribute to the R-value as well, but we are certain that even the cumulative yield of all fission products will still keep us under the current FA level of $225k.

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Table 2. R-values taking into account 0.2 mCi of Cs-137.

U-235 Enrichment (%)	LEU Mass (g)	U-234 Mass (g)	U-235 Mass (g)	U-238 Mass (g)	Cs-137 activity (mCi)	Zn-65 activity (mCi)	$225,000 FA R-value
10.00	23.3	1.5E-02	2.3	21.0	0.2	1	0.999
11.00	21.0	1.5E-02	2.3	18.7	0.2	1	0.997
12.00	19.1	1.5E-02	2.3	16.8	0.2	1	0.996
13.00	17.5	1.5E-02	2.3	15.2	0.2	1	0.996
14.00	16.2	1.5E-02	2.3	13.9	0.2	1	1.000
15.00	15.0	1.5E-02	2.3	12.8	0.2	1	0.999
16.00	13.9	1.5E-02	2.2	11.7	0.2	1	0.994
17.00	13.0	1.5E-02	2.2	10.8	0.2	1	0.995
18.00	12.2	1.5E-02	2.2	10.0	0.2	1	0.996
19.00	11.5	1.5E-02	2.2	9.3	0.2	1	0.998
19.75	11.0	1.5E-02	2.2	8.8	0.2	1	0.998

Summary

The total activity of all the short-lived incidentally produced radioisotopes ($T_{1/2}$ <120 days) possessed by Niowave (from irradiating both stable and uranium targets) will not exceed 15 mCi.

Activity of each individual long-lived incidentally produced radioisotope ($T_{1/2}$ >120 days) possessed by Niowave will not exceed 1 μCi. The total activity of all the long-lived incidentally produced radioisotopes possessed by Niowave will not exceed 1 mCi. At the same time, the activities of different long-lived radioisotopes will be such that the calculated R-value will keep Niowave under the current financial assurance level of $225k.

We hope the above information on the estimates of the incidentally produced radionuclides is helpful. If you have any further questions please let us know.

Sincerely,

Dr. Terry L. Grimm, Ph.D.
President and Senior Scientist

BRENDA CHAMPION
517-999-3475
NIOWAVE
1012 N. WALNUT ST
LANSING MI 48906

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KEVIN NULL
NRC REGION III OFFICE
2443 WARRENVILLE ROAD, SUITE 210
LISLE IL 60532-4352

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