Friday, September 25, 2014

MEMORANDUM TO: James Clifford, Director
Division of Nuclear Materials Safety
Region I

FROM: Gregory Suber, Deputy Director (Acting)
Environmental Protection and /RA/
Performance Assessment Directorate
Division of Waste Management
and Environmental Protection
Office of Federal and State Materials
and Environmental Management Programs

SUBJECT: FINAL RESPONSE TO TECHNICAL ASSISTANCE REQUEST, DATED MARCH 24, 2014, FOR THE REVIEW OF DERIVED CONCENTRATION GUIDELINE LEVELS FOR THE RELEASE OF THE PFIZER, INC., ECLIPSE CYCLOTRON VAULT, GROTON, CONNECTICUT

Region I submitted a Technical Assistance Request (TAR), dated March 24, 2014, requesting a review of site-specific derived concentration guideline levels (DCGLs) developed in support of license termination of the cyclotron facility operated at the Pfizer Inc. facility in Groton, Connecticut. For areas without volumetric contamination, the licensee proposed to use a combination of default surface screening values and values calculated with the building occupancy scenario of the DandD dose model software (version 2.1). The licensee also proposed site-specific DCGL values for areas with both surface and volumetric contamination. The licensee discusses the development and use of these values in "Pfizer, Inc. Eclipse Cyclotron Facility Decommissioning Final Status Report," which is included in the request for license termination package [ML14094A454].

The Office of Federal and State Materials and Environmental Management Programs (FSME) Performance Assessment Branch (PAB) staff replied to Region I by memo dated July 10, 2014 [ML14189A111]. PAB staff found the licensee's proposed DCGL values for areas with surface contamination only to be appropriate for the site. PAB staff also found the licensee's method for developing site-specific DCGL values for areas with both surface and volumetric contamination to be acceptable. PAB staff found the DCGL values for the remaining concrete in the cyclotron vault to be acceptable. However, PAB staff indicated additional information was needed to make a determination about the metal remaining in the cyclotron vault.

Subsequently, Region I requested additional information from the licensee and the licensee supplied characterization of the remaining metal and an assessment of potential doses from exposure to the remaining metal [ML14260A125]. The enclosed Technical Evaluation Report discusses PAB staff's review of the additional information supplied by the licensee.

CONTACT: Christianne Ridge, DWMEP/PAB
(301) 415-5673

Based on the additional information provided by the licensee and the staff's original assessment [ML14189A111], PAB staff finds the proposed DCGL values to be appropriate for the site.

If you have any questions regarding this review, please contact Christianne Ridge of my staff. She can be reached at 301-415-5673 or christianne.ridge@nrc.gov.

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Enclosure:
Technical Evaluation Report

cc w/enclosure:
Elizabeth Ullrich, Region 1

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cc w/enclosure:
Elizabeth Ullrich, Region 1

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NAME	ARidge	CMcKenney	GSuber
DATE	09/23/14	09/24/14	09/25/14

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Building 274 Cyclotron Vault Supplemental Technical Evaluation Report
Prepared by: Christianne Ridge, Sr. Systems Performance Analyst

1. Background

Pfizer, Inc. has requested unrestricted release of the cyclotron vault in Building 274 of the Pfizer Inc., facility in Groton, Connecticut. Although the cyclotron has been removed, the concrete and remaining steel in the cyclotron vault contain detectable activation products. The remaining material is considered part of the Group 2 Decommissioning Group per NUREG-1757. Group 2 facilities are not required to submit a decommissioning plan. However, they must demonstrate that the site meets U.S. Nuclear Regulatory Commission (NRC) screening criteria for residual radioactive material remaining at the site. To meet NRC requirements for the release of the cyclotron vault in Building 274 as acceptable for unrestricted use, all licensed material must be removed, areas decontaminated as necessary, and a close out survey must be performed.

Staff of the Office of Federal and State Materials and Environmental Management Programs (FSME) Performance Assessment Branch (PAB) previously assessed the licensee's proposed Derived Concentration Guideline Levels (DCGLs) for the site. The licensee proposed separate DCGL values for (1) areas that only have surface contamination and (2) areas that could contain both surface contamination and volumetric activation products. The licensee developed surface DCGLs based on two sources: (1) the default screening values provided in NUREG-1757 v. 1 Rev. 2 Table B.1 and (2) values calculated with the building occupancy scenario of DandD. PAB staff verified that the use of the default surface screening values and the values developed with DandD were appropriate for areas of the site that only had surface contamination. For areas with both surface and volumetric contamination, the licensee based site-specific DCGLs on the building occupancy scenario described in NUREG-5512, Vol. 1. NRC staff reviewed the licensee's calculations for the building occupancy scenario and found the DCGLs to be appropriate for that scenario.

In addition to considering the building occupancy scenario, the licensee used NUREG-1640 to estimate the dose from the residual contamination in a variety of alternate scenarios, including building renovation, demolition, recycling, and disposal. The licensee concluded that doses from residual contamination in the cyclotron vault would be much less than the 25 mrem/yr dose limit. The NRC staff reviewed the licensee's calculations and verified the conclusion for contaminated concrete at the site. However, the NRC staff could not verify the licensee's conclusions about alternate scenarios for the steel remaining in the cyclotron vault without additional information about the locations of the remaining metal and the activation products in the steel. In response to a request from Region I, the licensee subsequently provided the following information:

1) the amount and location of steel remaining in the cyclotron vault;
2) volumetric concentrations of Co-60 and Mn-54 in the remaining steel, as measured by gamma spectroscopy;
3) volumetric concentrations of Fe-55 and Ni-63 in the steel, which were based on ratios to the measured concentration of Co-60; and
4) projected doses from Co-60, Mn-54, Fe-55, and Ni-63 based on a steel recycling scenario.

Enclosure

This document summarizes the PAB staff's review of this additional information.

2. Source Term

The source term at the site results from (1) volumetric contamination in activated concrete, (2) surface contamination from concrete dust generated during fixture removal, and (3) volumetric contamination in activated steel rebar embedded in the concrete. PAB staff previously reviewed the licensee's original description of this source term [ML14094A454] and found the description of the first two parts (i.e., the volumetric and surface contamination resulting from the activated concrete) to be acceptable. However, PAB staff found that more information was needed about the source term in activated metal remaining in the cyclotron vault.

In response to a request from Region I, the licensee clarified that the only metal remaining in the cyclotron vault is carbon steel rebar embedded in the concrete. The licensee used gamma spectroscopy to analyze a piece of rebar that had been embedded between 5 to 10 centimeters (2 to 4 inches) below the concrete surface directly under one of the target locations. The licensee stated that rebar from this location should provide a conservative estimate of the activation products in the remaining rebar.

The licensee quantified Co-60 and Mn-54 in the steel by gamma spectroscopy and estimated Fe-55 and Ni-63 concentrations based on their expected ratios to Co-60. The ratios were calculated based on the projected production and radioactive decay of each radionuclide. Production of activation products is given by Equation 1.

$$A = N \sigma \Phi [1 - e^{(-\lambda t)}] \qquad \text{Equation (1)}$$

Where

A = Activity (dps)
N = number of atoms of the target isotope

$$N = \frac{\text{mass of the element in the sample}}{\text{atomic weight of the element}} \times \text{isotopic abundance of the target} \times 6.02 \times 10^{23}$$

λ = decay constant (year^{-1})
Φ = neutron flux (neutrons per cm^2 per second)
σ = activation cross-section (Barns = 1 x 10^{-24} cm^2)
t = time (years)

The licensee also provided the results of Equation 1 for each radionuclide after 1 year of irradiation, based on an assumed thermal neutron flux of 1 x 10^{11} neutrons per cm^2 per second (Table 1). The activity values given in decays per second (dps) in Table 1 do not describe the actual source term. Instead, the licensee used these surrogate values to obtain the ratios of Fe-55 and Ni-63 to Co-60.

The licensee's source term is provided in Table 2. To estimate the concentration of Fe-55, the licensee noted that because Fe-55 has a shorter half-life than Co-60 the ratio of Fe-55 to Co-60 decreases with time. The licensee then repeated the calculation shown in Table 1, setting the time to 0 years and noted the maximum ratio of Fe-55 to Co-60 is eight. For Ni-63, the licensee noted that because Ni-63 has a longer half-life than Co-60, the ratio of Ni-63 to Co-60 increases with time. The licensee then repeated the calculation shown in Table 1 for a time of 53 years and noted that the concentration of Ni-63 to Co-60 was still significantly less than the concentration of Co-60. The licensee therefore decided to bound the source term of Ni-63 by setting equal to the concentration of Co-60. Thus Table 2 provides the source term based on (1) Co-60 and Mn-54 measured with gamma spectroscopy, (2) Fe-55 based on the ratio of Fe-55 to Co-60 calculated in Table 1 for an irradiation time of 1 year and (3) Ni-63 set to an upper limit of the Co-60 activity concentration.

Table 1 Calculated formation of Fe-55 and Ni-63 relative to Co-60 after one year of irradiation

Parameter	Parameter Value		
	Fe-55	Ni-63	Co-60
Half-life (yr)	2.7	96	5.27
Target Nuclide	Fe-54	Ni-62	Co-59
Target Isotopic Abundance	0.0585	0.0364	1.00
Target Cross Section (Barns)	2.25	14.5	31.18
Elemental Abundance in Rebar (fraction by weight)	0.99	0.01	0.0009
Atomic Weight (g/mole)	55.85	58.69	58.93
Calculated Expected Activity (dps) for a 1gram sample at one year of irradiation for a fixed neutron flux of 1×10^{11} neutrons per cm^2 per second (surrogate values used to obtain ratios)	3.18×10^7	3.89×10^4	4.21×10^6
Ratio to Co-60 Activity At 1 year	7.5	0.009	1.0

Table 2 Source Term in Rebar

Nuclide	Method	Activity Concentration (pCi/g)
Co-60	Gamma Spectroscopy	3.96
Mn-54	Gamma Spectroscopy	0.19
Fe-55	Calculated based on relative accumulation of Fe-55 to Co-60 (from Table 1)	31.7
Ni-63	Bounded by the Co-60 concentration	3.96

3. Projected Dose from Activated Rebar in Alternate Scenarios

As discussed in NRC's first analysis [ML14189A111], the licensee previously provided sufficient information to address projected doses from both steel and concrete in the building occupancy scenario, as well as projected doses from concrete in alternate scenarios such as building renovation, demolition, recycling, and disposal. Thus this report only addresses projected doses from the remaining rebar in alternate scenarios.

For each activation product in the steel, the licensee chose the scenario from NUREG-1640 that yielded the highest dose. For Co-60, Mn-54, Fe-55, and Ni-63 in steel, the limiting scenario in NUREG-1640 is workers processing scrap at a scrap yard. The licensee used the scenario dose conversion factors (DCFs) provided in the NUREG to calculate a projected dose based on the estimated source term in the steel.

The scenario DCFs for steel calculated in NUREG-1640 were based on the estimated mass of steel resulting from decommissioning a nuclear power plant, which is much greater than the mass of contaminated steel present in the cyclotron vault. Therefore, the licensee adjusted the estimated doses by multiplying by the ratio of the mass of steel in the cyclotron vault to the steel mass used in NUREG-1640. The licensee conservatively chose the lower end of the mass range considered in NUREG-1640 and an upper estimate of the mass of contaminated steel in the cyclotron vault, to maximize the ratio. The range of steel removal rates used in the NUREG-1640 is 15,000 to 24,000 metric tons of steel cleared in 1.7 years. Rounding 1.7 years to 2 years, the licensee used an annual average annual rate of 7,500 tons steel as the lower bound of the steel scrap removal rate assumed in NUREG-1640. The licensee estimated that less than one metric ton of potential activated steel remained at the site, and adjusted the dose by a factor of 1 metric ton divided by 7,500 metric tons, or 0.013% (Table 3).

Table 3. Alternate Scenario Dose Estimate for Volumetrically Contaminated Steel

Nuclide	Average Activity Concentration (pCi/g)	Mass-Based Scenario DCF (mrem/yr per pCi/g)*	Dose Using NUREG-1640 Volume Assumptions (mrem/yr)	Volume-Corrected Dose (mrem/yr)
Co-60	3.96	1.9×10^{-1}	7.6×10^{-1}	1.0×10^{-4}
Mn-54	0.19	5.9×10^{-2}	1.1×10^{-2}	1.5×10^{-6}
Fe-55	31.7	1.7×10^{-6}	5.4×10^{-5}	7.4×10^{-9}
Ni-63	3.96	1.7×10^{-6}	6.9×10^{-6}	9.4×10^{-10}
		Total	7.7×10^{-1}	1.1×10^{-4}

* NUREG-1640 Table 2.1 provides DCFs in units of (microseiverts / year) per (becquerel / gram). The DCFs were converted to (millirem / year) per (picocurie / gram) using a conversion factor of 0.0037.

4. Review and Evaluation of the Source Term and Projected Dose in Alternate Scenarios

4.1 Evaluation of Source Term

Table 1 shows the licensee's results for Equation 1 for each radionuclide after 1 year of operation, for a nominal thermal neutron flux of 1 x 10^{11} neutrons per cm^2 per second. PAB staff reviewed the licensee's calculations and duplicated the results shown in Table 1. NRC staff noted that for a fixed assumed thermal flux and sample mass, Equation 1 becomes:

$$A_i / A_j = \frac{(m_i / a_i)\ w_i\ \sigma_i\ [1 - e^{(-\lambda i\ t)}]}{(m_j / a_j)\ w_i\ \sigma_j\ [1 - e^{(-\lambda j\ t)}]} \qquad \text{Equation (2)}$$

Where

A_i / A_j = ratio of activity of radionuclide i to activity of radionuclide j (unitless)
m_i = mass fraction of element i in the target (unitless)
w_i = atomic weight of element i (grams / mole)
a_i = isotopic abundance of element i in the target (unitless)
λ_i = decay constant for element i ($year^{-1}$)
σ_i = activation cross-section for target radionuclide i (Barns = 1 x 10^{-24} cm^2)
t = time (years)

Because the equation is being used to calculate ratios of one radionuclide to another, using Equation 2 eliminates the need to calculate intermediate surrogate values for the individual activities of each radionuclide. It also clarifies the relationships among the variables. For example, Equation 2 demonstrates that the ratios the licensee calculated did not depend on their assumed thermal neutron flux. Using Equation 2, PAB staff notes that the ratio of Ni-63 to Co-60 cannot exceed 0.16. Therefore, the licensee's use of the Co-60 value to bound the Ni-63 value is acceptable. Similarly, the NRC staff notes the ratio of Fe-55 to Co-60 has a maximum of approximately eight and decreases with further decay time. Therefore, the licensee's representation of the activity concentration of Fe-55 as eight times the Co-60 concentration is acceptable. Based on this analysis, the NRC staff found the source term values in Table 2 to be acceptable.

4.2 Evaluation of Projected Dose Alternate Scenarios

NRC staff verified the dose conversion factors used by the licensee and duplicated the calculations of the projected dose from each radionuclide shown in Table 3. Although the calculations in NUREG-1640 involve many approximations, because the dose results were orders of magnitude below the 25 mrem/yr dose limit, adjustments of the approximations involved in the NUREG-1640 scenarios are unlikely to cause the estimated doses to exceed the dose limit. Therefore, the NRC staff determined this approach was adequate for demonstrating volumetrically contaminated steel at the site would meet the 25 mrem/yr unrestricted release limit in these alternate scenarios.

5. Conclusions

The NRC staff previously reviewed the licensee's approach of developing one set of DCGL values for surface contamination and another set of DCGL values that accounted for both surface and volumetric contamination and found the approach to be acceptable [ML14189A111]. The NRC staff reviewed the licensee's selection of DCGL values for total and removable contamination in areas without volumetric contamination and found the proposed $DCGL_{Total}$ values to be acceptable for areas with surface contamination only. The NRC staff also previously reviewed the proposed DCGL values for areas with both surface and volumetric contamination, and concluded that they would limit doses to below 25 mrem/yr in a building occupancy scenario. The NRC staff agreed with the licensee's conclusion that the residual contamination in concrete at the site is not expected to exceed the dose limit in alternate scenarios, including building renovation, demolition, recycling, and disposal. However, PAB staff previously found additional characterization was needed to determine the potential dose from residual radioactivity in metal in the cyclotron vault in these alternate scenarios [ML14189A111]. The new information submitted by the licensee addressed only the projected dose from the remaining steel at the site in these alternate scenarios.

The NRC staff reviewed the licensee's measured concentrations of Co-60 and Mn-54 in a piece of rebar taken from 5 to 10 cm (2 to 4 inches) below a target area. The NRC staff agreed this was an acceptable sample location. PAB staff duplicated the licensee's calculation of the ratios Fe-55 and Ni-63 to Co-60 (Table 1). PAB staff found the approximations used to develop the Fe-55 and Ni-63 source term in Table 2 based on the measured Co-60 values to be acceptable.

The NRC staff verified the licensee's selection of the scrap yard scenario as the limiting alternative scenario in NUREG-1640 and duplicated the licensee's projected dose based on (1) the pathway dose conversion factors in NUREG-1640 (2) consideration of the amount of steel left in the cyclotron room, and (3) the measured and calculated concentrations of Co-60, Mn-54, Fe-55, and Ni-63. Although the calculations in NUREG-1640 involve many approximations, because the dose results were orders of magnitude below the 25 mrem/yr dose limit, adjustments of the approximations involved in the NUREG-1640 scenarios are unlikely to cause the estimated doses to exceed the dose limit.

Therefore, based on the new information presented by the licensee [ML14260A125] in combination with the PAB staff's previous review [ML14189A111], the PAB staff concludes the licensee's proposed DGCL values are acceptable based on the building occupancy scenario and the residual radioactivity at the site is not expected to exceed the dose limit in alternate scenarios, including building renovation, demolition, recycling, and disposal.

7. References

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