Technical Evaluation Report for Derived Concentration Guideline Level Supporting a License Amendment Request for Release of Room 101, Building 4707, Marshall Space Flight Center National Aeronautics and Space Administration

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SUMMARY

Nuclear Material Safety and Safeguards (NMSS) staff agrees with the Region I recommendation to accept the derived concentration guideline level (DCGL) that the National Aeronautics and Space Administration (NASA) used to demonstrate decontamination of Room 101 in Building 4707 at the Marshall Space Flight Center (MSFC) because independent calculations by NMSS staff did not change the outcome of NASA's demonstration of decontamination.

Although the licensee's calculated DCGL omitted the contribution of uranium (U) U-234, which is enriched more than U-235 during enrichment by gaseous diffusion, revising the calculation to account for U-234 caused only a small decrease in the calculated screening DCGL (i.e., approximately 10 percent [%]). Nuclear Regulatory Commission (NRC) staff determined that a 10% decrease in the DCGL would not affect the outcome of NASA's demonstration of decontamination or the adequacy of the minimum detectable concentration (MDC) values NASA used. Furthermore, the conservatism of the screening DCGLs provides additional assurance that a 10% decrease in the DCGL value would not affect reasonable assurance that the decontaminated room would meet the 0.25 millisievert per year (mSv/yr) (25 millirem per year [mrem/yr]) dose criterion in 10 CFR 20.1402 for unrestricted release.

BACKGROUND

NASA uses radioactive material at the MSFC, Huntsville, Alabama, under NRC Material License 01-06571-10. NASA previously used a direct current sintering furnace to consolidate low enriched uranium (LEU) and molybdenum into pellets in a portion of Room 101 in Building 4704. NASA no longer uses radioactive material in Room 101 and has decontaminated the radioactive materials area.

On June 13, 2024, NASA filed a license amendment request with NRC Region I to release Room 101 for unrestricted use. To demonstrate decontamination of building surfaces, NASA used a screening DCGL from Table 5.19 of NUREG-15512, vol. 3, "Residual Radioactive Contamination from Decommissioning Parameter Analysis Draft Report for Comment." NASA selected the value for U-238 without progeny corresponding to the 90th percentile projected dose of the screening calculation (i.e., 101 disintegrations per minute [dpm] per 100 centimeters squared [cm^2]). NASA established MDCs less than 50 percent (%) of the DCGL value and conducted a 100% scan of the radioactive materials area below 2 meters (6 feet) height. NASA used a 5-minute static alpha measurement on areas that exceeded the scanning threshold. NASA concluded that the radiation levels from all impacted and non-impacted building surfaces were less than the DCGL.

On May 13, 2024, Region I issued a request for additional information (RAI) asking, in part, for the technical basis for using a screening DCGL for depleted uranium for a room potentially contaminated with enriched uranium. Region I noted the generic screening DCGL for uranium-235 (U-235) and its decay chain (i.e., U-235 + C) from NUREG-5512, vol. 3, Table 5.19 is 1.48 dpm/100 cm^2) and asked whether including that value in a weighted average for would significantly change the DCGL. In response to that RAI, NASA indicated that it would be more appropriate to consider the screening DCGL for U-235 without the decay chain because the progeny would be removed during the enrichment process and would take 130,000 years to reestablish equilibrium with U-235. NASA indicated that, because the screening DCGL for U-235 without progeny is very similar to the screening DCGL for U-238 without progeny (i.e., 97.6 dpm/100 cm^2 for U-235 compared to 101 dpm/100 cm^2 for U-238), including the screening DCGL for U-235 in a weighted average would have a negligible effect on the calculated screening DCGL.

NASA used DandD Version 2.4 with default parameters to calculate a screening DCGL for high assay LEU (HALEU) with an assumed enrichment of 19.9%. NASA indicated that the use of 19.9% enrichment was conservative because NASA used uranium with a range of enrichments less than that value in Room 101. Based on that DandD calculation, NASA calculated a screening DCGL of 98.42 dpm/100 cm^2. NASA concluded that changing the DCGL value from 101 dpm/100 cm^2 to 98.42 dpm/100 cm^2 would not affect either (1) the MDCs used in the static alpha measurements or (2) the outcome that measured radioactivity on building surfaces was below the DCGL.

On Jul 18, 2024, Region I submitted a Technical Assistance Request (TAR) for staff in the Division of Decommissioning, Uranium Recovery, and Waste Programs in the Office of NMSS to assess the acceptability of NASA's use of a DCGL value of 101 dpm/100 cm^2.

REGULATORY REQUIREMENT

The applicable regulatory requirement is the 10 CFR 20.1402 criterion for unrestricted release:

> A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a total effective dose equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must consider any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.

DISCUSSION

NMSS staff considered three factors affecting the acceptability of the licensee's use of a DCGL based on the screening value for U-238 without its decay chain: (1) treatment of short-lived progeny, (2) consideration of U-234, and (3) implications of a revised DCGL for the completed static measurement methods and results.

Short-Lived Progeny

NMSS staff agree with the licensee's use of screening values without the entire decay chain (i.e., rather than the + C values in NUREG-5512 vol. 3) because impurities would be removed during enrichment. One short-lived child of U-235, thorium-241 (Th-241) (1.06 day half-life should be included in the DCGL because it would reestablish equilibrium with U-235 within several days and would therefore be expected to be present in Room 101. However, the effect of Th-231 on the DCGL is accounted for in screening values based on all-radionuclide doses calculated with DandD because DandD uses an exposure time of one year, so equilibrium with Th-231 is included for essentially all the exposure time. Therefore, no steps need to be taken to include consideration of Th-231 in the calculated screening DCGL if U-235 is included in the initial source term.

In addition, Th-234 (24.1 day half-life) and its short-lived progeny protactinium-234m (Pa-234m) (1.16 minute half-life) and Pa-234 (6.70 hour half-life) would also be expected to be present in Room 101 due to ingrowth from U-238. Because of the 24.1 day half-life of Th-234, those radionuclides would grow in over months and would not be at equilibrium for a significant fraction of the DandD 1-year modeled exposure time. To assess the impact of neglecting the initial concentration of Th-234 and its short-lived progeny on the calculated screening DCGL, NMSS staff replicated the DandD calculation NASA provided with its RAI response and then performed a sensitivity analysis with an initial Th-234 activity concentration in equilibrium with U-238. NMSS staff found that adding an initial concentration of Th-234 did not change the calculated screening DCGL.

The insensitivity of the projected dose to inclusion of an initial concentration of Th-234 can be attributed to two factors. First, Th-234 and Pa-234m have much lower dose conversion factors compared to U-238. Second, although Pa-234 has larger direct exposure dose conversion factors than U-238, it is produced with a very low branching factor (i.e., 0.002) and has much lower ingestion and inhalation dose conversion factors than U-238. Because explicitly accounting for ingrowth of Th-234 and its short-lived progeny did not change the dose projected by DandD, no steps need to be taken to include those radionuclides in the screening DCGL calculation.

Uranium-234

The NMSS staff agrees with the Region I basis for requesting that NASA use a weighted average of relevant uranium isotopes to establish a DCGL for Room 101. As discussed in the Department of Energy (DOE) Standard DOE-STD-1136-2000, "Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities," gaseous diffusion enriches U-234 to a greater extent than U-235. The following empirical formula from 10 CFR Part 20 Appendix B, footnote 3, provides an approximate specific activity of a mixture of uranium isotopes enriched (or depleted) by gaseous diffusion:

$$Specific\ Activity = 10^{-6} \times (0.4 + 0.38E + 0.0034E^2) \qquad \text{Equation 1}$$

where specific activity (SA) is in curies per g (Ci/g) and E is the mass percent enrichment of U-235 (expressed as a percent).

In its RAI response, NASA indicated that modeling the residual radioactivity as high assay LEU (HALEU) would be a conservative upper bound of the enrichment of the uranium used in Room 101. NMSS staff calculated the relative activities of U-234, U-235, and U-238 in uranium enriched by gaseous diffusion to 20% U-235 by mass in four steps:

1. Calculate the total activity of the mixture with Equation 1 using E = 20.
2. Calculate the activity contributions of U-235 and U-238 by multiplying the specific activities of the isotopes (i.e., 2.16×10^{-6} Ci/g and 3.36×10^{-7} Ci/g) by their mass fractions in the mixture. For U-235, the mass fraction is 0.20 because of the chosen 20% enrichment. Uranium-238 can be assumed to account for the remaining mass (i.e., a mass fraction of 0.80) because the mass contribution of U-234 in the mixture is negligible (<1%).
3. Find the activity contribution of U-234 by subtracting the activity contributions of U-235 and U-238 calculated in step 2 from the total SA calculated in step 1.
4. Find the fractional contributions of each isotope to the SA by dividing each individual contribution by the total SA calculated in step 1.

That calculation resulted in relative activities of 92.5% U-234, 4.62% U-235, and 2.97% U-238. Repeating that calculation for values of E from 0 to 1 result in Figure 1 (below), in agreement with DOE-STD-1136-2000, Figure 2-2.

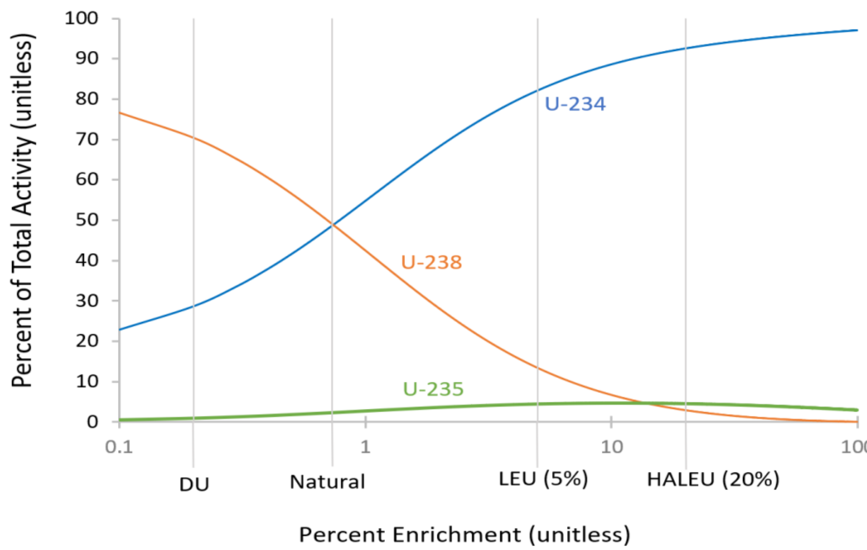

Figure 1 Percent contributions of uranium isotopes to total activity as a function of uranium enrichment by gaseous diffusion (adapted from DOE-STD-1136-2000, Figure 2-2)

To assess the impact of including U-234 activity on the calculated screening DCGL, the staff used DandD Version 2.4 with default parameters and an initial activity concentration of 1 dpm/100 cm^2 split among the uranium isotopes in the relative abundances calculated above (i.e., 0.925 dpm/100 cm^2 U-234, 0.462 dpm/100 cm^2 U-235, and 0.297 dpm/100 cm^2 U-238). That model calculation resulted in a projected dose of 0.275 mrem/yr per 1 dpm/100 cm^2. Normalizing to the release criterion of 0.25 mSv/yr (25 mrem/yr) resulted in a calculated DCGL of 90.9 dpm/100 cm^2. That value is only slightly higher than the screening DCGL for U-234 without progeny in Table 5.19 of NUREG-5512 vol. 3 (i.e., 90.6 dpm/100 cm^2), which is reasonable for an isotopic mixture dominated by the activity of U-234.

<u>Implications of a Revised DCGL for the Measurement Methods and Results</u>

To assess the acceptability of the licensee's use of a DCGL of 101 dpm/100 cm^2, NMSS staff compared the MDCs and static alpha mesurement results to the lower MDC of 90.9 dpm/100 cm^2 that the NMSS staff calculated considering contributions of U-234, U-235, and U-238. Table 3-1 of NASA's RAI response (ML24199A120) indicates the 5-minute static total MDC for alpha detection ranged from 28 dpm/100 cm^2 to 37 dpm/100 cm^2 over three replicates. The mean value of 32.7 dpm/100 cm^2 is 32% of the original DCGL of 101 dpm/100 cm^2 and 36% of the DCGL calculated by NMSS staff of 37 dpm/100 cm^2. The NMSS staff determined that the difference between an MDC at 36% of the DCGL compared to 32% of the DCGL does not affect reasonable assurance that the licensee could reliably detect residual radioactivity at or above the DCGL.

Appendix A of NASA's license amendment request (ML24089A060) provides static measurements for the impacted and non-impacted areas[1] of Room 101. None of the alpha static measurements on the impacted floor or walls exceeded the revised DCGL (90.9 dpm/100 cm^2) and none of the wipes for removable contamination exceeded 10% of the DCGL value. In the non-impacted areas, one floor location exceeded both NASA's original DCGL and the revised DCGL calculated in this report with an alpha static scan result of 114 dpm/100 cm^2. However, in its license amendment request NASA indicated that that reading was attributable to a building material with a high concentration of naturally occurring radioactivity (NORM). Because (1) none of the alpha static measurements that could not be attributed to NORM exceeded the revised screening DCGL calculated in this report and (2) none of the wipes for removable contamination exceeded 10% of that value, changing the DCGL would not change the results of NASA's compliance demonstration.

CONCLUSION

NMSS staff agrees with the Region I recommendation to accept NASA's demonstration of decontamination based on the screening DCGL of 101 dpm/100 cm^2 because a slightly lower revised screening DCGL that accounts for U-234 did not change the acceptability of NASA's MDCs or static measurements. NMSS staff agrees with the licensee's choice to use screening values without the decay chain (i.e., rather than the "+ C" values in NUREG-5512 vol. 3

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[1] Appendix A also provides measurements for equipment and materials, which this response does not address because those measurements were compared to different DCGLs that were not part of the TAR.

Table 5.19) because (1) impurities would be removed during enrichment and (2) NMSS staff verified that including the short-lived progeny that would reestablish equilibrium during the period of use of radioactive material in Room 101 did not change the calculated screening DCGL. Furthermore, the conservatism of the DandD calculations used to develop the screening DCGLs provides additional assurance that a 10% decrease in the DCGL would not affect reasonable assurance that the decontaminated room would meet the 0.25 millisievert per year (mSv/yr) (25 millirem per year [mrem/yr]) dose criterion in 10 CFR 20.1402 for unrestricted release.

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