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Considerations for Using FGE Conversion Factors in Type A Shipping Packages at the Savannah River Site

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INTRODUCTION

Contact Handled-Transuranic Waste Authorized Methods for Payload Control (CH-TRAMPAC) conversion factors are typically used as fissile gram equivalent (FGE) values in systems such as transuranic waste at the Savannah River Site (SRS). Publicly available technical justifications for CH-TRAMPAC conversion factors are lacking. Special considerations are needed to justify the use of the CH-TRAMPAC conversion factor for ^{235}U to ^{239}Pu, over the full range of Pu and U densities for Type A shipping packages in the K-Area Complex (KAC) at SRS. It is important to understand the limitations and the area of applicability for using these conversion factors.

FGE CONVERSION FACTORS

The purpose of FGE conversion factors is to determine the mass of nuclide A that yields the equivalent multiplication in an identical system containing nuclide B. Table 3.1-2 of CH-TRAMPAC lists the FGE ^{239}Pu conversion factors for many radionuclides. For ^{235}U, the conversion factor is 0.643. This means 1 g ^{235}U = 0.643 FGE ^{239}Pu = 0.643 g ^{239}Pu. In a given system, 1 g ^{235}U should result in the same system multiplication as 0.643 g ^{239}Pu. This conversion factor is based on a ratio of subcritical mass limits from ANS-8.1 or ANS-8.15, depending on the isotope.

Potential Non-Conservatism

A potential non-conservatism in the CH-TRAMPAC conversion factors can be seen when the critical mass is plotted vs. concentration. CritView was used to generate a plot for reflected critical spheres of ^{239}Pu and ^{235}U. The concentration region of concern is shown in the red box in Figure 1. The red box spans from ~0.05 g/cc to ~4.0 g/cc. In this region, a conversion factor close to 1.0 (meaning 1 g ^{239}Pu ≈ 1 g ^{235}U) would be more appropriate than the CH-TRAMPAC conversion factor. Additional justification is needed to demonstrate this region is not a concern for Type A shipping packages in KAC.

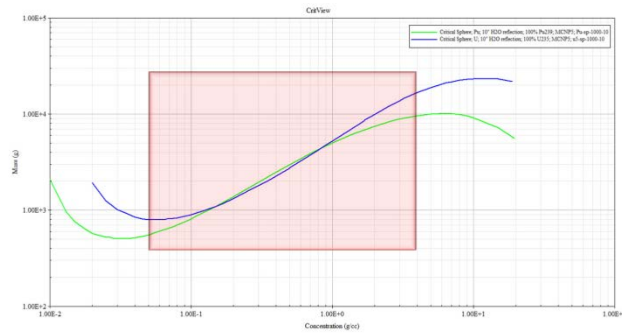

Fig. 1. Critical Mass of Reflected Spheres of Pu and U

Since the configurations from Figure 1 are fissile/water mixtures, the concentration can be converted to H/X values. When this is done, the H/X values in the region of concern are ~530 on the left side of the red box to ~5 on the right side of the red box.

Mass Considerations

The lowest point on the Pu curve in Figure 1 is greater than 500 g ^{239}Pu . If the mass of the fissile unit in question is less than or equal to 500 g ^{239}Pu, then converting that mass to ^{235}U (using the FGE conversion factors from CH-TRAMPAC) will always yield a value less than 780 g ^{235}U. This is less than the lowest point on the U curve in Figure 1, which is greater than 790 g ^{235}U. Therefore, if a fissile unit has less than or equal to 500 g ^{239}Pu, regardless of the concentration or density, it is acceptable to use CH-TRAMPAC conversion factors.

Interaction Considerations

CH-TRAMPAC conversion factors are based on ANS-8.1 and ANS-8.15 subcritical solution limits, which are applicable to single units that are optimally moderated and fully reflected. However, the material present in KAC exists in large arrays, which differ from the individual unit represented by Figure 1. Limits from ANS-8.1 and ANS-8.15 do not apply to arrays, and this further calls into question the usage of conversion factors based on ANS-8.1 or ANS-8.15 subcritical limits for single units (i.e., CH-TRAMPAC conversion factors).

If two systems are modeled that are identical except for a mass difference equal to the mass calculated using the CH-TRAMPAC conversion factors, then the system multiplication should be the same. One KAC Nuclear Criticality Safety Evaluation tested this hypothesis. That Evaluation includes calculations showing that large arrays of 60 - 90 collocated downblend cans with 190 FGE ^{239}Pu each is safely subcritical, regardless of if the fissile material is modeled as 190 g ^{239}Pu or 295 g ^{235}U (using the 0.643 CH-TRAMPAC conversion factor). In some cases, the ^{235}U results had up to 2% higher multiplication than the ^{239}Pu results. Even with this large collocation of material, the largest impact seen from using CH-TRAMPAC conversion factors is a 2% increase in multiplication.

Although there was an increase in system multiplication for some cases, all cases were still significantly subcritical. If the results from the downblend can study are applied to Type A shipping packages, a 2% increase in multiplication will not cause any case (single package, normal array, or upset array) to challenge system limits.

Moderation Considerations

There is one Type A shipping package used in KAC that may contain more than 500 FGE ^{239}Pu and requires additional justification for using CH-TRAMPAC FGE conversion factors. The Standard Waste Box (SWB) has an upset mass of 650 FGE ^{239}Pu, and the above discussion is not directly applicable to SWBs. Due to the large volume of an SWB, if the mass was evenly distributed, the density would be ~0.0005 g/cc, which is two orders of magnitude outside of the region of concern in Figure 1. Also, the H/X of the normal condition SWB that is modeled in the calculation is ~100,000, which is over two orders of magnitude outside of the region of concern from an H/X perspective in Figure 1. The upset condition for SWBs considers the configuration of the mass being in a more compact geometry by shrinking the SWB to the size of a 35-gallon drum. In this highly conservative model, the H/X value is ~7,000, which is still over an order of magnitude outside the region of concern from an H/X perspective in Figure 1. This provides a basis for why SWBs are not in the region of concern and CH-TRAMPAC conversion factors may be used for SWBs.

CONCLUSION

Since technical justification for CH-TRAMPAC conversion factors is not available from CH-TRAMPAC, special consideration was given to the use of FGE conversion factors for Type A shipping packages in KAC. These considerations include examining the mass, interaction, and moderation of the various systems, and justification was provided for each example. Therefore, it is reasonable to use CH-TRAMPAC conversion factors for FGE for all Type A shipping packages analyzed for use in KAC. Other systems and configurations may warrant other conversion factors.

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