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Derivation of Updated ^{238}Pu Subcritical Limits for ANS-8.15

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Subcritical limits for the non-fissile but fissionable nuclide, ^{238}Pu, contained in ANS-8.15-1981, *American National Standard for Nuclear Criticality Control of Special Actinides Elements*, were derived based upon the codes and nuclear data sets available at the time[1,2] and the sparse experimental data from a few ^{238}Pu replacement experiments.[3,4]

In support of the ANS-8.15 working group, updated critical mass estimates and subcritical limits have been derived for ^{238}Pu. Updated critical mass estimates were generated using several combinations of computer codes and current nuclear data sets.[5] The code and nuclear data set combinations are given in Table 1. These updated critical mass estimates serve as the basis for development of new subcritical limits for ^{238}Pu.

^{238}Pu subcritical limits were developed for both metal and oxide systems. For each system, bare, water reflected (30 cm), and 304 stainless steel reflected (30 cm) subcritical limits were derived. The general method of developing the subcritical limits follows:

- The critical mass estimates were reviewed for consistency in modeling metal and oxide systems. For example, the MCNP4b/JENDL-3.2 metal results were discarded based on the Working Group review. Subsequent checking of the data set by the Japanese identified improvements that will be incorporated into the next version of the data set.

- The most conservative (i.e., smallest) critical mass estimate for each case from the suite of code/nuclear data sets from Ref. 5 was identified.

- An appropriately conservative safety factor was applied to transform each critical mass to a subcritical limit. For ^{238}Pu, the mass reduction safety factor was 0.7, which generally corresponds to k_{eff} = 0.9 for the systems under consideration. Given the very limited experimental data available and the spread in the critical mass estimates for the several code/nuclear data set combinations, the safety factor of 0.7 is reasonable. Subcritical limit values were specified to two significant figures, rounded down.

- After application of the safety factor, each subcritical limit was reviewed by the working group. In one case, additional conservatism was applied as shown in Table 2.

Table 2 provides the smallest calculated critical mass from Ref. 5 for each unmoderated core of interest along with the corresponding subcritical limit.

With regard to moderated systems, Section 6.1 of ANS-8.15-1981 describes a subcritical limit for PuO_2–H_2O mixtures, regardless of the H/Pu atomic ratio. This subcritical limit applies to systems in which the primary plutonium isotope is ^{238}Pu; the remainder is assumed to be ^{239}Pu. The proposed updated subcritical limit for such PuO_2–H_2O mixtures is 9.5 kg total Pu, provided there is at least 68 wt % ^{238}Pu (Ref. 5).

Table 1. Code and nuclear data set combinations used to calculate updated critical mass estimates for ^{238}Pu

SCALE4.3; KENO V.a with ENDF/B-V, 238-group cross sections;
MCNP4b with ENDF/B-V continuous cross sections;
MCNP4b with ENDF/B-VI continuous cross sections;
MCNP4b with JENDL-3.2 continuous cross sections;
MONK7B with UKNDL 8220 group cross sections;
MONK7B with JEF-2.2 13193 group cross sections;
DANTSYS 3.0 with ENDF/B-V 238 group cross sections.

Table 2. Dry-core critical masses and corresponding subcritical limits for ^{238}Pu

	Bare	Water reflected*	304 Stainless steel reflected*
^{238}Pu metal (kg)			
Critical mass	9.04	7.29	4.72
Subcritical limit	6.3	5.1	3.3
^{238}Pu oxide (kg)			
Critical mass	23.93	19.26	10.81
Subcritical limit	16.0	12.0**	7.6

* 30 cm reflectors

** After discussion among working group members, this value was reduced from 13.0 to 12.0 kg to provide additional conservatism.

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