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by Deuterium Oxide

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Critical Mass Analysis for ^{235}U and ^{239}Pu Systems Moderated and Reflected by D_2O

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1. Introduction

Criticality dimensions for highly enriched $^{235}\text{U}(93.5)$ and $^{239}\text{Pu}(95.5)$ systems mixed with D_2O were studied. The objective of this work is to investigate the minimum critical mass and concentration of uranium and plutonium systems in a reflector-moderated arrangement. The present work demonstrates the critical instability of these systems that are moderated and reflected by D_2O and expands in previous unpublished work.¹ These calculations were performed in a spherical geometry with the DANTS² codes using the Hansen-Roach cross section library. Densities examined ranged from normal to very small, and are assumed to be uniform throughout the core. These spherical systems are reflected by 100 cm of D_2O .

2. Method

The calculations for this work were done using the ONEDANT deterministic transport code. Several input parameters were analyzed to adequately characterize the systems. Small, fine mesh points were used to ensure that all interactions in the fissionable material were accounted for. This means that the fine mesh points were smaller than the mean free path of neutrons in the material. The dependence in the order of quadrature was also analyzed. Because the systems investigated in this work are small, special attention was given to the order of quadrature. Parametric analysis showed that a Sn value of 8 was enough for our problem without compromising the results. Since the fissionable isotopes were mixed with neutron moderating material, the adequate potential scattering cross sections for resonance self-shielding were calculated.

3. Results

The results are presented in Figures 1 and 2. Figure 1 shows the critical mass curve for a sphere with pure ^{235}U and the curve for a spherical ^{235}U system mixed with D_2O . The fissile density is reduced from normal densities to gaseous densities. It is worth noting that as the density is decreased the critical mass decreases to a minimum value, but as the fissile material density continues to decrease, the critical mass of the system increases. This type of behavior is known as criticality unstable. The critical mass of the system will continue to increase until the external reflector becomes too thin due to the increase of temperature.

The minimum critical mass for a pure ^{235}U system is 1.29 kg with a 100 cm D_2O reflector. For confirmation purposes the pure ^{235}U calculations were compared to previously unpublished data¹ and no differences were observed between the two computations. The critical mass for the D_2O mixed system is 0.43 kg with a 100-cm reflector. This shows that deuterium is an excellent moderator. The deuterium in the core serves as a trap for neutrons; consequently, the neutrons are held in the core until their main energy has been reduced to thermal energies by the elastic scattering process. Since deuterium has a very small thermal absorption cross section, neutrons diffuse into the region of fissionable material to sustain a chain reaction. In addition, the D_2O reflector acts as a reflector and moderator with almost zero absorption, thus increasing the probability of neutrons interacting in the core, and decreasing probability of leakage.

Figure 2 shows the critical mass curves for a pure ^{239}Pu spherical system and for a system of ^{239}Pu mixed with deuterium. This figure exhibits characteristics similar to the uranium system. It is a critical unstable system and the critical mass of plutonium decreases with the addition of deuterium in the core. The core densities range from normal to gaseous. The minimum critical mass for the pure ^{239}Pu system is 0.86 kg while the plutonium-deuterium system has a minimum critical mass of 0.303 kg. Both systems have a 100-cm D_2O reflector.

4. Conclusions

Satisfactory results were obtained with the ONEDANT deterministic code for highly enriched systems. A tendency in the critical mass of uranium

and plutonium was observed with decreasing density. It was shown that deuterium is both an excellent moderator and reflector.

5. References

1. Los Alamos National laboratory, "User's Guide for TWODANT: A Code Package for Two-dimensional Diffusion-accelerated, Neutral-particle, Transport." Group X-6, LA-10049-M, Los Alamos, NM (1990).
2. W. Stratton and R. Roach, "Critical Mass Studies," Los Alamos National Laboratory Progress report, N-2-7716 (1963).

Critical Mass of U(93.5) Sphere in Kg

U235 and Pu-239 Sphere mixed in D20 with 100cm D20 Reflector