The Idea of "Dispersible" in Criticality Safety

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The purpose of this paper for the *Special Session on LLNL Plutonium Facility* is to provide a retrospective of work that was done to resolve a vexing problem involving the use of small plutonium parts where moderating materials were present. Limits were in place for solid parts and for homogeneously-mixed materials. The standard limit for moderated plutonium is 220 g in order to satisfy double-contingency requirements. Limits for non-moderated plutonium are much larger, normally at 2600 g. However, there was still a "gray" area involving small plutonium samples encased in moderating materials.

The concern was included in a 1978 memo from the chair of the Criticality Safety Committee:

> We have traditionally established fissile material mass limits for various work stations in two categories: "solid" and solution/dispersible." Periodically, questions have arisen as to the meaning of "dispersible" and these have been answered in the general sense. Two "misunderstandings" of the limits have occurred in recent years when metal cylinders of fairly small size have been placed in matrices of moderating material. A recent inspection of Bldg. 332 operations revealed they frequently handle 10-30 g plutonium parts under "solid" mass limits, but in moderator environments which perhaps are inappropriate. Though this problem is of long standing *it is one of the most important unresolved operational questions we face.*

We then embarked on a substantial computational study using neutron Monte Carlo tools available at the time. The very large number of computations required many weeks of effort but, finally, sufficient data were available to propose a workable definition of "dispersible" plutonium. This definition has served the facility ever since.

The calculations were done with the MORSE-C neutron Monte Carlo code with a 92-group cross-section set. The basic model was for spherical metal units inside cubic cells surrounded by interstitial water. The entire array was also cubic and surrounded by thick water. Parameters that were varied in the calculations included (a) the number of units, (b) unit mass, (c) unit spacing, (d) unit density, (e) unit shape, and (f) water moderator density.

The conclusion of the study was the following:

> An array of compact plutonium units, dry or fully immersed in water, is less reactive than an array of the same number of units in contact if the mass of each unit is 10 g or more. Therefore mass limits set for solid units can be applied to assemblages of smaller metal units if each exceeds 10 g, regardless of the degree of assemblage moderation.

It is obvious, of course, that reactivity enhancement is possible for arrays of metal units exceeding 10 g if the units are of non-compact shape, e.g., rods or disks. This concern was then addressed by MORSE-C calculations for assemblages of plutonium in the form of metal cylinders with interstitial water moderation. The total mass of the assemblage was kept at 2600 g (the facility limit for metal units). The number of units in the arrays was varied between 8 and 1000 and the unit separations were varied. It was found that if the cylinder aspect ratios were five-to-one or less, the arrays remained safely subcritical. Metal units meeting the five-to-one shape restriction were thus considered to be non-dispersible.

The definition of dispersible plutonium metal mass applied in Building 332 includes the following:

> Dispersible plutonium is: 1) any solid piece of plutonium containing material with a plutonium mass equal to or less than 10 grams, or 2) liquids or gases containing plutonium…box loss is considered as dispersible…dispersible examples include plutonium

oxide, solutions, or slurries, lathe turnings, and filings.

The dispersible plutonium definition has been in place at the facility for many years now and has served well for normal operations. We have never forgotten, however, that continued interaction of the facility personnel and the LLNL Criticality Safety Department will help ensure that special circumstances would be evaluated on a case-by-case basis.

Details of the dispersible definition computations were summarized for the summer meeting of the American Nuclear Society in 1980 [1]. A more thorough study of the effect of moderation on small metal-unit arrays for plutonium and uranium units was presented more recently by Koponen [2] at the Chelan, Washington topical ANS meeting in 1997.

REFERENCES

1. B. L. KOPONEN, "Criticality of Water-Moderated and –Reflected Plutonium Arrays," *Trans. Am. Nucl. Soc.*, **34**, 327-328 (1980).

2. B. L. KOPONEN, "An Examination of Parameters Affecting Optimum Array Moderation," *American Nuclear Society Topical Meeting on Criticality Safety Challenges in the Next Decade*, Chelan, Washington, September 7-11, 1997, American Nuclear Society (1997).