# Lawrence Livermore National Laboratory

# The Idea of "Dispersible" in Criticality Safety

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# The LLNL Dispersible Definition

- Any solid piece of plutonium containing material with a plutonium mass equal to or less than 10 grams, or
- Liquids or gases containing plutonium…box loss is considered as dispersible.
- Dispersible examples include plutonium oxide, solutions, or slurries, lathe turnings, and filings.

# A Brief Background

- Limits were in place for solid parts and for homogeneously-mixed materials.
- The standard limit for many years for moderated plutonium was 220 g.
- The facility limit for non-moderated plutonium was set for many years at 2600 g. Operations with larger parts require special study.
- However, there was still a “gray” area involving small plutonium samples encased in moderating material.

# The Dispersible Issue Came to Light in 1978

- "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.

# Addressing the Problem

- A computational study was done to determine the unit mass value at which an array of small, moderated, units would be of concern
- 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.

# Results of the Study

- 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, compact, metal units if each exceeds 10 g, regardless of the degree of assemblage moderation.

# There Was Still a Concern for Large Surface Area Parts

- Parts larger than 10 g could be handled under the 2600 gram assemblage limit…
- …but there was still a concern, i.e., larger-than-10 g pieces that have shapes that expose large surface areas to thermal neutrons.
- Calculations for such parts showed that shape factor of the parts did not exceed five, the 2600 g limit could be used.

# There Was Still a Concern

- Unfortunately, the shape-factor limit was not fully adequate.
- The facility occasionally handled a few large parts where it was obvious that they did not comprise an array that needed to be considered dispersible.
- We have recently explored what might be a better approach.

# Calculations for Non-Compact Shapes

- The $k_{eff}$ of a water-reflected 2600 g alpha-plutonium sphere is about 0.8.
- If the 2600 g sphere is separated into smaller spherical pieces, exceeding 10 g each, the $k_{eff}$ will remain under 0.8.
- If a group of larger-than-10-gram pieces are stretched, flattened, or otherwise changed, and interstitial neutron-moderating material is present, there is a potential for *reactivity enhancement*.
- The surface area of plutonium exposed to thermal neutrons shall be controlled such that the reactivity of an array will not exceed that of a solid 2600 g sphere.

# Monte Carlo Calculations for Water-Moderated and –Reflected Cubic Arrays of Plutonium Metal Disks with D/H=5

| Number of Units | Unit Mass (g) | Array Mass (g) | Surface Area of Plutonium in Assembly ($cm^2$) | Cell Width for Maximum $k_{eff}$ (cm) | Maximum $k_{eff}$ |
|---|---|---|---|---|---|
| 8 | 325 | 2600 | 392 | 6 | **0.62** |
| 27 | 96 | 2592 | 586 | 5 | **0.60** |
| 64 | 41 | 2625 | 788 | 4 | **0.65** |
| 125 | 21 | 2625 | 985 | 3 | **0.73** |
| 343 | 8 | 2744 | 1420 | 2 | **0.78** |

# Possible Extension of Dispersible Definition for Non-Compact Units Exceeding 10 g

- A 2600 g array of water-moderated and reflected plutonium metal parts with a surface area equal to, or less than, 1420 $cm^2$ is less reactive than a solid 2600-gram, water-reflected, alpha-phase plutonium sphere.
- A possible extension of the dispersible definition is:

  **An array of plutonium metal parts with a total surface area exceeding 1420 $cm^2$ is limited to a total mass of 220 grams of plutonium. Such arrays are considered to be comprised of dispersible parts.**

- A variety of shapes could be evaluated simply by determining the area of plutonium exposed to thermal neutrons.


Thank You For
Your Attention