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A NEW PLUTONIUM BUTTON STORAGE ARRANGEMENT

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A NEW PLUTONIUM BUTTON STORAGE ARRANGEMENT

The largest known near cubic array of plutonium ingots, called buttons, has recently been assembled at Hanford and the loading of a slightly larger array is in progress. This paper is a report on the methods used to analyze these new vault arrangements for criticality prevention.

The Atomic Energy Commission's Chemical Separations complex, operated by the Atlantic Richfield Hanford Company, has been designated a repository for plutonium. As a result of this action, additional plutonium storage at small cost was required. Although this storage facility readily meets safety and economic requirements, it is not presented as an ideal plutonium vault design due to rather high radiation dose rates.

When the problem of storage was presented, an initial calculation using the density analogue method indicated that the existing Hanford Button spacing of 18 inches center to center (ctc) could be considerably decreased and still remain within the then existing ARHCO safety criteria⁽¹⁾ of one half of a critical array in the worst foreseeable conditions. The safety criteria has since been changed to read, "The permitted array shall have a k-effective no greater than 0.98 under the worst foreseeable conditions. Double batching of a single unit in the array must not exceed the designated k-effective."

Calculations to determine the critical array size were then made using the United Kingdom Monte Carlo Code GEM 3⁽²⁾. The GEM code had been correlated with many different critical experiments. Some of these correlations have been reported in the interaction section of the ARHCO, Criticality Handbook⁽³⁾. Table I shows three of these correlations with Lawrence Radiation Laboratory experiments using 3 kg plutonium ingots in bare cubic arrays of 8, 27 and 64 pieces⁽⁴⁾. The table also includes the critical number of ingots calculated by the density analogue method and k-effectives calculated by the KENO⁽⁵⁾ Monte Carlo code. KENO was obtained after this study was completed but is included here to show the agreement between the codes. Note the good agreement of density analogue for these close packed bare arrays. In the GEM calculations, 50 stages of 100 neutrons were used and required 4 to 8 minutes running time of the IBM 7090 computer. The KENO calculations were made using 100 batches of 100 neutrons and required 2 to 5.5 minutes on the Univac 1108 computer.

To extrapolate from these experiments, the required spacings for bare critical arrays of 1000 and 8000 units were calculated using GEM. These calculated critical spacings, converted to array plutonium density are shown in the first figure. Extrapolations were also made using density analogue, Joe Thomas' modified density analogue⁽⁶⁾, and later when it became available, by KENO. While GEM, KENO and the Thomas method agree, the density analogue extrapolations deviate considerably, but in a conservative manner.

To abide with the safety criteria, the worst foreseeable conditions expected in the vault were used as the basis for the GEM calculations; these are:

- a. Maximum mass of plutonium per storage position, 2.5 kgs.
- b. Minimum ^{240}Pu content 3 Wt%.
- c. Maximum moderation - All voids contained 0.001 g/cm^3 water to simulate a $_{16}$ gal/min fire fog and four water columns at 1.0 g/cm^3 to simulate men working in the vault.
- d. To simulate reflection of the 8 and 9 inch thick concrete enclosures, an albedo of 0.78 was used to reduce computer time. This compares with the 0.75 concrete albedo proposed by the United Kingdom⁽⁷⁾.
- e. The plastic and steel contiguous to the buttons were considered to be 0.05 and 0.125 inches thick respectively.
- f. The steel supporting structure was ignored.

The safety criteria requires that a double batch in the array will not exceed a k of 0.98, and this was also considered in the final calculations. The Δk of a double stacked button in the final array was only slightly greater than the standard deviation of the calculation.

Buttons in the vault were arranged to give maximum storage at minimum cost. Ease of accessibility dictated that the arrangement be double rows with 24-inch access aisles on each side. Calculations were made for vault arrangements with the double rows running both lengthwise and crosswise of the vault.

The second figure shows the GEM k-effective calculations with standard deviation flags and least square fits for three vault arrangements. The length, width and height spacings shown are for the ctc distance between the buttons. Orientation of the double rows is indicated by the two dimensions showing distance between the double rows and between rows in the double rows. To obtain the critical array, rows of buttons were added to the sides and top of the array keeping the corresponding reflector at a constant distance from the buttons so that the array and the vault approached a cube.

These calculations were made using 150 stages of 150 neutrons and required 17 to 25 minutes of computer time. The deviation in the critical number (of 2500 buttons in the second array indicated by hexagonal symbols) is estimated to be ± 200 buttons at a 95 percent confidence level.

Although this crosswise 9-inch spacing gave a larger critical array, operational and design personnel preferred the lengthwise 9-inch spacing with a critical size of 2200 buttons. The selected arrangement is shown in Figure 3. This arrangement of 1092 buttons has three double rows separated by 24 inches from each other and the concrete walls. Spacing between the buttons is 9 inches in the lengthwise direction and 12 inches between the buttons in the double rows and 12 inches vertically. The buttons are 12 inches from the floor and 18 inches from the ceiling. A 30-inch wide aisleway runs across the center of the vault. The three BF_3 detectors used during vault loading are also shown.

The fourth figure, a photograph taken in the center aisle looking toward the end of the loaded vault, shows details of the construction. The button supports are made of 0.25 by 1 inch bars, 4.25 inches in diameter. The supports are slightly tipped to prevent double stacking and the curved $3/8$ inch rod prevents taller oxide cans from tipping out of the holder. The supports are welded to 3-inch vertical channels that are in turn welded to steel bars attached to the walls and floor. Note that although the button supports are on 12-inch centers between the double rows the buttons are actually on 13.5-inch centers due to the slanted holders. These structural parts of the vault are designed to withstand any seismic activity of the severity expected in the Hanford Area.

Normal packaging of the buttons is shown in Figure 5. The button still inside a production hood is sealed into the aluminum can. For contamination control purposes, the canned

buttons are sealed into Polyvinyl Chloride sleeves as they are removed from the hoods. The bagged can is in turn placed into an aluminum foil nest before being sealed in the outer steel can. The buttons stored were of two types, 0.75 and 0.37 height-to-diameter ratio. Six percent of the buttons were under 2.0 kgs and 18 percent were slightly over 2.2 kgs. The average weight was 2.1 kgs, the average metal density 19.45 g/cm³, and the average ²⁴⁰Pu content 11 Wt%.

With the 1092 buttons loaded, the vault areal plutonium density was 8.7 kgs/ft² and the overall density 0.34 g/cm³, a 100 percent increase over existing Hanford vaults. Another slightly larger vault now being loaded will contain 1248 buttons with an areal density of 13.1 kg/ft² and 0.31 g/cm³ overall density.

Neutron counts and radiation dose rates were taken during vault loading. The loading started at the end near the BF₃ counters and proceeded lengthwise. The counting results are shown in Figure 6 both as inverse countrate and buttons per countrate. Extrapolation of the inverse countrate indicates a critical array to be greater than 2600 2.1-kg buttons. This is in the same order of magnitude as the extrapolated GEM calculations that showed 2200 2.5-kg buttons critical. The N/CR plot indicates little neutron multiplication as does a GEM-calculated k-effective of 0.85 + .01 for the actual vault array using the average button weight, 12-inch ctc spacing between buttons in the double rows, and no interspersed moderation. The final vault dose rate was 550 mrem/hr including 150 mr/hr gamma which was considered acceptable because of infrequent access. It can be seen that in arrays of this size or greater where buttons are stored sequentially and dose rate readings taken at regular intervals that the dose rate will be the limiting factor.

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CALCULATIONAL CORRELATION TO LRL
3 KG PLUTONIUM INGOT BARE ARRAYS

LRL ARRAY	DENSITY ANALOG CRITICAL NUMBER	K-EFFECTIVE	
		GEM III	KENO
2 X 2 X 2	8	1.017 $\pm$.015	0.990 $\pm$.007
3 X 3 X 3	27	0.993 $\pm$.012	1.012 $\pm$.011
4 X 4 X 4	64	1.013 $\pm$.019	1.006 $\pm$.011

TABLE I

FIGURE I

FIGURE II

FINAL VAULT ARRANGEMENT

FIGURE III

FIGURE IV

PLUTONIUM BUTTON

ALUMINUM CAN

20 MIL PVC PLASTIC

ALUMINUM FOIL NEST

OUTER STEEL CAN

STANDARD PLUTONIUM PACKAGE

FIGURE V

FIGURE VI