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AEC Research and Development REPORT

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MONSANTO RESEARCH CORPORATION

A SUBSIDIARY OF MONSANTO COMPANY

MOUND LABORATORY

MIAMISBURG, OHIO

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ABSTRACT

Subcritical neutron multiplication determinations with seven SNAP 19C-2 heat sources containing plutonium-238 were performed at different array spacings in both an air and a water medium. The maximum neutron multiplication of 1.14 was obtained with seven SNAP 19C-2 heat sources completely water reflected in a 1/16-inch edge-to-edge planar array. The results from this experiment will provide information concerning the nuclear hazards associated with the future design of larger and more powerful heat sources containing plutonium-238.

SUMMARY

A sub-critical neutron multiplication experiment was performed with seven SNAP 19C-2 heat sources containing high isotopic analysis plutonium-238. The isotopic abundance of the plutonium was approximately 80% ^{238}Pu, 16% ^{239}Pu, 3% ^{240}Pu, and 1% ^{241}Pu.

The neutron multiplication measurements involved the placing of SNAP heat sources in regular arrays in a prescribed manner and determining by the neutron yield the degree to which the assembly multiplied neutrons. The neutron multiplication was determined in each experiment as a function of the different array spacings in both a water and an air medium. Based upon the results obtained in these experiments, the following conclusions were drawn:

(1) In general, the experimental results indicated that the neutron multiplication increased as the edge-to-edge spacing between heat sources was decreased in both the air and water media. These results indicated that a fast neutron critical system of plutonium-238 was more probable than a moderated system.

(2) In general, the neutron multiplication was significantly larger in the water medium than in the air medium. The array spacings were such that the water medium was more of a reflector than a moderator. These results show that the neutron multiplication of SNAP heat sources containing plutonium-238 can be enhanced by a reflector.

(3) A small neutron multiplication did exist with a cluster of SNAP heat sources. The maximum multiplication observed was approximately 1.14. The multiplication was not large enough to extrapolate to the critical size of clusters of heat sources containing plutonium-238.

(4) It was determined that neutron multiplication measurements in low multiplying configurations are valid only when the neutron scattering and reflecting characteristics of the heat source capsules have been corrected by the use of dummy capsules.

INTRODUCTION

The use of plutonium-238 as fuel for isotopic power generators and thrusters is being considered for more space, terrestrial, and oceanographic applications. Within the past two years the quantity of plutonium-238 has become large enough to be considered a potential nuclear criticality hazard. Only limited experimental criticality data have been obtained for plutonium-238 and, therefore, it is difficult to define reliable nuclear safety guides.

Mound Laboratory is engaged in the assembly of SNAP isotopic power heat sources containing large quantities of the enriched plutonium-238 isotope. To insure nuclear safety in the storage, processing, and assembly of devices containing plutonium-238, subcritical neutron multiplication experiments have been performed whenever significant quantities of plutonium-238 were available. These multiplication experiments were performed with the concurrence of the Operational Safety Division of the AEC's Albuquerque Operations Office.

The results of a subcritical neutron multiplication experiment with SNAP 19C-2 heat sources are discussed. The experiment was performed at different planar array spacings in both a water and an air medium. The data obtained in this experiment provide information which will be beneficial in establishing the following: the safe design parameters for future SNAP heat sources, that is, quantity of fuel and configuration of capsules; the number of encapsulated heat sources which may be assembled safely in a cluster; and the spacing required between capsules.

RESULTS AND DISCUSSION

A subcritical neutron multiplication experiment was performed with seven SNAP 19C-2 heat sources containing plutonium-238. The neutron multiplication was determined for three different array spacings in both a water and an air medium. The details are presented in the following sections.

NEUTRON MULTIPLICATION MEASUREMENTS WITH SEVEN SNAP 19C-2 HEAT SOURCES

Seven SNAP 19C-2 heat sources were assembled in different hexagonal planar arrays. The fuel in the SNAP 19C-2 sources is a metal alloy of plutonium and zirconium. The isotopic abundance of the plutonium was approximately 80% plutonium-238, 16% plutonium-239, 3% plutonium-240 and 1% plutonium-241. Six of the seven sources contained approximately 175 grams of plutonium-238; the seventh source contained approximately 292 grams of plutonium-238.

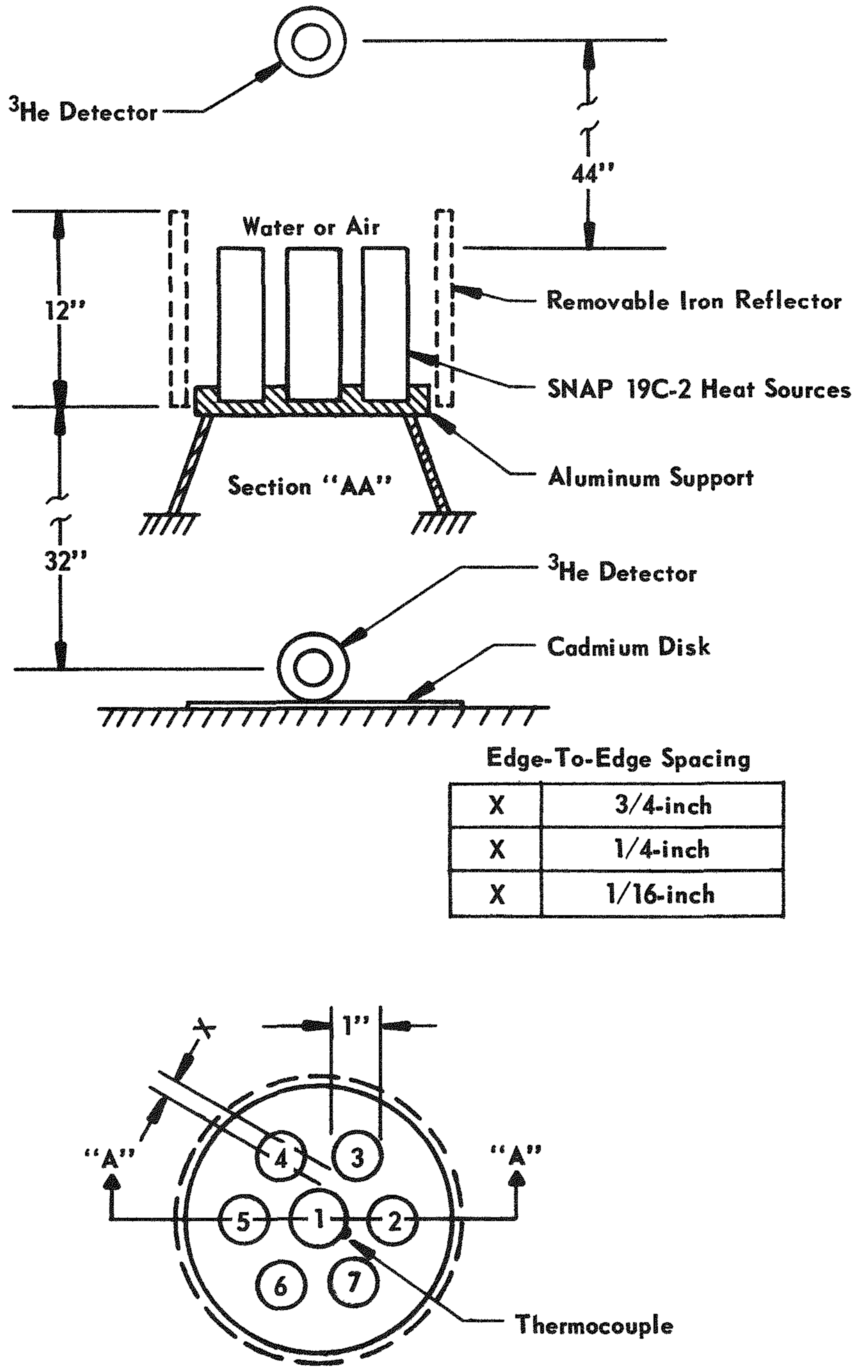
The neutron multiplication was determined independently for the three planar arrays with edge-to-edge spacings between heat sources of 3/4, 1/4, and 1/16-inch. Each array was evaluated in an air and a water medium. A schematic of the experimental arrangement is shown in Figure 1 and a laboratory photograph is shown in Figure 2. The experimental procedure and data obtained in each medium are discussed below:

Multiplication in an Air Medium An unmoderated, or, fast neutron critical system appears to be the most probable for the plutonium-238 isotope. A thermal neutron critical system does not appear likely because of the large thermal neutron capture cross-section and the small thermal fission cross section for plutonium-238. The experiment performed in air determined the neutron multiplication as a function of the quantity of plutonium-238 for different planar array spacings.

The neutron multiplication was first determined for the array with the largest spacing, and thus the safest geometry. The recorded neutron count rate of each heat source was measured individually in its array position with the helium-3 proportional detectors. Simulated capsules made of stainless steel pipe and filled with equivalent weights of lead shot were used in the array build up to correct for the neutron scattering and reflection characteristics of the heat source capsules. The heat sources were added one at a time, each to its unique preassigned location, to build up the array as the corresponding simulated capsule was removed. The neutron yield was measured with each increment of added source and a neutron multiplication calculated as follows:

$$M = \frac{\text{Recorded Count Rate - Background}}{\text{Accumulative Count Rate - Background}}$$

A plot of the neutron multiplication as a function of plutonium-238 for each array is shown in Figure 3. The multiplication plotted was the average of the two detectors and the error bars shown represent the approximate statistical error for each point. These results indicated that a small neutron multiplication existed in each array and the array of the smallest spacing (curve 3) showed the highest multiplication; that is, the array of 1/16-inch edge-to-edge spacing showed a maximum multiplication of 1.08.



Edge-To-Edge Spacing

X	3/4-inch
X	1/4-inch
X	1/16-inch

Figure 1. *Neutron Multiplication Experimental Arrangement for SNAP 19C-2 Heat Sources*

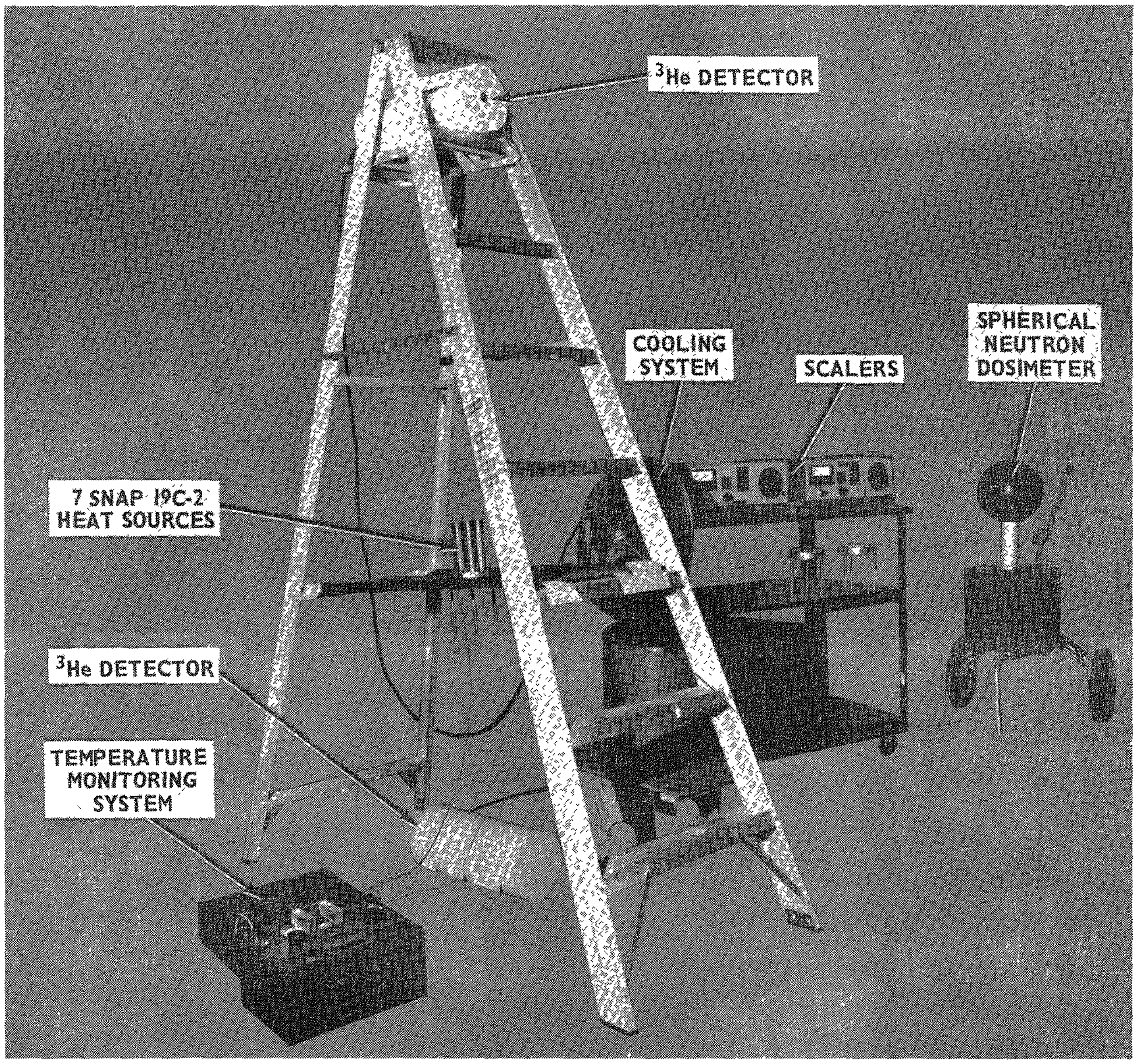


Figure 2. *Photograph of Neutron Multiplication Experiment with Seven SNAP 19C-2 Heat Sources*

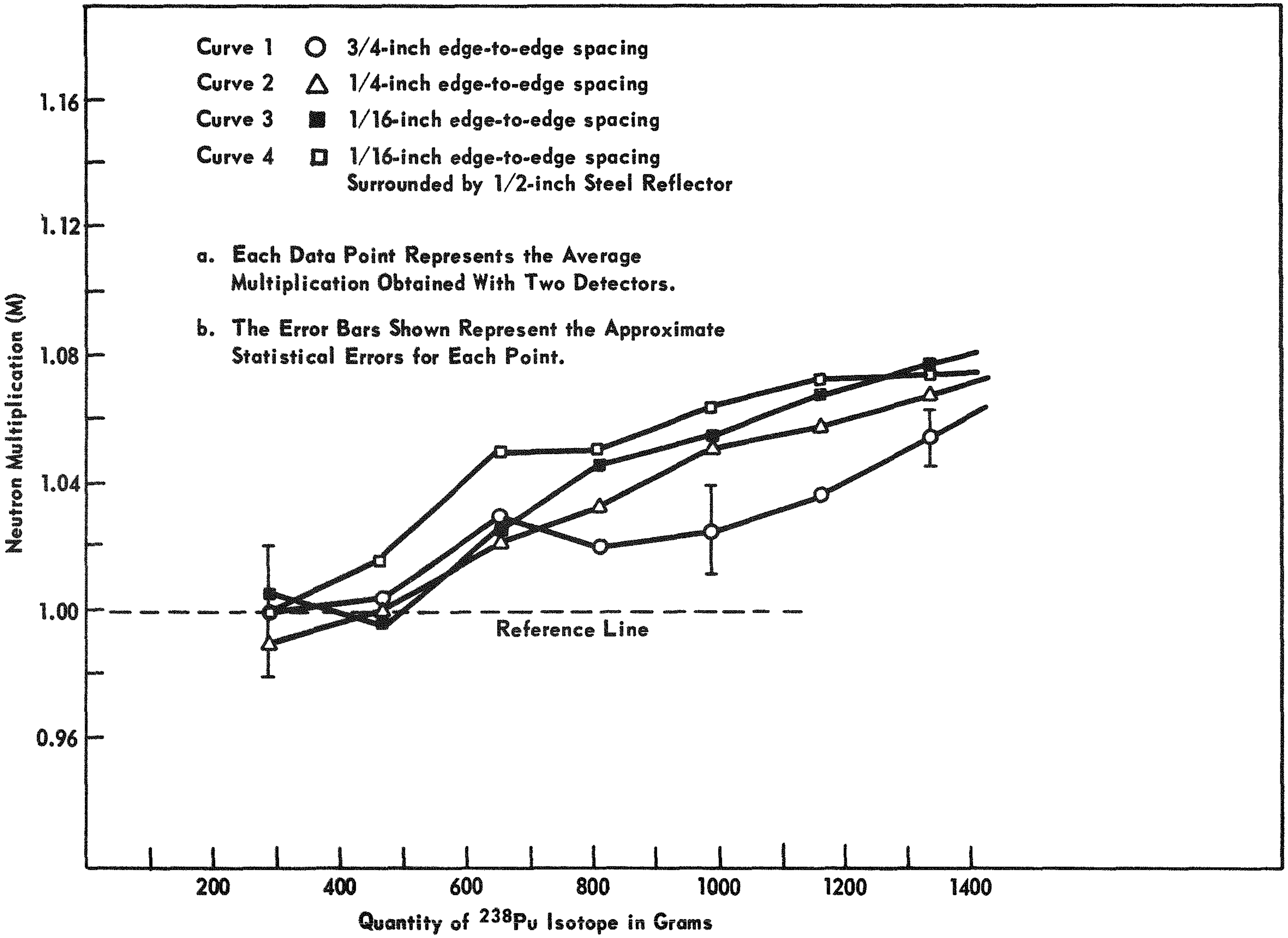


Figure 3. *Neutron Multiplication of Seven SNAP 19C-2 Heat Sources Containing Plutonium-238 Assembled in Different Planar Arrays in an Air Medium*

The effect of assembling the 1/16-inch spaced array surrounded by a 1/2-inch thick cylindrical steel reflector was investigated; no significant increase in the multiplication existed due to the presence of this "thin" reflector (curve 4). The 1/2-inch steel reflector was only two tenths of a mean free path for high energy neutrons and, therefore, was relatively thin and ineffective as a reflector for fast neutrons.

Multiplication in a Water Medium The purpose of the experiments in water was to determine whether the neutron multiplication would increase as the heat sources were brought closer together, thus changing the water medium properties from less moderation to more reflection.

The neutron multiplication for each array was determined in the same manner as described for the air measurements. A plot of the neutron multiplication as a function of plutonium-238 for each array is shown in Figure 4. Comparison of Figure 4 with Figure 3 indicates that an increase in the neutron multiplication was achieved in each array due to the addition of the water. That the maximum multiplication (approximately 1.14) existed in the closest array spacing (1/16-inch edge-to-edge spacing) shows the reflecting contribution of the water medium. Also, the increase in multiplication as the array spacing decreased, as shown in Figure 4, indicates that arrays containing plutonium-238 exhibit less multiplication in a moderating medium (curve 1, 3/4-inch edge-to-edge spacing) than in a fast medium (curve 3, 1/16-inch edge-to-edge spacing). Although the array with 3/4-inch spacings did not provide optimum moderation, some degree of moderation was achieved, and this resulted in a slight decrease in the neutron multiplication.

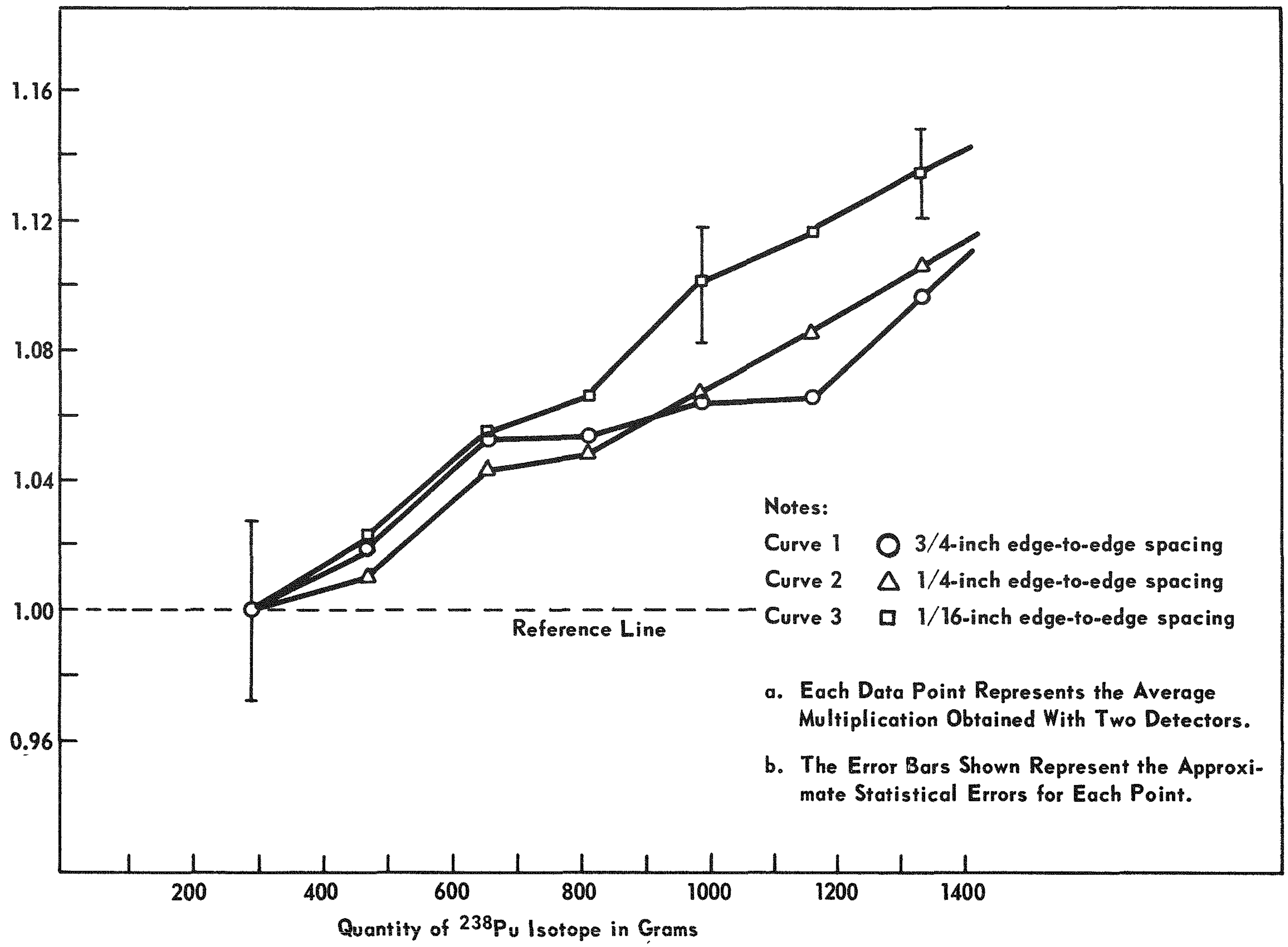


Figure 4. *Neutron Multiplication of Seven SNAP 19C-2 Heat Sources Containing Plutonium-238 Assembled in Different Planar Arrays in a Water Medium*

CONCLUSIONS

Based upon the results obtained in these experiments, the following conclusions were drawn:

1. In general, the neutron multiplication increased as the edge-to-edge spacing between heat sources was decreased in both the air and water media. These results indicated that a fast neutron critical system of plutonium-238 was more probable than a moderated system.

2. In general, the neutron multiplication was significantly higher in the water medium than in the air medium. The array spacings were such that the water medium was more of a reflector than a moderator. These results show that the neutron multiplication of SNAP heat sources containing plutonium-238 can be enhanced by a reflector.

3. A small neutron multiplication did exist with a cluster of SNAP heat sources. The maximum multiplication observed was approximately 1.14. The multiplication was not large enough to extrapolate to the critical size of clusters of heat sources containing plutonium-238.

4. It was determined that neutron multiplication measurements in low multiplying configurations are valid only when the neutron scattering and reflecting characteristics of the heat source capsules have been corrected by the use of dummy capsules.