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DISTRIBUTION OF PARTICLE SIZE FOUND IN BREATHING AIR AT HANFORD PLUTONIUM FABRICATION FACILITIES

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ABSTRACT

The nature of particles associated with breathing air is extremely important in the field of radiation protection. In a complete particle study, parameters such as particle size, mass, shape and chemical state should be measured. In characterizing these particles, it is desirable to relate, if possible, their generation to a particular process or function. The results from a study on the particle size distribution found in a Hanford plutonium fabrication facility are discussed. These data are related, where possible, to characteristic operations.

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INTRODUCTION

A knowledge of the aerodynamic particle size of radioactive contaminants in breathing air is extremely important to the Health Physicist in the evaluation of inhalation problems. Data, such as that obtained by J. H. Brown, et al.,[1] indicates that the respirability of particles below 1 to 2 microns approaches 100% while the respirability of particles greater than 10 microns approaches 0%. The equation defined by the International Committee on Radiation Protection[2] for calculating values for the maximum permissible concentration of radionuclides in air (MPC_A) includes a factor (f_a) for the fraction of material taken into the body by inhalation that arrives in the critical organ. Normally, the factor (f_a), for the lungs is defined as 0.12 assuming that the exposure is to a spectrum of particle sizes rather than a defined range of particle sizes. Thus, this method of calculation of an MPC_A assumes that only 12% of the total activity collected on an "absolute filter" will reach the critical organ. It appears that the factor (f_a), may be significantly in error in many of these calculations, depending, of course, on the nature of the operation and the particle size distribution of the radionuclides involved. At some facilities,[2,3] the development of particle size selective air samplers has been initiated in order to collect only those particles that are respirable.

The Radiation Protection Operation has initiated a study of the characteristics of radioactively contaminated air at Hanford work locations. This study is intended to characterize the nature of the contaminated air as to particle size distributions, particle size versus particle radioactivity and other physical and chemical characteristics. Studies characterizing the size of the radioactive particles are now in progress. This report summarizes the data collected on the general particle size distribution at two plutonium fabrication facilities.

DISCUSSION

A Royco Particle Counter, Model PC 200-A, was used in obtaining the data on the particle size distribution at various locations in two Hanford facilities. The aerosol of interest is circulated at 100 cubic centimeters per minute through the optical chamber of the Royco Counter. White light from a well regulated lamp is focused on the 1.98 cubic millimeter sensitive volume of the 4 cubic millimeter particle chamber. The light is deflected or reflected when it strikes a particle passing through the chamber producing a light pulse with an amplitude proportional to the square of the particle diameter. These pulses are observed by a photomultiplier tube and sorted according to size by the electronics of the counter. The results are displayed in 15 channels corresponding to defined particle diameter ranges (Slide 1).

The Royco Counter was operated in corridors and laboratory areas in the Plutonium Metallurgy Building (308 Building) and in offices, corridors and laboratory areas of the Plutonium Fabrication Building (234-5 Building). The particle size distribution data collected at the

Plutonium Fabrication Building is illustrated in Slide 2. This data was corrected for counting coincidence losses and is reported as particles per cubic centimeter. It may be noted that the office areas where smoking is permitted have the greatest concentration of particles for each particle size. During the day, the corridors and laboratory areas exhibited similar particle distributions. The minimum particle concentrations were found in the corridors during the night hours when most of the building personnel were absent.

The data collected at the 308 Building is presented in Slide 3. There are no office areas in the operating part of this building. Smoking was permitted in the corridors. The particle size distributions found in the corridors are quite similar to the results found in the office areas in the 234-5 Building. Again, the particle concentrations in the corridors are lowest at night when most of the personnel are absent from the building. The particle size distribution curves for the laboratory areas are quite similar in both buildings.

A comparison of the particle size distribution in the 308 Building for laboratory areas, supply air (filtered by a roughing filter and water washed) and unfiltered outside air is shown in Slide 4. The supply air and the air in the laboratory areas exhibit similar particle size distribution curves although the air in the laboratory areas has an increased number of both the smaller and the larger-sized particles than the supply air. For the untreated outside air, the particle concentration below 1 micron is significantly less and above 1 micron is significantly greater than the concentration in the treated air.

The particle counter was used in an attempt to observe changes in the airborne particle size distributions during minor plutonium contamination incidents. No significant changes in particle size distributions were observed. A calculation of the theoretical microcurie concentration for various particle sizes was performed to determine what magnitude a contamination incident would have to reach to be observed above the normal particle background seen by the Royco Counter. The calculation was made assuming the particles were in the form of PuO_2 spheres with a density of 11.5 grams per cubic centimeter. Slide 5 shows the relationship of concentration in microcuries per particle to the particle size in microns. A single PuO_2 particle at the minimum particle size (0.32 micron) detectable with the Royco Counter is equivalent to 1×10^{-8} uc of plutonium and the maximum particle size (8.0 micron) is equivalent to 1.8×10^{-4} uc of plutonium. Assuming a contamination incident where the plutonium concentration was 1 MPC_A (2×10^{-12} uc/cc), the number of pure PuO_2 particles per cubic foot for particle sizes from 0.01 to 10 microns were calculated. The data from this calculation is illustrated in Slide 6. For the minimum and maximum-sized particles detectable by the instrument, only 5.4 pure PuO_2 particles per cubic foot and only 3.5×10^{-4} pure PuO_2 particles per cubic foot respectively would be present at one MPC_A. For the 100 cc/min sample rate, the Royco Counter would have to operate approximately 50 minutes in a 1 MPC_A atmosphere to count one 0.32 micron PuO_2 particle and about 8×10^5 minutes to count one 8.0 micron PuO_2 particles. Very obviously, these isolated particles would not be distinguishable from the normal background particle distribution.

SUMMARY

In the laboratory areas where contamination may occur, approximately 90% of the total particles in the range from 0.32 microns to 10 microns were below 0.5 micron and 98% of the particles were below 0.8 micron. If the plutonium particles follow a similar distribution where the majority of the particles lie below 1 micron, it would appear that a size-selective sampler would not be necessary. However, the submicron plutonium particles may be attached by some mechanism to larger dust particles, thus, suggesting the use of special sampling equipment. After completion of electron microscope-emulsion work to relate specifically particle size and radioactivity content, a better understanding of air sampling equipment requirements and evaluation techniques should become available. This study is being pursued. The results of this study may be directly applicable in establishing appropriate biological research programs to further evaluate the factor (f_a) for conditions as they exist in a major plutonium producing plant.

REFERENCES

(1) Brown, J. H., K. M. Cook, F. G. Ney and T. Hatches, American Journal Public Health, 40, pp 450 (1950).

(2) Report of Committee II on Permissible Dose for Internal Radiation (1959), Health Physics Journal, 3 (1960).

(3) Hyatt, E. C., "A Study of Two Stage Air Sampler Designed to Simulate the Upper and Lower Respiratory Tract", LA-2440 (UNCLASSIFIED).

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FIGURE I

HOYCO COUNTER PARTICLE SIZE RANGES

Channel Number	Range-microns
1	0.32 to 0.40
2	0.4 to 0.5
3	0.5 to 0.64
4	0.64 to 0.8
5	0.8 to 1.0
6	1.0 to 1.3
7	1.3 to 1.6
8	1.6 to 2.0
9	2.0 to 2.5
10	2.5 to 3.2
11	3.2 to 4.0
12	4.0 to 5.0
13	5.0 to 6.4
14	6.4 to 8.0
15	8.0 and greater

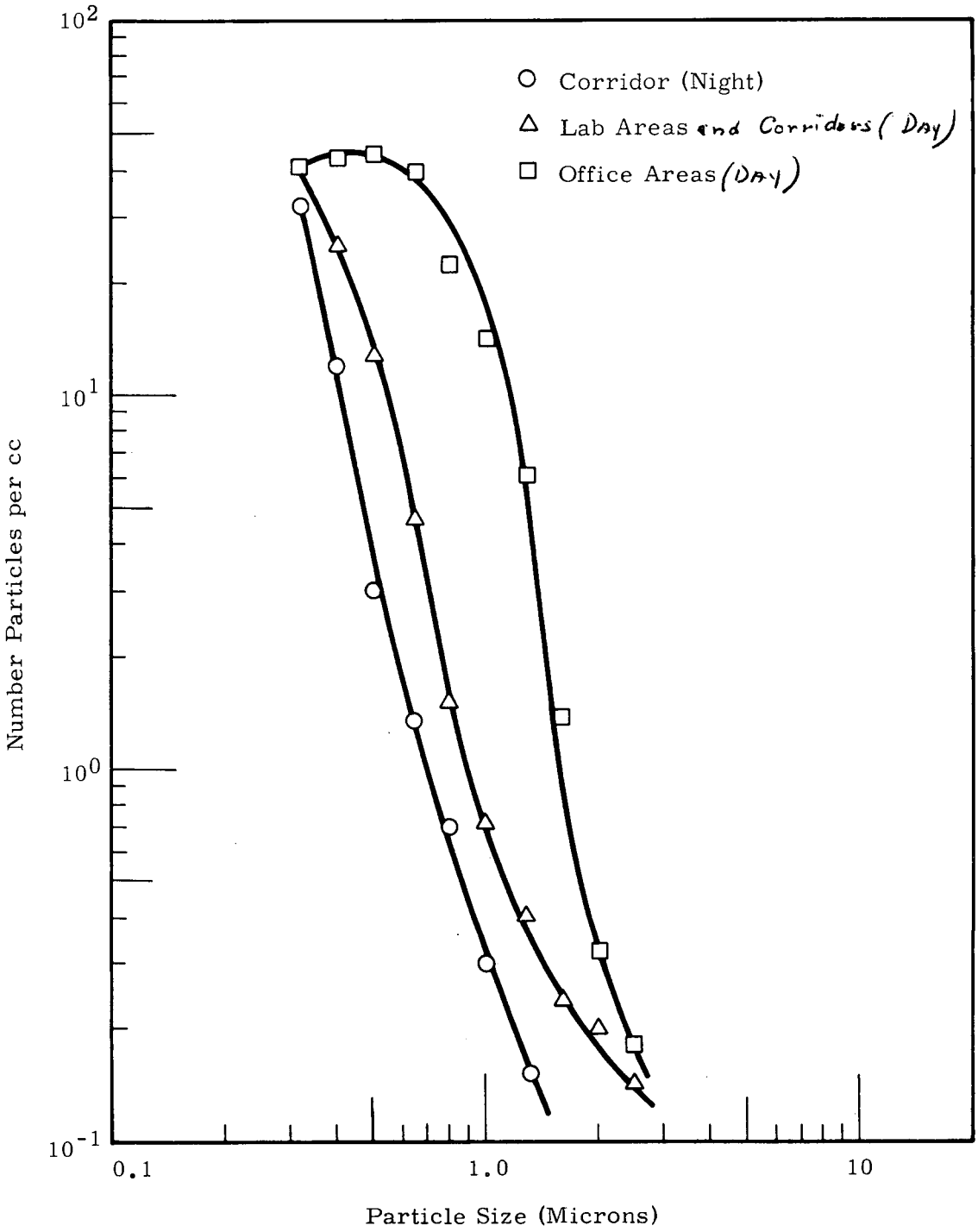

FIGURE 2

Particle Size Distribution 234-5 Building

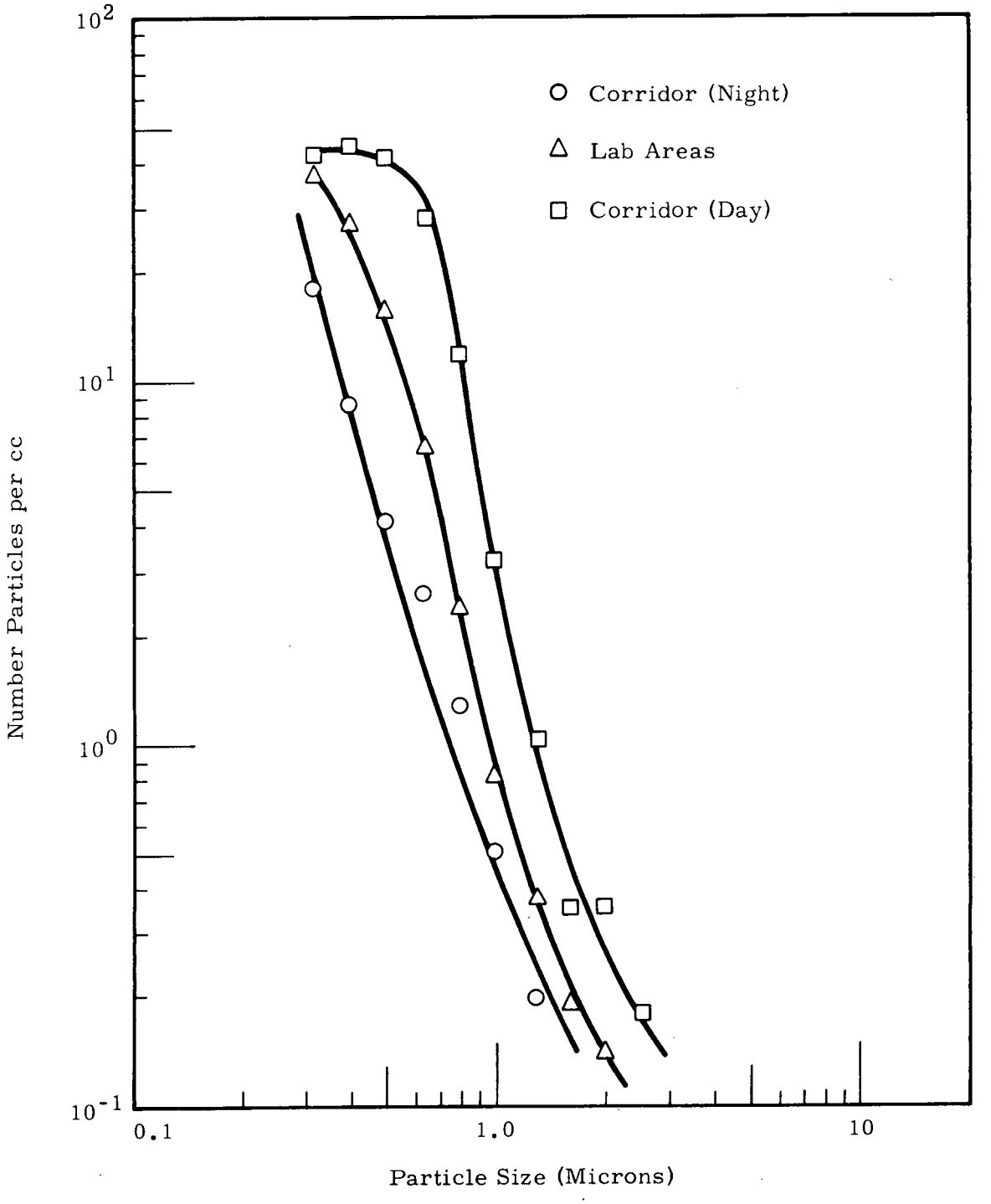

FIGURE 8

Particle Size Distribution 308 Building

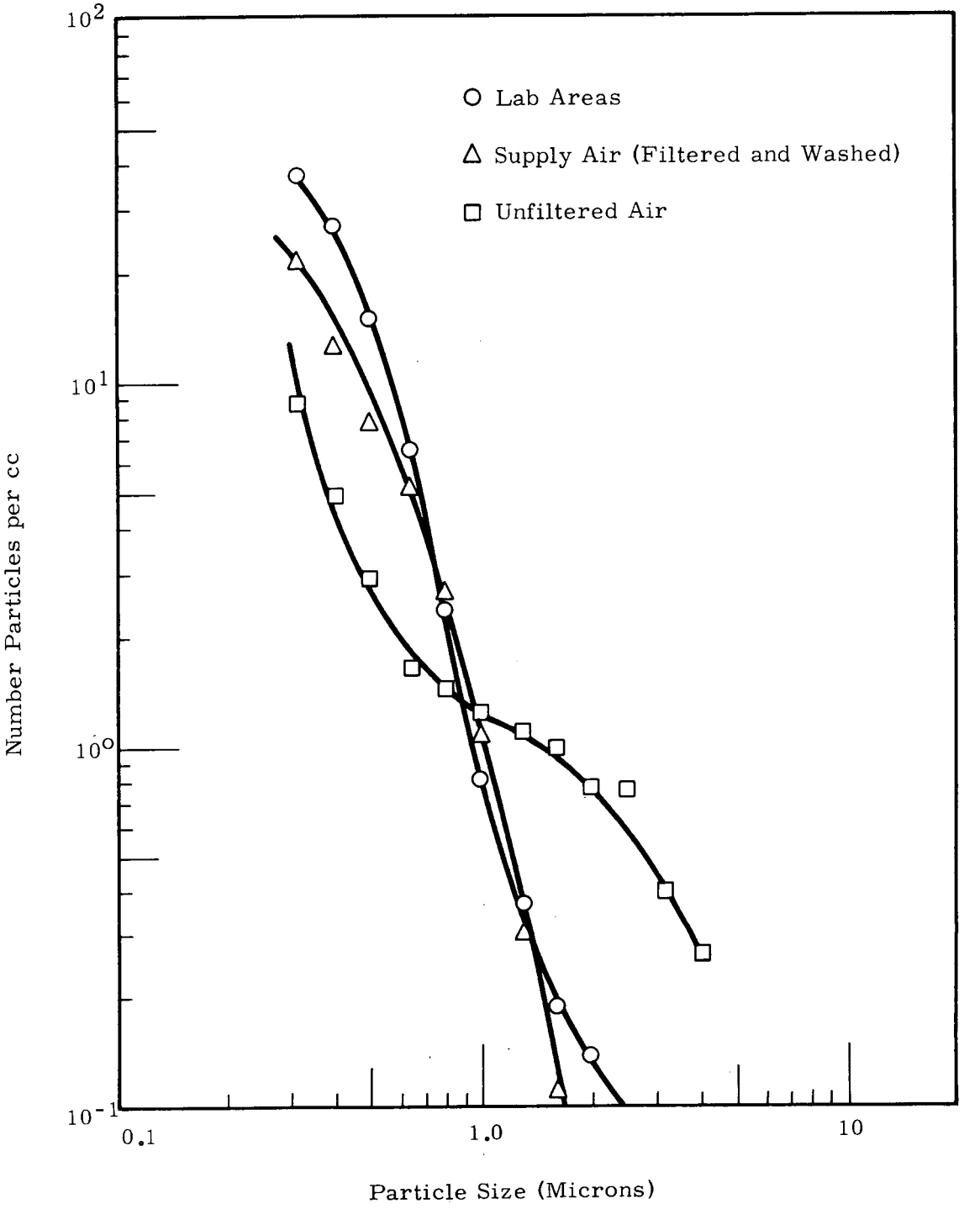

FIGURE 4

Comparison Particle Size Distribution Treated and Untreated Air

AEC-GE RICHLAND, WASH.

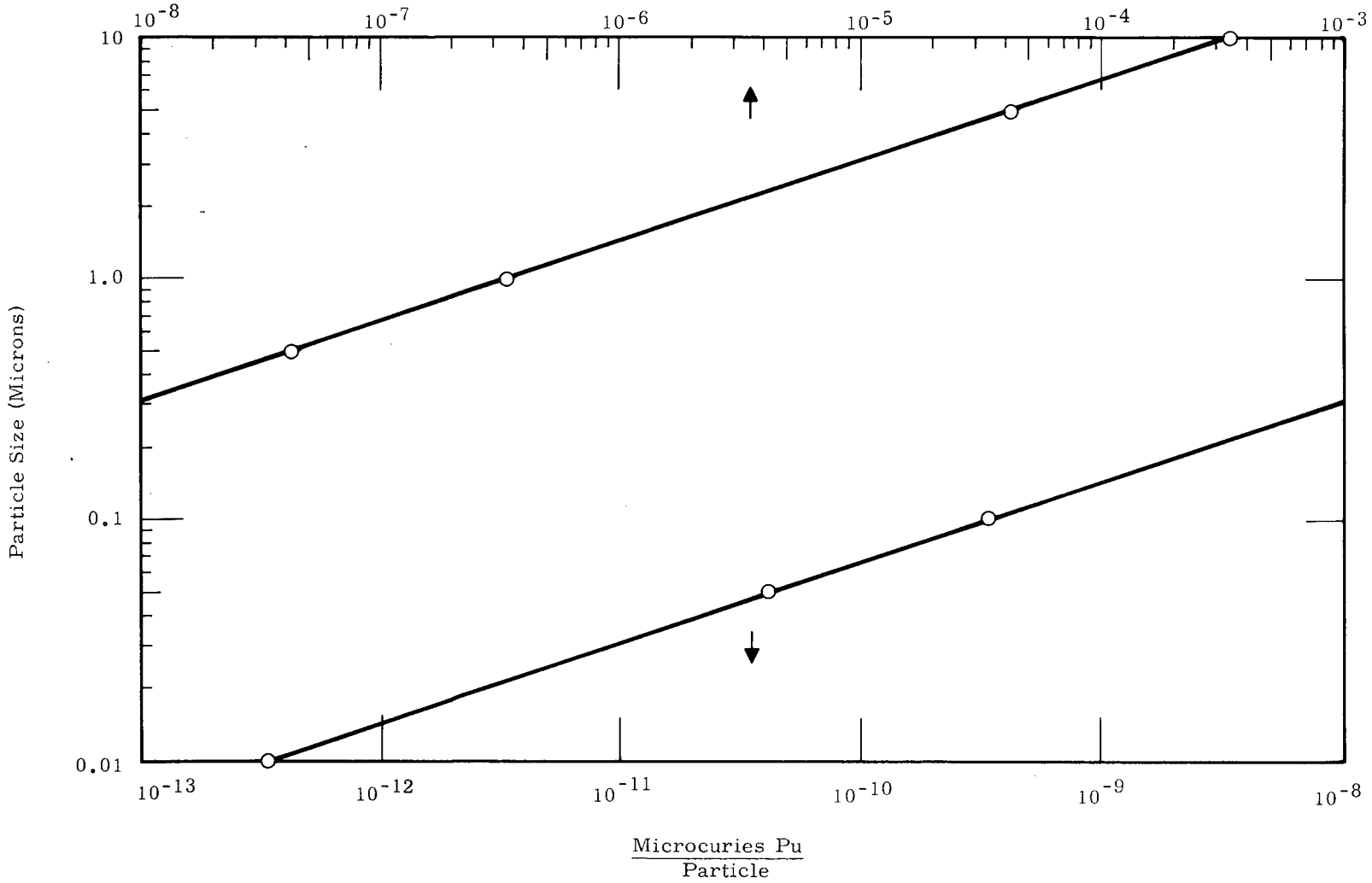

FIGURE 5

PuO_2 Particle Size vs Activity/Particle

AEC-GE RICHLAND, WASH.

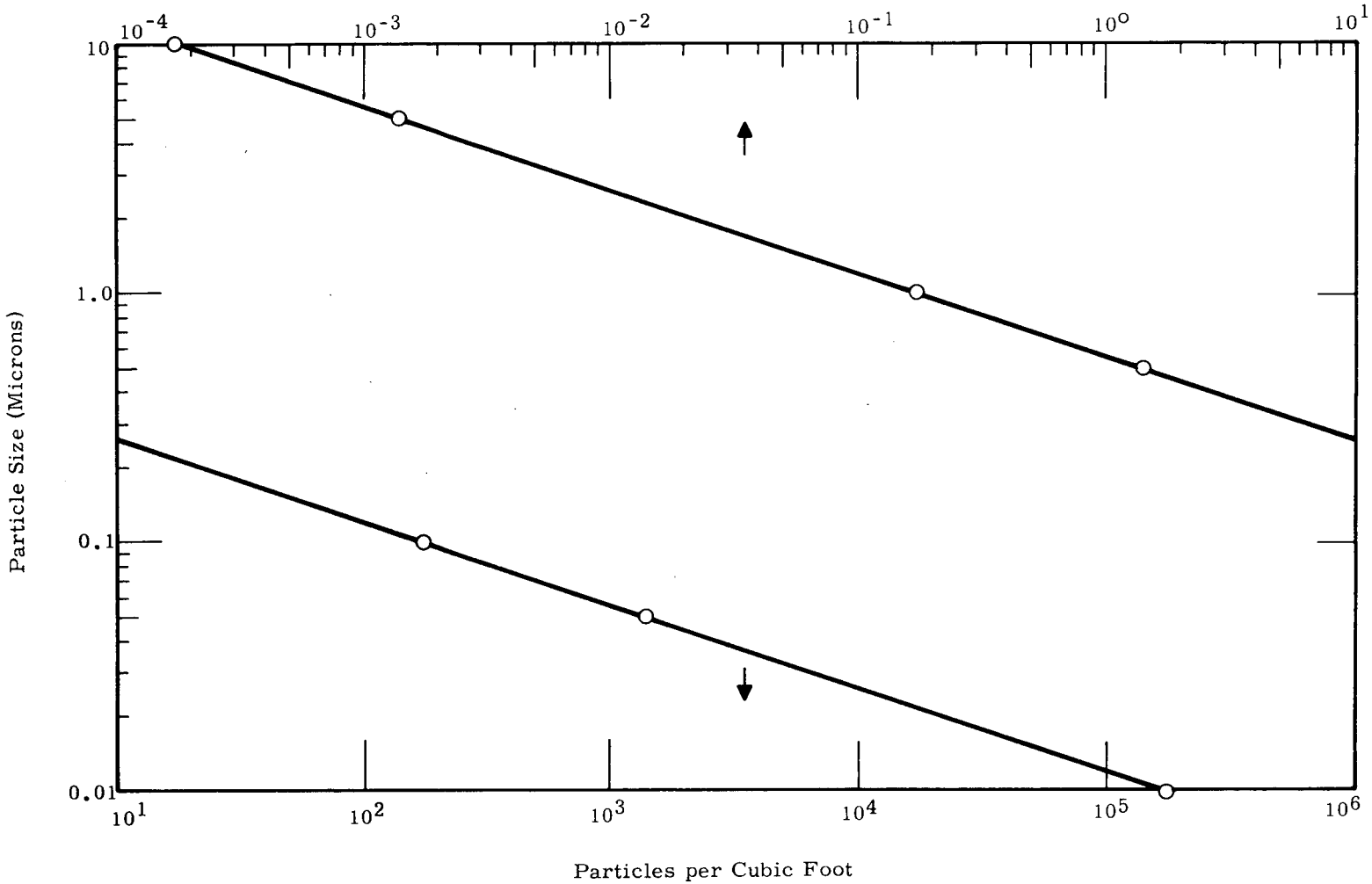

FIGURE 6

PuO_2 Particle Size vs Particles per Cubic Foot for 1 MPC_A

AEC-GE RICHLAND, WASH.

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