OSR 3-4A

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RECORDS ADMINISTRATION
R0120226

INTER-OFFICE MEMORANDUM

DPSPU-82-272-103

SAVANNAH RIVER PLANT

AC# 78513

V184 4/91

August 11, 1982

TO: J. L. FORSTNER

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V-184

NUCLEAR CRITICALITY SAFETY IN SHIPPING RADIOACTIVE WASTE TO BUILDING 643-G

Introduction and Summary

A previous letter (1) considered the safety of shipping radioactive waste to Building 643-G for storage. It was conservatively recommended that the sum of nuclear safety fractions for a shipment be two or less. For Pu-239 this means 390 grams or less per shipment, which was found to be too restrictive for JB-Line operations. This study was undertaken to study shipping configurations of 55 gal drums containing up to the drum limit of 195g Pu-239 and provide limits based on these calculations.

An infinite planar array of 55 gal drums two layers high with up to 200 g Pu-239 centered in each drum was found to be safe. Maldistribution of Pu in the drums can be allowed for by limiting a shipment to no more than three drums with greater than 130 g Pu-239.

Discussion

The truck transferring waste to Building 643-G will generally contain less than 30 drums arranged in a single layer. For this study an infinite planar array of 55 gal drums two layers high was conservatively considered. The model used for the drum in this array is listed in Table 1. The diameter of the drum has been reduced slightly (~ ½ cm) so that the square pitch array will represent actual drums touching in a triangular pitch array (i.e. Pu per sq ft of the surface covered by the square pitch array equals the Pu per sq ft of a triangular array with drums touching).

Also listed in Table 1 is the drum model for drums in a triangular pitch touching at their rolling hoops. This model was used to consider the situation where Pu in the bottom of three drums in a top layer of drums along with the Pu in the top of three drums in a bottom layer of drums form a cylindrical or spherical shape. Figure 1 shows a cross section through the drums.

Calculations and Calculational Bias

Calculations were made with the KOKO[2, 3] HRXN-II[3, 4] KENO-IV[5] and KENO-IV/CG[6] codes which are modules in the SRL JOSHUA System. KENO-IV and KENO-IV/CG are three dimensional codes which solve the transport equation using Monte Carlo techniques. KENO-IV/CG allows for description of more complex geometric models than does KENO-IV and was needed to describe drums on a triangular pitch. KOKO is a driver module which computes input for the other modules and chains various modules together. HRXN-II computes nuclear parameters for use by KENO.

Work reported in Reference 7 establishes that a k-effective (critical) of 0.99 should be conservative for both moderated and unmoderated Pu systems when calculated by KENO. Applying a k-effective margin of 0.05 and allowing for the statistical nature of KENO results, k-effective (safe) will be taken as 0.99-0.05 - (3.09 x k-effective standard deviation). In most cases this will yield a k-effective (safe) of 0.92.

Results

Results for the infinite planar arrays of drums two layers high with the 200g of Pu-239 centered in the drum are presented in Figure 2. The Pu is present as a Pu - full density polyethylene sphere. The Pu density was taken as 19.6 g/cc. A one foot water reflector is present on the top and bottom of the array. The k-effective values are for KENO-IV calculations with 30,000 neutron histories. The array will be safe for a k-effective less than or equal to 0.92. It can be seen from the figure that even for optimum moderation the k-effective is less than 0.92.

The majority of the calculations considered a carbon steel drum wall 0.109 cm thick. This corresponds to a DOT 17H drum with minimum wall thickness. The drum currently used for waste is a DOT 17C drum which has a nominal wall thickness of 0.152 cm. Figure 2 shows that increasing the drum wall thickness from 0.109 cm to 0.152 cm reduces array reactivity. Figure 2 also shows that array reactivity is decreased by the presence of a polyethylene liner and when the Pu - polyethylene is present at a reduced density. Waste drums normally contain a polyethylene liner.

Figure 3 shows the effect of water of varying densities interspersed in the array. The reactivity is maximum when there is no water in the array.

Figure 4 presents results for the system described in Figure 1 where 200 g of Pu-239 is located in each of six touching drums to form a sphere or a cylinder. The drums are surrounded by a one ft water reflector. Fewer neutron histories were obtained for these cases resulting in a larger standard deviation in k-effective. With the larger standard deviation k-safe will be 0.91. Figure 4 shows that Pu-polyethylene spheres and cylinders exceed this value. It appears unreasonable that a Pu-full density polyethylene sphere or cylinder would be present in the drums and calculations were done for Pu-full density water. Full density water is also unlikely but more probable. For these cases the k-effectives are less than 0.91 except when the area of the drum not occupied by the Pu-water mixture is flooded with water. To reduce the k-effective to less than 0.91, three of the six drums must contain 130 g Pu-239 or less.

In summary, except for a few cases of Pu maldistribution, shipping infinite planar arrays of 55 gal drums two layers high is safe when the drums contain up to 200 g Pu-239. (Calculations were done for 200 g Pu-239 per drum. Actual drum limits are a maximum of 195 g Pu-239)[8]. Although the cases of Pu maldistribution hypothesized here are extremely unlikely, they can be accounted for by putting no more than three drums with greater than 130 g Pu-239 in a shipment.

References:

1. DPSPU-82-72-5, T. A. Reilly to J. L. Forstner, "Nuclear Criticality Safety in Shipping Radioactive Waste to Building 643-G", January 20, 1982

2. DPST 74-489, H. K. Clark to P. L. Roggenkamp, Additions to Joshua Criticality Safety Calculations", September 24, 1974.

3. DPST-77-206, H. K. Clark to P. L. Roggenkamp, "Criticality Safety Module Changes", January 5, 1977.

4. DPST-76-368, H. K. Clark to P. L. Roggenkamp, "HRXN II", July 27, 1976.

5. DPST-76-365, H. K. Clark to P. L. Roggenkamp, "KENO IV", July 26, 1976.

6. DPST-78-283, H. K. Clark to J. D. Spencer", "KENO CJ", March 27, 1978.

References: (contd)

7. DPST-79-524, H. K. Clark to M. M. Anderson, "Computer Program Bias and Subcritical Limits for Pu Systems," November 2, 1979.

8. DPSOP 40, 404.2.2

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TABLE 1

Drum Dimensions for Arrays

Cavity Radius (to steel wall):	27.997 cm
Cavity Height:	86.778 cm
Thickness of Carbon Steel Wall, Top and Bottom:	0.109 cm
Polyethylene Drum Liner Thickness Where Considered:	0.23 cm
Square Pitch of Drums:	56.212 cm

Drum Dimensions for Drums Touching (Triangular Pitch)

Cavity Radius to Steel Wall	28.425 cm
Cavity Height: Variable (usually to limits of Pu)	
Thickness of Carbon Steel Wall, Top and Bottom	0.152 cm
Polyethylene Drum Liner Thickness	0.23 cm
Triangular Pitch of Drums:	60.404 cm

FIGURE 1

CROSS SECTION OF 55 GAL DRUMS ON TRIANGULAR PITCH

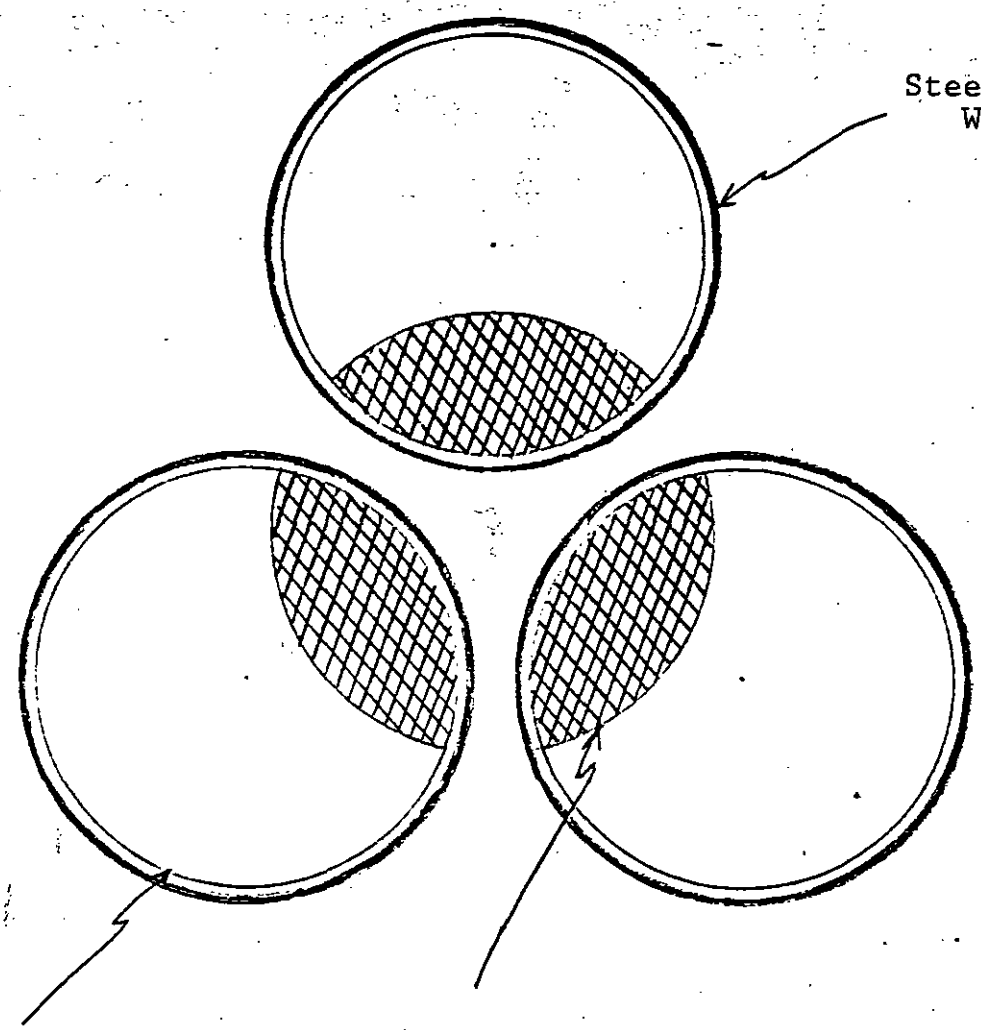

FIGURE 2
INF. X INF. X 2 ARRAY OF 55 GAL DRUMS,SQ.PITCH=56.212 CM.
200 G PU-239 PER DRUM AS PU-POLY SPHERES
NO POLY DRUM LINER,DRUM WALL=0.109 CM

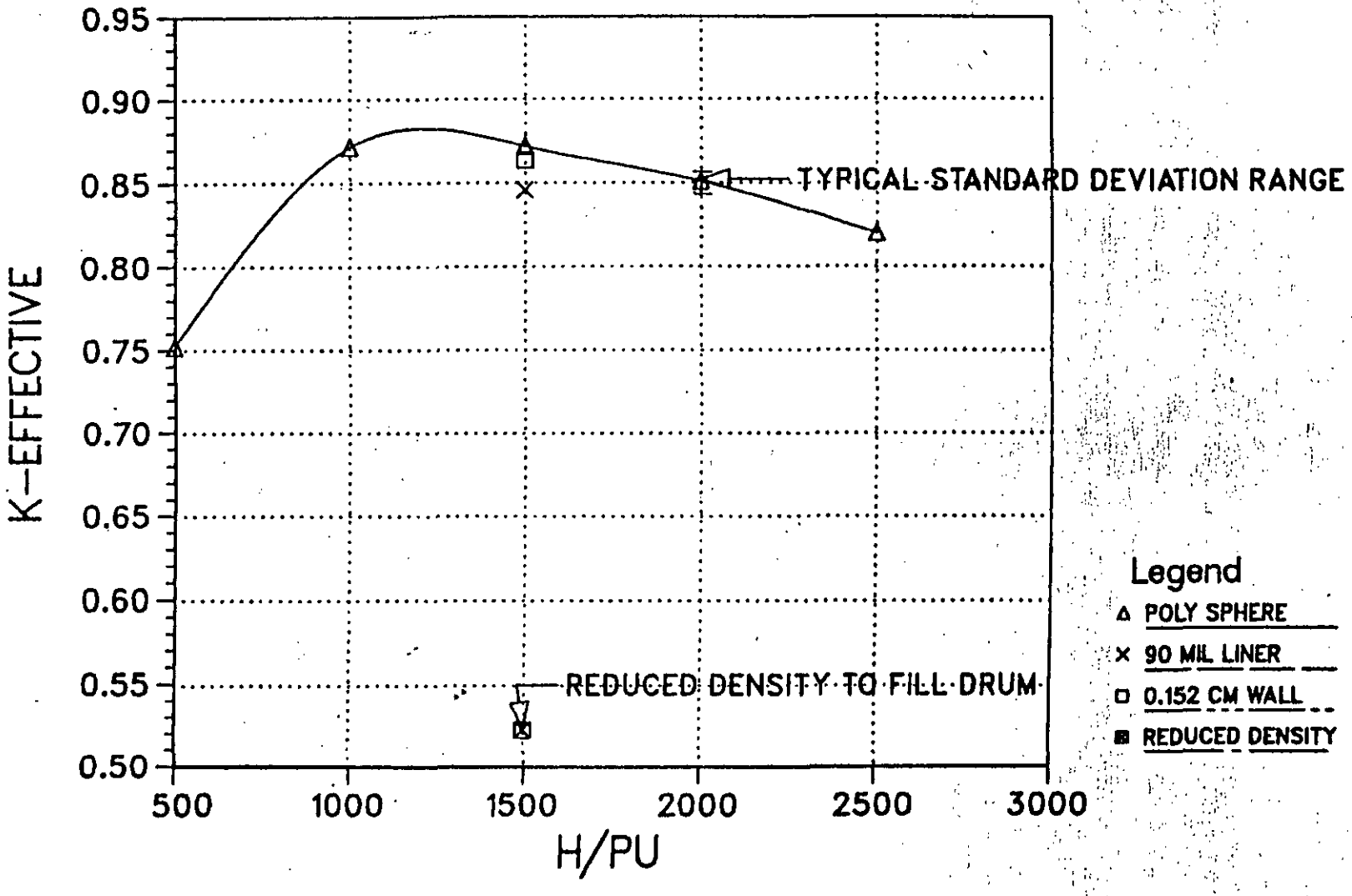

FIGURE 3
INF. X INF. X 2 ARRAY OF 55 GAL DRUMS,SQ.PITCH=56.212 CM.
200 G PU-239 PER DRUM AS PU-POLY SPHERES,H/PU=1500
WATER INTERSPERSED BETWEEN DRUMS
NO POLY DRUM LINER,DRUM WALL=0.109 CM

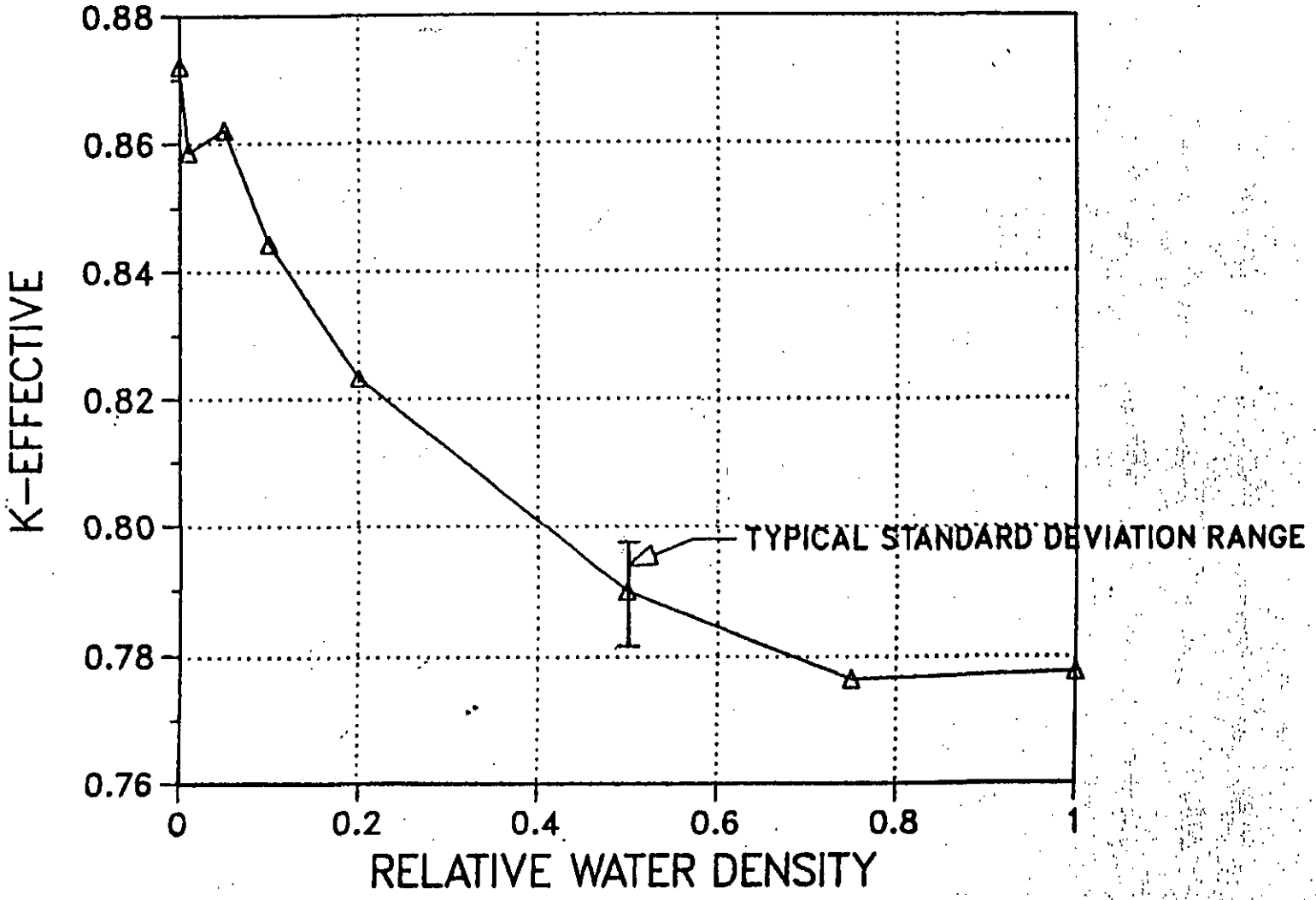
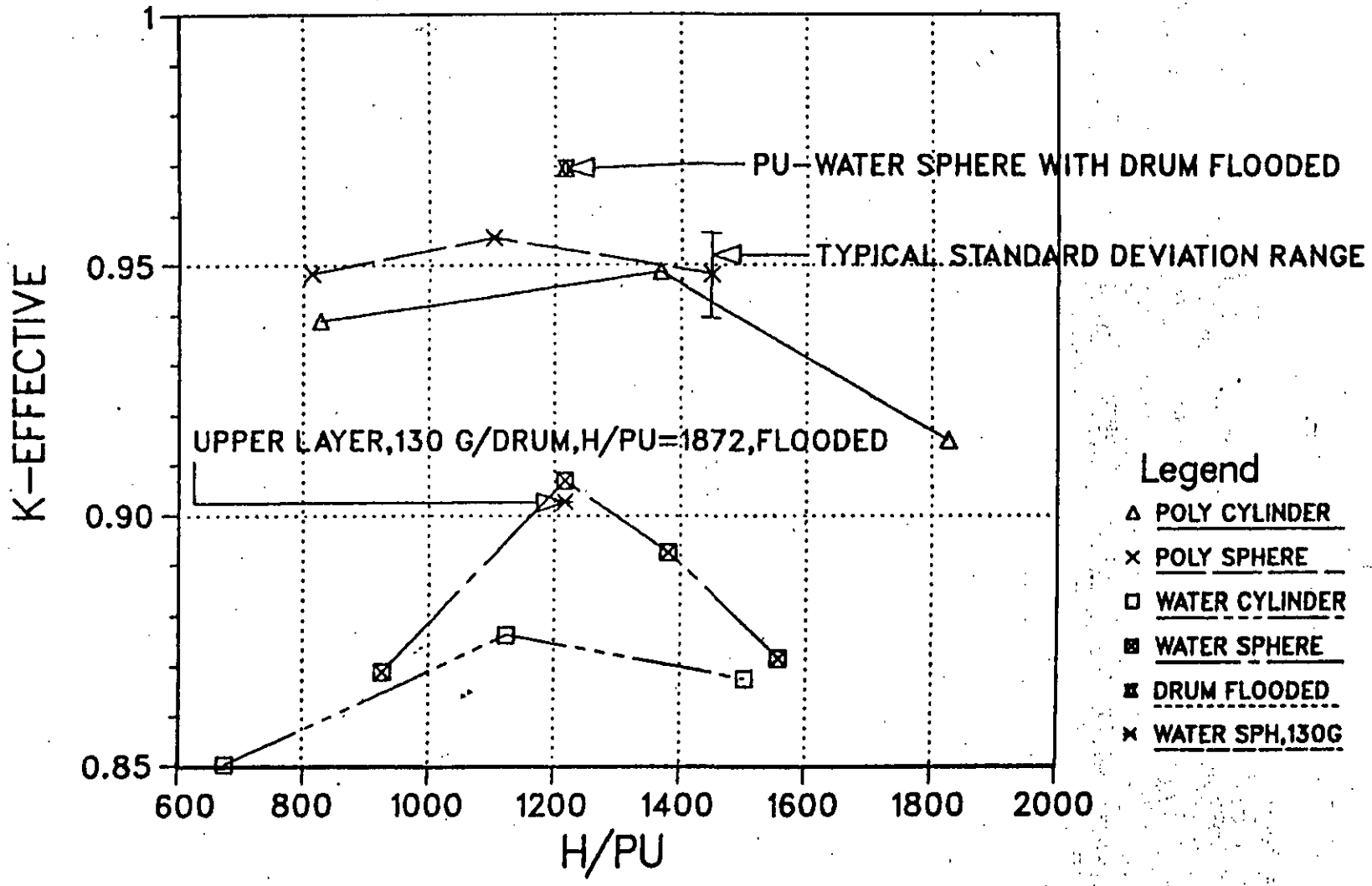
FIGURE 4
SIX 55 GAL. DRUMS, TRIANGULAR PITCH, TWO LAYERS
200 G PU-239 PER DRUM