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ORALLOY CYLINDRICAL SHAPE FACTOR AND CRITICAL MASS MEASUREMENTS
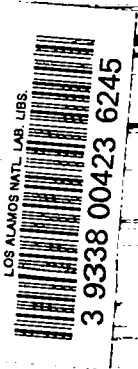
IN GRAPHITE, PARAFFIN, AND WATER TAMPERS

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ABSTRACT

Critical mass of an Oy (93.9%) sphere in graphite is given as a function of graphite tamper thickness. It was shown that ~20" of graphite is effectively infinite and that the ~17" used herein is ~98% infinite. Critical mass measurements of Oy (93.9%) spheres and cylinders of different diameters are given for ~17" graphite tamper, for effectively infinite paraffin tamper, and for effectively infinite water tamper. From these measurements cylindrical shape factors were computed. Both shape factors and critical masses are shown in Figs. 22 and 23 as functions of the critical height to diameter ratio of the cylinders.

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ORALLOY CYLINDRICAL SHAPE FACTOR AND CRITICAL MASS MEASUREMENTS IN GRAPHITE, PARAFFIN, AND WATER TAMPERS

I. INTRODUCTION

Oy shape factor is defined as M_c(Oy sphere) / M_c(Oy shape). Shape factor is one of the parameters upon which the critical mass depends. The others are tamper (material, density, thickness, distribution), average Oy density, U-235 isotopic concentration in Oy, and distribution of gaps and low concentration regions in the Oy assembly.

In LA-1155 Oy cylindrical shape factor and critical masses are given for air (untamped) and for different thicknesses of Tu tamper. In this present document Oy cylindrical shape factors and critical masses are given for ∿17" graphite tamper, for effectively infinite paraffin tamper, and for effectively infinite water tamper. Figures 1 and 2 show that ∿20" of graphite tamper is the minimum tamper that is effectively infinite and that ∿17" graphite tamper used in this experiment is ∿98% infinite; i.e., the critical mass observed in the ∿17" graphite tamper is ∿2% greater than that expected in infinite graphite. LA-1101, Fig. 9 (page 11) shows that the 8" minimum paraffin tamper used in these experiments is effectively infinite. LA-1235, Fig. 3 (page 12) shows that the 8" minimum water tamper used in these experiments is more than is required for effectively infinite tamper.
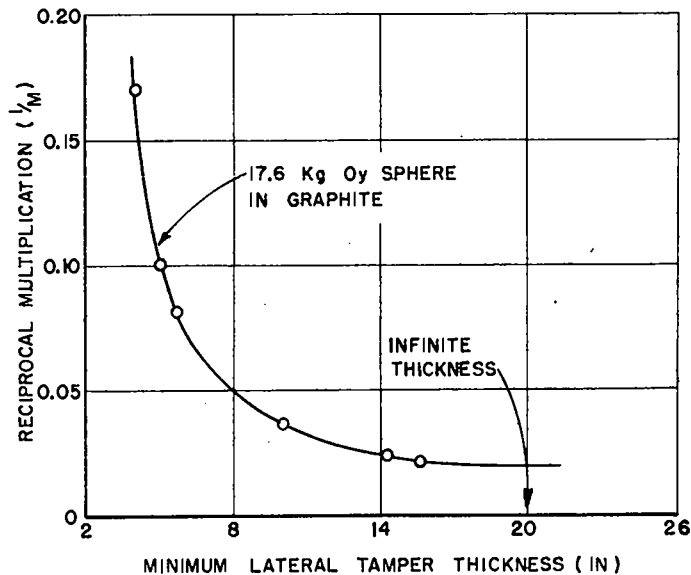
FIG. 1. Reciprocal multiplication of a 17.6 kg Oy "sphere" (OD of one half 4.68" and OD of other half 4.95") vs minimum lateral tamper thickness as the graphite tamper was built up slightly beyond the assembly shown in Figs. 4, 5 and 6. It is shown that ∿20" of graphite tamper is effectively infinite.
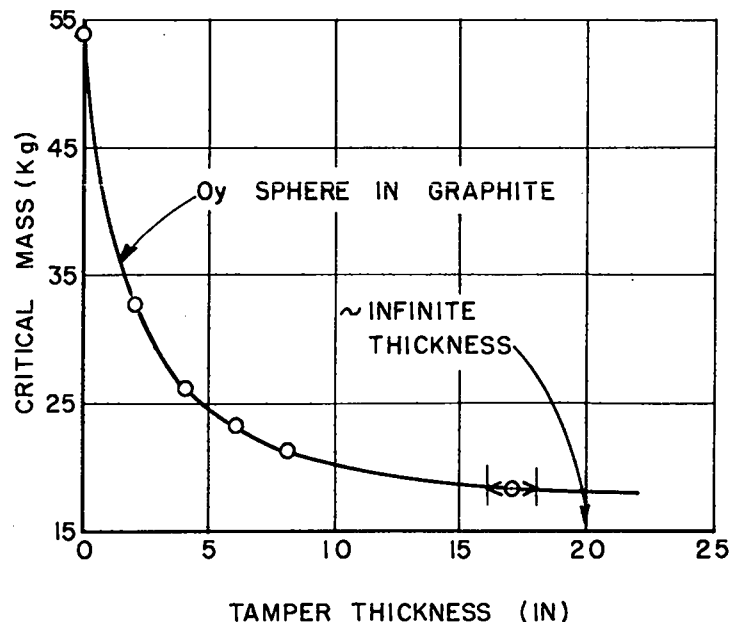
FIG. 2. Critical mass of Oy spheres vs graphite tamper thickness. The tamper and Oy for the point of lowest critical mass were the same used for the highest multiplication in Fig. 1. The tamper was estimated to be equivalent to a spherical shell of ∿17" thickness. The point for no tamper was taken from LA-1155, Fig. 14 (page 26). The other points were determined with hemispherical tampers as shown in Fig. 3. It is shown that ∿20" of graphite tamper is effectively infinite.

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II. APPARATUS AND MATERIALS USED

The two similar machines, Comet and Elsie, were used interchangeably in the measurements involving graphite and paraffin tampers. These machines consist essentially of a hydraulic lift that can raise the lower part of the split assembly against the upper portion, which is supported above the lift. The different tamper arrangements used are shown in Figs. 3-9 inclusive. Figure 3 is a photograph showing the Comet with CS 312 grade graphite tamper used for obtaining the data shown in the curve of Fig. 2 for tamper thicknesses of 2", 4", 6" and 8". The tamper was formed with matching hemispherical shells of the desired OD and ID. Figures 4-6 inclusive show the manner in which the ~17" graphite tamper was arranged for measurement of the critical mass of an Oy sphere, Oy cylinders of different diameters, and Oy pseudocircular disks of different heights. The thickness of the graphite tamper was limited largely by the size of the machines available. In these figures the 4-1/8" x 4-1/8" graphite bars were pile grade graphite, and the specially fabricated graphite parts in the center of the assembly were CS 312 grade graphite. The density of the CS 312 grade, which is relatively pure graphite, averages a little less than 1.7 gm/cc; and the density of the pile grade, which is even a purer graphite, is a little less.

Figures 7-9 inclusive show the manner in which the paraffin tamper was arranged for measurements of the critical mass of an Oy sphere and different diameter Oy cylinders. The tamper shown in Figs. 7 and 8 consists of cast paraffin, and the tamper shown in Fig. 9 consists of a pile of paraffin slabs which were obtained commercially. The specific gravity of the cast paraffin checked favorably with the specific gravity of the slabs (0.89), but nevertheless several measurements previ-
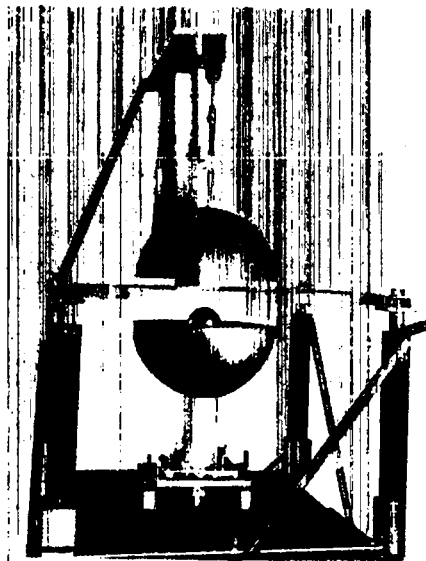
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FIG. 3. Graphite tamper assembly on Comet in unassembled position with Oy sphere containing a central source. The tamper was made of two hemispherical shells which were available in 2", 4", 6" and 8" thicknesses in sufficient ID values to accommodate all the Oy spheres measured.
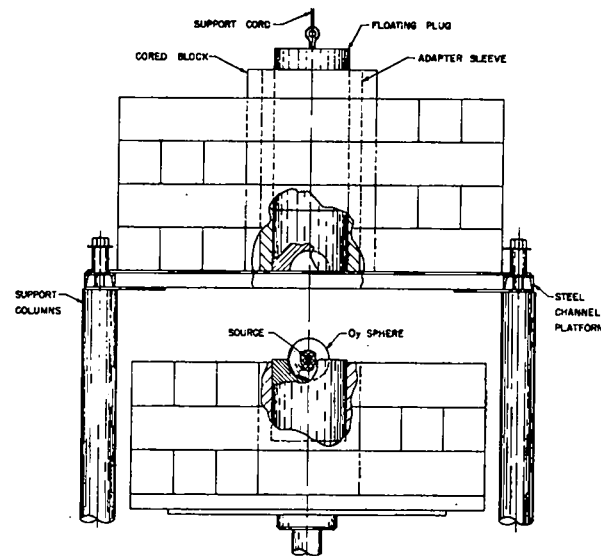

FIG. 4. Graphite tamper assembly in unassembled position with Oy sphere containing a central source. Graphite pieces containing the spherical cavities were available for every size of Oy sphere measured.
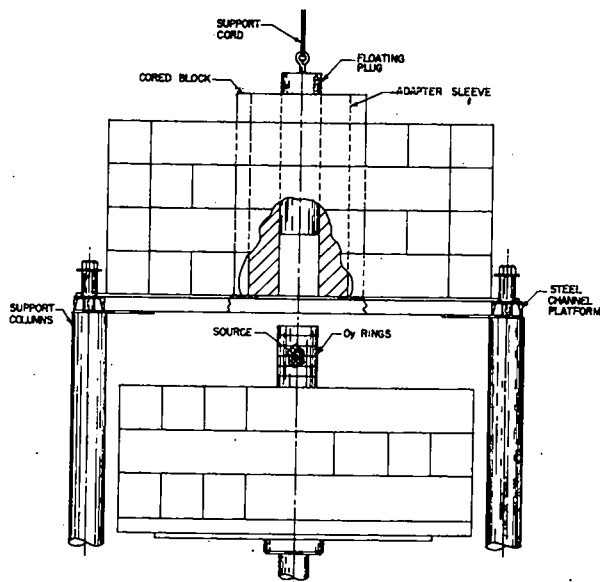
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FIG. 5. Graphite tamper assembly in unassembled position with Oy cylinder containing a central source. Graphite adapter sleeves and floating plugs were available in sufficient sizes to accommodate all the Oy cylinders measured.
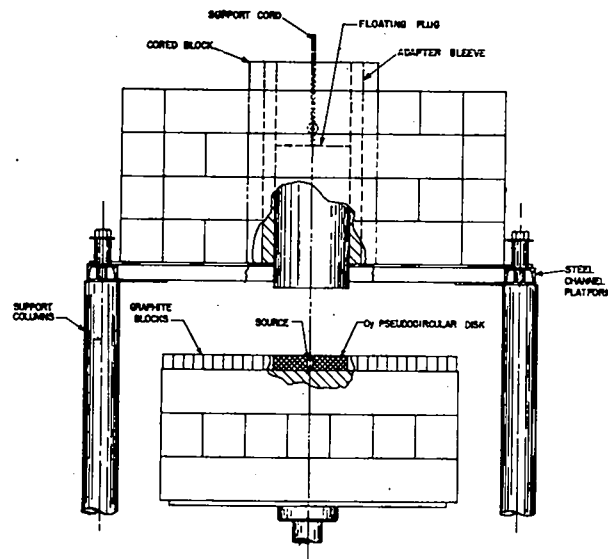

FIG. 6. Graphite tamper assembly in unassembled position with Oy pseudocircular disk containing a central source. The floating plug had a diameter of 7.5". The pseudocircular disk was made of Oy blocks.
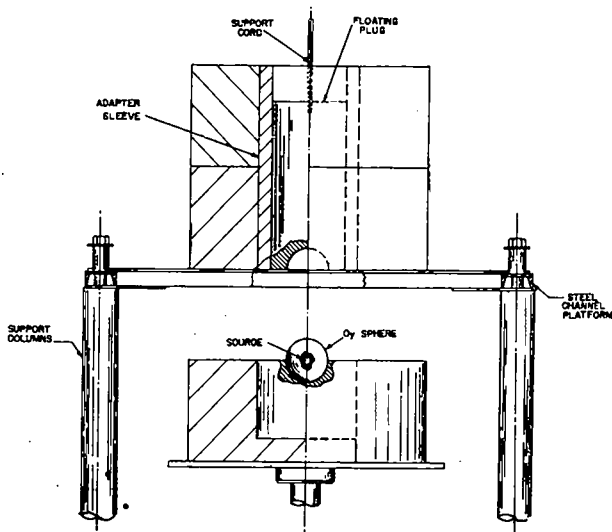
FIG. 7. Cast paraffin tamper assembly in unassembled position with Oy sphere containing a central source. Paraffin pieces containing the spherical cavities were available for every size of Oy sphere measured.
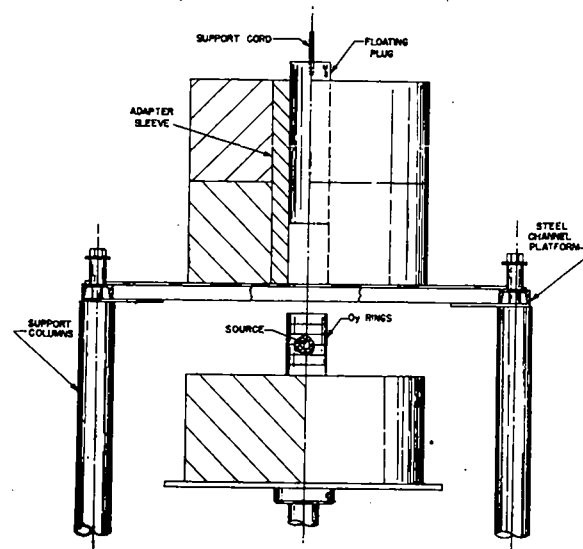

FIG. 8. Cast paraffin tamper assembly in unassembled position with Oy cylinder containing a central source. Paraffin adapter sleeves and floating plugs were available in sufficient sizes to accommodate all the cylinders measured.

ously made in the cast paraffin assembly were repeated with the paraffin slabs to verify that any possible blow holes in the paraffin castings did not appreciably affect the results of the measurements.

The membrane used on Elsie and Comet to support the upper portion of the tamper (see Figs. 4-10 inclusive) had a central 8" diameter hole for entry of the active material into the upper portion of the tamper. An extra membrane, essentially identical, was used to determine the effect of doubling the membrane thickness as described in the next section.

The Aquarium machine was used in the measurements involving water tamper. Photographs of and information on the Aquarium can be found in LA-1235. For these measurements a new air piston was installed to move the fissile material in or out of the water. Figure 10 shows schematically the arrangement used with water tamper. Care was taken to prevent air from being trapped in any portion of the supporting unit.

The isotopic concentration of all Oy used was ∿93.9% of U-235. The Oy pseudocircular disks were made of $\frac{1}{2}$" x $\frac{1}{2}$" x $\frac{1}{2}$", $\frac{1}{2}$" x $\frac{1}{2}$" x 1", and $\frac{1}{2}$" x 1" x 1" Oy blocks. The Oy cylinders were formed of universal rings which are listed in LA-1155 (page 7). The Oy spheres were formed from hemispherical nesting shells which are listed in Table I below. All spheres built up from these shells had a 0.83" diameter spherical cavity in the center. Some of the later measurements, as noted, were made with a 70 gram, 0.825" diameter spherical filler in this cavity. This filler contained a central cylindrical cavity 0.45" long and 0.375" in diameter for the mock fission source used. This is the same size cavity used for this source in the cylinders and disks. There was also a 0.25" thick x 5.24" diameter Oy disk used in a measurement shown in Figs. 11 and 12. With the exception of this disk, there were sufficient Tu parts to mock up any Oy configuration.
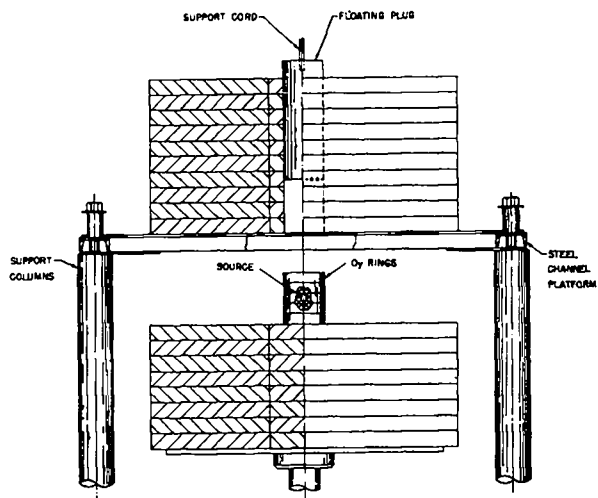
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FIG. 9. Paraffin tamper assembly of stacked slabs in unassembled position with Oy cylinder containing a central source. The floating plugs and the slabs containing a circular hole were available for every size of cylinder measured. A similar arrangement, which is not shown, was used for Oy spheres with this type of paraffin tamper.
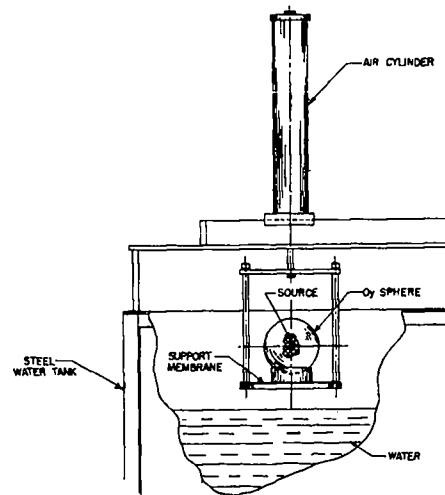

FIG. 10. Arrangement for water-tamped assembly in unassembled position with an Oy sphere containing a central source. When cylinders were measured in water, they were placed directly on the support membrane.

TABLE I.   Oy and Tu hemispherical nesting shells.

ID (in)	OD (in)	ID (in)	OD (in)
0.83	3.00	3.60	4.50
0.83	3.60	4.08	4.68
0.83	4.95	4.08	4.95
3.00	4.06	4.69	4.95
3.61	4.06	4.68	5.23

In measurements involving graphite tamper, three long geometry boron-lined counters were used.   In measurements involving paraffin and water tampers, the boron-lined neutron counter tubes were placed along the outer edge of the tampers.
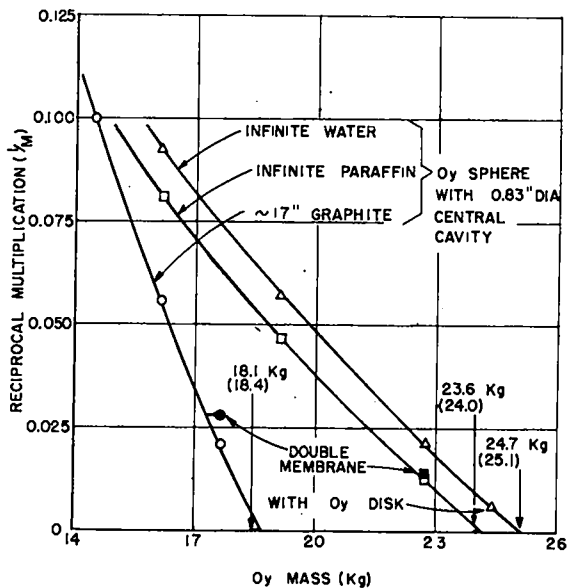
FIG. 11.   Reciprocal multiplication vs mass of Oy sphere in the tampers indicated. The masses given in parentheses are the critical masses corrected for the effects of the supporting membrane where necessary. The masses given just above these are the critical masses corrected for the empty central cavity also.
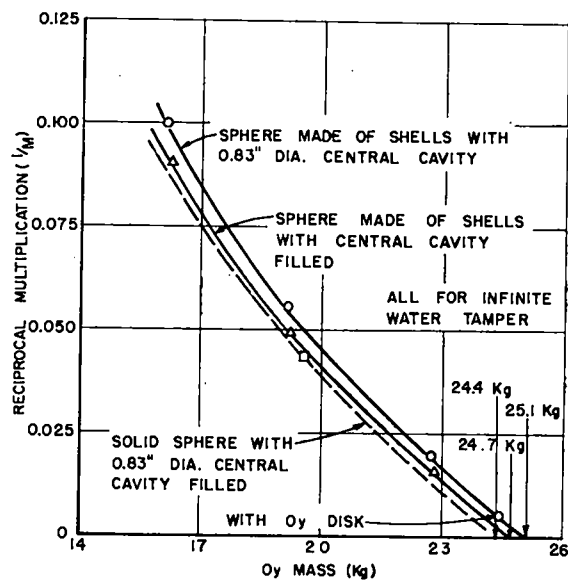

FIG. 12.   Reciprocal multiplication vs mass of Oy sphere in infinite water tamper. The masses given are the critical masses. Note especially the 0.4 kg decrease in the critical mass by adding 70 grams in the central cavity and the further 0.3 kg decrease in the critical mass by increasing the average Oy density. This latter correction, however, was not used.

III. PROCEDURE

All machine assembly and counting were done by remote control from the control room about a quarter of a mile from the laboratory, both buildings being located in Pajarito Canyon at Los Alamos. Standard counts were taken at intervals to check the drift of the counters. Background counting rate was determined each day during the experiment. After assembling the machine, unmultiplied counts were determined for Tu configurations corresponding to each Oy configuration measured (with one exception noted). The external neutron leakage multiplication for the central source position (hereafter referred to simply as "multiplication") was determined as the ratio of a multiplied counting rate with Oy to the corresponding unmultiplied counting rate with identical Tu, both corrected for background if necessary. As shown in the curves of Figs. 11-21, the apparent critical mass of each configuration was determined by extrapolating the reciprocal multiplication vs Oy mass curves to zero reciprocal multiplication. In some instances, this has to be corrected for the effect of the supporting membrane.

As shown in Figs. 11, 14 through 18, 20, and 21, multiplication measurements were made with double thickness of supporting membrane to correct for the effect of the single supporting membrane. Other experiments have shown that the effect of the membrane of this approximate thickness is very nearly linear with membrane thickness. Therefore the correction of the apparent critical mass was made by subtracting from the apparent critical mass with single supporting membrane the apparent increase in critical mass caused by doubling the membrane thickness. This latter quantity was assumed to equal the lateral displacement of the double membrane point from the curve for the single membrane.

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Tests in the water tamper showed that the supports had no appreciable effect on the measurement of critical mass.

There was a small variation in counting rate for a given Oy assembly in water tamper as the temperature of the assembly was changed, but tests showed that the effect on the measured critical mass was not appreciable. However, all measurements in a water tamper were made after the fissile material and water were in thermal equilibrium and the water was approximately at room temperature.

The 0.825" diameter Oy filler with the source cavity was not obtained until after these experiments were completed and the tamper assemblies dismantled. The measurement of the critical mass of an Oy sphere in water was repeated and the effect of the central filler determined. See Fig. 12. The effect of this filler in a water tamper was then used to correct the Oy sphere critical masses in graphite and paraffin tampers. Other experiments in graphite tamper (with the arrangements shown in Fig. 3) and other tampers show that this correction is valid.

In determining the critical mass of a sphere in water, the assembly of Oy shells giving a sphere of diameter 5.24" and a mass of 22.70 kg was the largest size on which multiplication measurements could be made because the next available size was supercritical. The ½" Oy disk of 5.24" diameter was then placed between the two hemispherical configurations (with no central filler). This gives a total mass of 23.4 kg of Oy. This configuration was used in a measurement shown in Figs. 11 and 12. Since the unmultiplied counting rate is relatively insensitive to the addition of small amounts of Tu, the unmultiplied counting rate for the 5.24" Tu sphere was used to determine the multiplication of the 5.24" Oy sphere with the disk.

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IV. RESULTS

Figures 11-21, inclusive, give all the results of critical mass determinations with corrections for supporting membrane, if any. Figures 22 and 23 give a summary of these results and of the computed shape factors, both as a function of the height to diameter ratios of the cylinders. Previous measurements (not shown in the figures cited) which could not be properly corrected for the effect of the supporting membrane, indicate that in effectively infinite paraffin tamper the lower limits of the critical mass of Oy pseudocircular disks are as follows: 1½" height, 50 kg; 1" height, 70 kg; and ½" height, essentially infinite mass. The Oy blocks listed in Section II were used for these measurements.

In comparing the average Oy density of all configurations used with the 18.81 gm/cc of solid Oy, it is found that this average density is between 1% and 2% low; i.e., between 18.45 gm/cc and 18.65 gm/cc. However, since the exact mass distribution is not known accurately, no correction is made for the measured critical masses. To obtain an idea from experimental results as to what corrections one might expect, a comparison can be made of the critical mass obtained from the lower curve of Fig. 12 for an approximately solid Oy configuration with that obtained from the middle curve made of nesting shells.

Other significant results of these tests might be found by comparing effects of tampers. In comparing the graphite tamper with either the paraffin or water tampers, a difference is noted. In Figs. 11, 15-18 inclusive, and 20, the reciprocal multiplication vs Oy mass curves for an Oy sphere, of the same diameter Oy cylinders in graphite tamper, are steeper than the same curves for paraffin or water tamper

and cross   them. It is therefore usually meaningless to
compare the reactivity of a given Oy mass in a graphite tam-
per with that in either paraffin or water tamper.

In comparing the reciprocal multiplication vs Oy mass
curves for paraffin and water tampers, considerable differ-
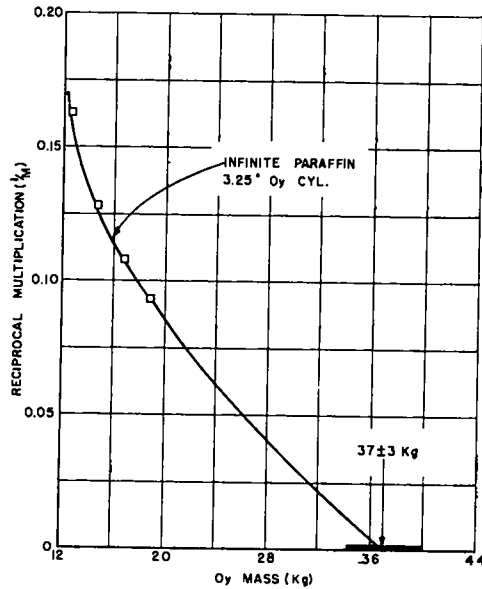ence in their shape is noted, but not understood.

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FIG. 13. Reciprocal multiplication vs mass of 3.25" diameter Oy cylinder in infinite paraffin tamper. The mass given is the critical mass. There was no more Oy available to add to the length of this cylinder; thus, the indefiniteness of the determined critical mass.
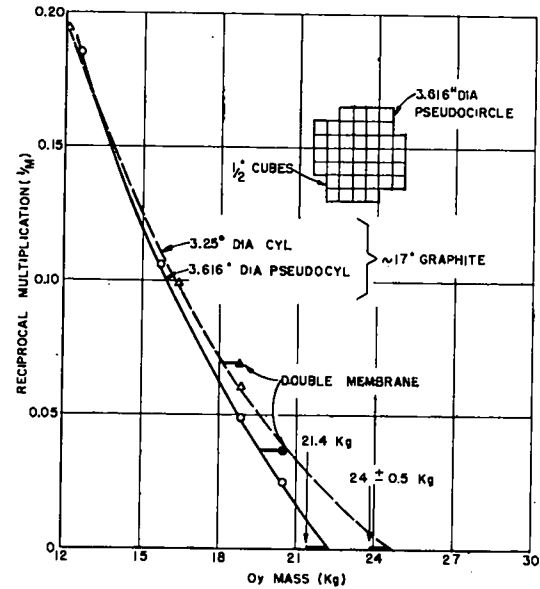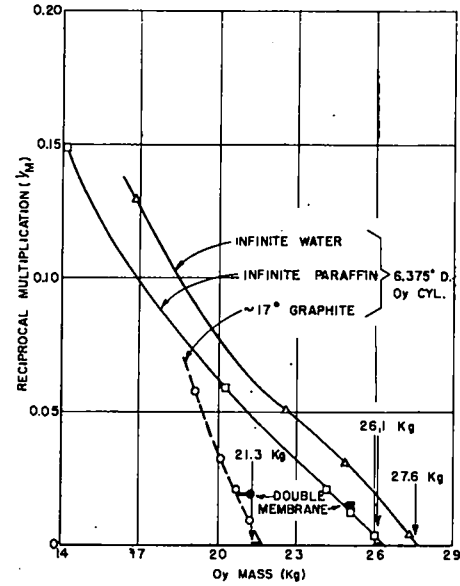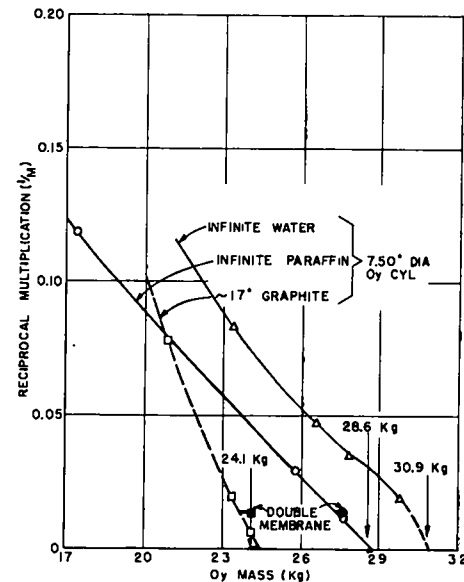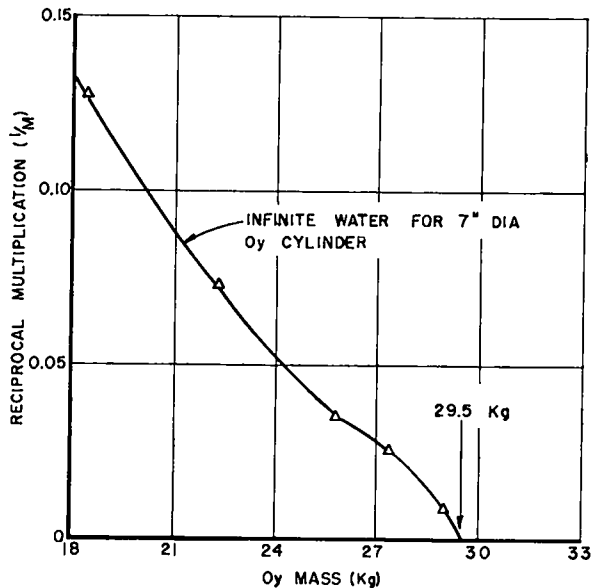

FIG. 14. Reciprocal multiplication vs mass of 3.25" Oy cylinder and 3.616" Oy pseudocylinder; and diagram of pseudocylinder cross-section used. The masses given are the critical masses corrected for the effect of the supporting membrane.
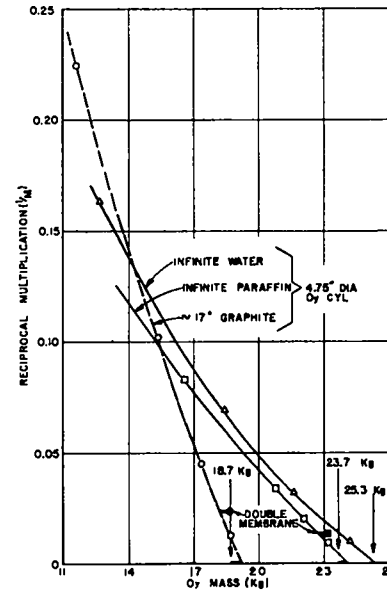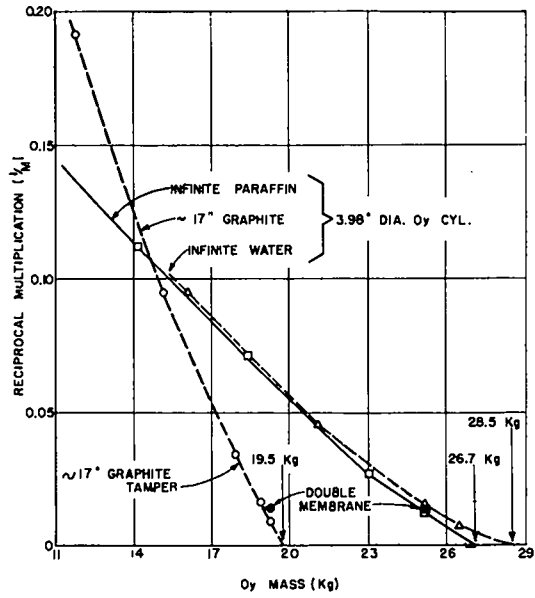
FIGS. 15 and 16. Reciprocal multiplication vs mass of Oy cylinders specified in the tampers indicated. The masses given are the critical masses corrected for the effect of the supporting membrane where necessary.
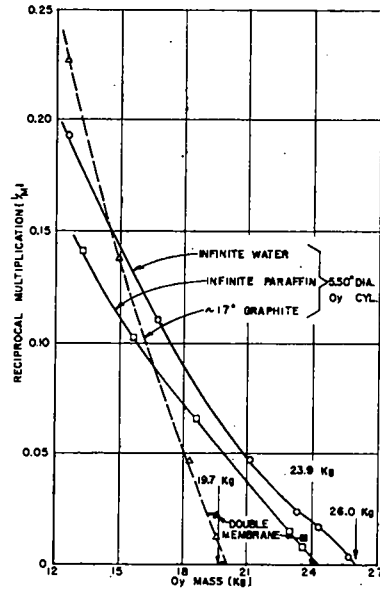
FIGS. 17 and 18. Reciprocal multiplication vs mass of Oy cylinders specified in the tampers indicated. The masses given are the critical masses corrected for the effect of the supporting membrane where necessary.

FIGS. 19 and 20. Reciprocal multiplication vs mass of Oy cylinders specified in the tampers indicated. The masses given are the critical masses corrected for the effect of the supporting membrane where necessary. The curve from Fig. 19 is used as a guide for extrapolating the upper curve in Fig. 20.
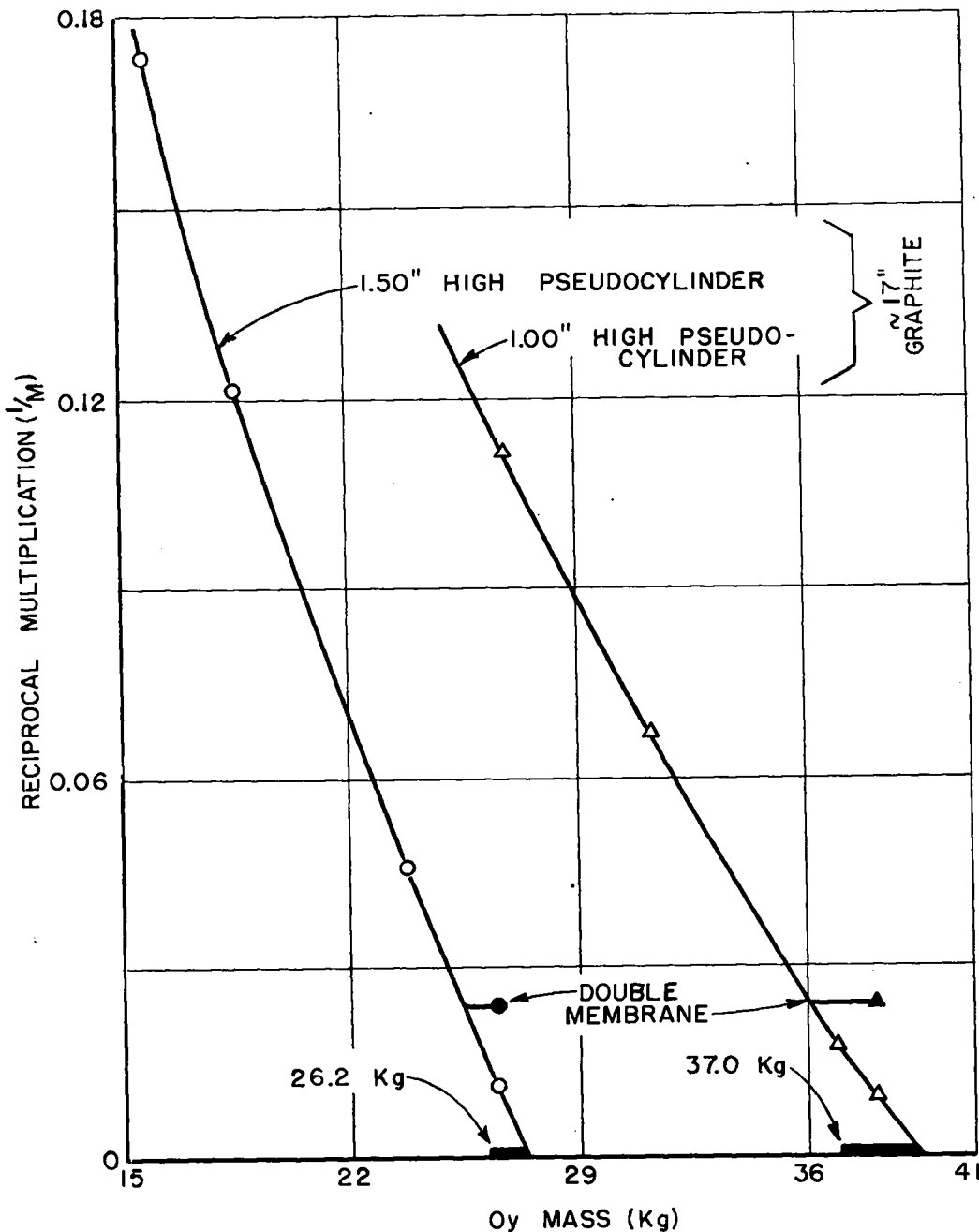
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FIG. 21. Reciprocal multiplication vs
mass of Oy pseudocylinders in ∿17" graphite
tamper. The masses given are the critical
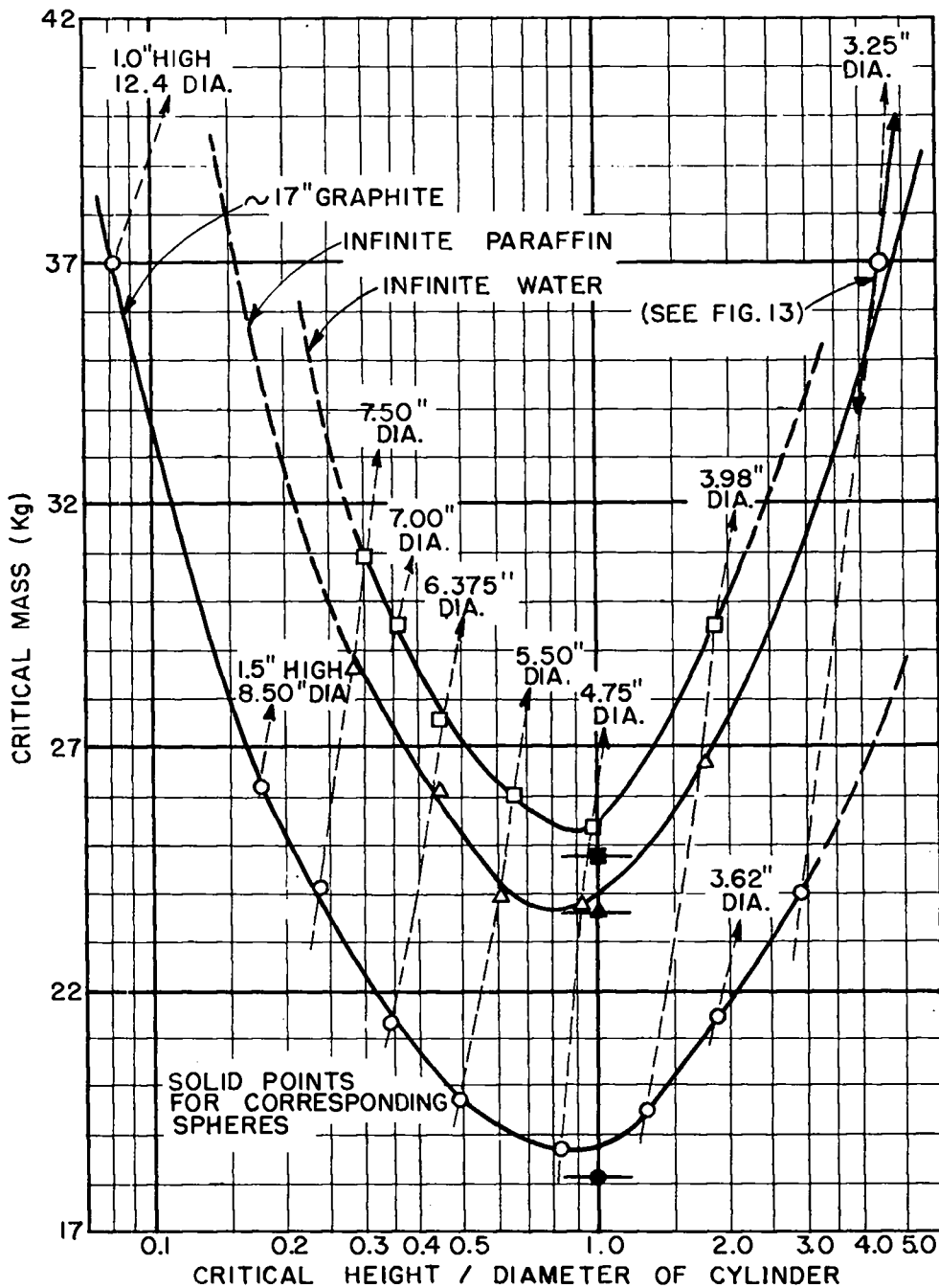masses corrected for the effect of the sup-
porting membrane.

FIG. 22. Critical mass of Oy cylinders vs critical height to diameter ratio of the cylinders for the tamper indicated. These critical mass values are not corrected for density deficiency. Note the iso-diameter broken lines, and the solid points with height to diameter ratio of 1 for the spheres.

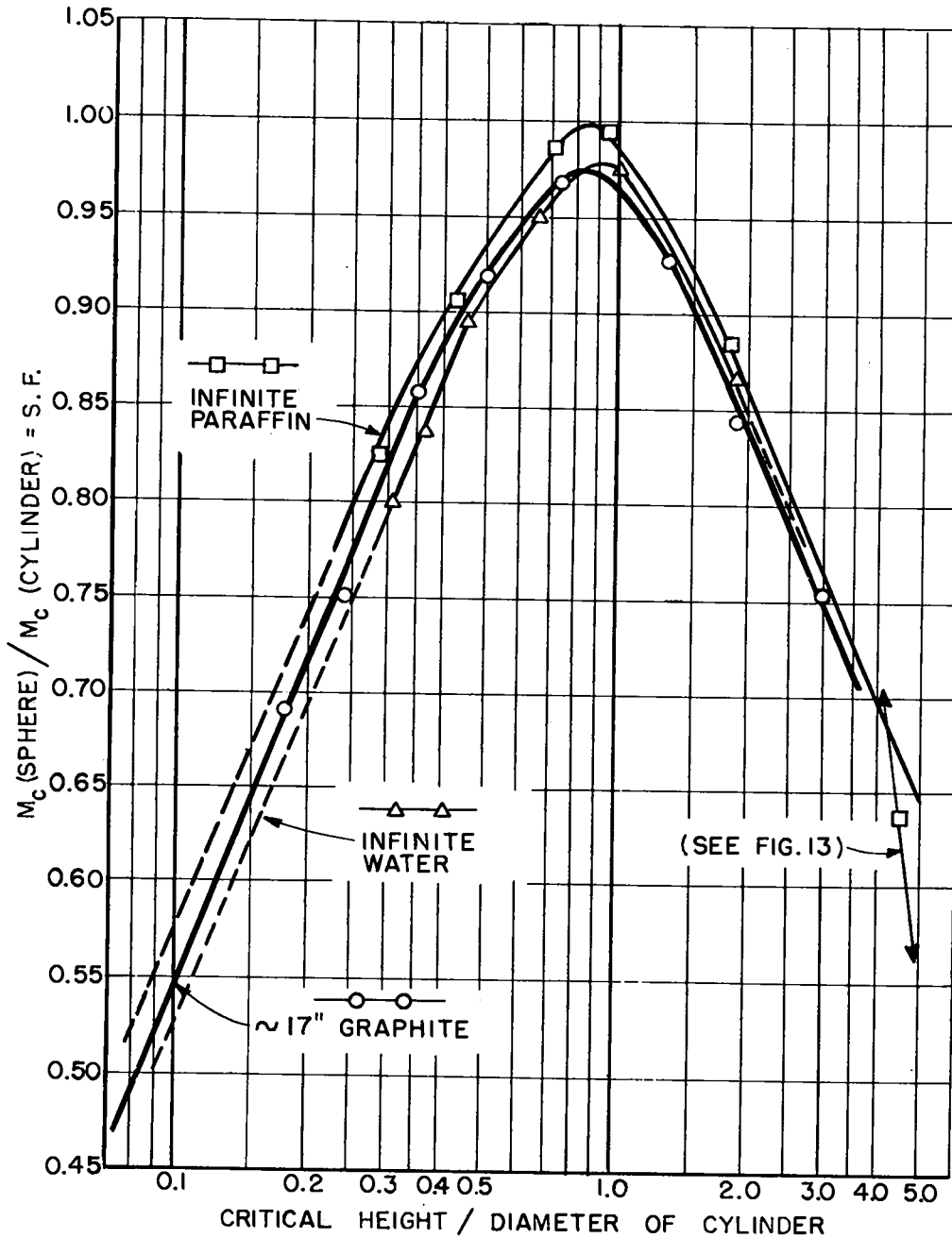FIG. 23. Shape factor of Oy cylinders vs critical height to diameter ratio of the cylinders for the tampers indicated.

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