REFERENCE 57

R. E. DONALDSON AND W. K. BROWN, "CRITICAL-MASS DETERMINATIONS OF LEAD-REFLECTED SYSTEMS," UNIVERSITY OF CALIFORNIA RADIATION LABORATORY REPORT UCRL-5255 (JUNE 1958).

UCRL 5255

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

CRITICAL-MASS DETERMINATIONS OF LEAD-REFLECTED SYSTEMS

LIVERMORE SITE

UCRL-5255
Criticality Studies, UC-47
TID-4500, 14th Edition

UNIVERSITY OF CALIFORNIA
Radiation Laboratory
Livermore, California

Contract No. W-7405-eng-48

CRITICAL-MASS DETERMINATIONS OF LEAD-REFLECTED SYSTEMS

Robert E. Donaldson and Wilbur K. Brown

June 9, 1958

Printed for the U. S. Atomic Energy Commission

Printed in USA. Price 50 cents. Available from the

Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.

CRITICAL-MASS DETERMINATIONS OF LEAD-REFLECTED SYSTEMS

Robert E. Donaldson and Wilbur K. Brown

Radiation Laboratory, University of California
Livermore, California

Abstract

A series of experimentally determined critical masses of cylindrical and spherical lead-reflected oralloy systems are presented. Critical masses are given for two oralloy core sizes in both cases and also for reflected and unreflected ends in the cylindrical case. Experimental methods are described and a photograph of the assembly machine is included.

I. Introduction

This report describes a series of cylindrical and spherical critical mass determinations of lead-reflected oralloy.

The cylindrical measurements were made by keeping the reflector thickness constant and increasing the Oy height. The spherical measurements were made by holding the Oy mass constant and increasing the reflector thickness. In both cases the critical values were determined by plotting the inverse multiplication as a function of the Oy height or reflector thickness. Extrapolation of the inverse multiplication to zero gives the critical value.

II. Apparatus

A. Assembly Machine

The assemblies were made on a vertical assembly machine which consisted of an 18-mil diaphragm supported above a vertical hydraulic ram. The assembly was divided between the diaphragm and the ram. The system could be assembled remotely from the control room by raising the ram. Figure 1 shows the assembly machine as used with a spherical assembly.

B. Counters

The generated neutrons were monitored by means of two LiI(Eu) crystal detectors, one Hanson counter, and one ionization chamber. The counter signals, in addition to being fed to scalers by conventional means, were fed to count-rate meters. These meters automatically separated the assembly if the counting rate exceeded a predetermined, safe value.

C. Materials

The cylindrical Oy was composed of discs of varying height, 9.881 cm in diameter and corresponding rings 11.15 cm o.d., 9.91 cm i.d. One disc had a hole 1.1 cm diam × 0.9 cm deep to contain the PoBe source. The cylindrical Pb was composed of rings 36.6 cm o.d., 11.2 cm i.d. and 11.2 cm o.d., and 9.9 cm i.d. The heights of the rings were such that any given height of Oy could be matched by the Pb. In addition, up to 13.3 cm of Pb was available to reflect each of the ends. The cylindrical Oy enrichment was 93.2% and the density was 18.8 g/cm^3.

The spherical Oy consisted of concentric hemispheric shells forming spheres of 14.96 cm and 14.22 cm in diameter (see Figure 5). The spherical Oy enrichment was 93.1% and the density was 18.7 g/cm^3. The spherical lead consisted of concentric shells nesting on the Oy and giving reflector thicknesses up to 11.4 cm. The reflector composition was lead plus 0.028% by weight Ca for hardening. The density of the Pb was 11.3 g/cm^3.

III. Procedure

The critical configurations were obtained by extrapolating the inverse multiplication curve to zero. The multiplication is defined as

$\frac{\text{counting rate with fissionable material}}{\text{counting rate without fissionable material}}$. The counting rate without fissionable material (base rate) was obtained by replacing the Oy in the assembly by D-38.

Background counting rates were taken by counting with the source removed and found to be insignificant.

To correct for the error resulting from the finite thickness of the steel diaphragm, multiplications were taken at each point for several diaphragm thicknesses. The results were then extrapolated to zero diaphragm thickness.

Due to the fact that the reflector shells were available only in finite thickness increments, the situation often arose where one reflector thickness gave a relatively low multiplication and the next made the system supercritical. In these cases, a closure check was made by plotting the inverse multiplication as a function of separation of the halves of the assembly for both thicknesses of reflector. In this way, an estimate of reflector worth as compared to separation of the halves can be obtained to allow the critical thickness to be estimated more accurately than by simple extrapolation of the multiplication curves. Figure 2 shows an inverse multiplication curve for the closure of a typical system.

IV. Results

A. Cylindrical

Critical mass determinations have been made on four configurations. Figure 3 shows a typical configuration and the inverse multiplication curve for this configuration. Table I lists the results for the cylindrical systems.

B. Spherical

The critical reflector thicknesses have been determined for two oralloy spheres. Figure 4 shows the inverse multiplication curve for the assembly pictured in Fig. 1. Table II lists the spherical results.

C. Errors

The critical values quoted have been corrected for the diaphragm thickness. Each measurement was made with three counters. The root-mean-square deviation of the extrapolations is included in the tables. A rough approximation of the over-all error is given by $100(1/M_{max})\%$, where M_{max} is the maximum measured multiplication.

Table I. Cylindrical Results.

Oy diam in cm	Pb reflector thickness in cm		Extrapolated critical mass in kg Oy	RMS spread in mass	Estimated over-all error
	Sides	Ends			
9.88	13.3	0	63.9	1.6%	2%
11.17	12.7	0	41.8	0.3%	1%
9.88	13.3	13.3	57.4	0.8%	1%
11.17	12.7	12.7	34.7	0.6%	1%

Table II. Spherical Results.

Oy diam cm	Oy mass kg	Extrapolated Pb critical thickness	RMS spread in extrapolated thickness	Estimated over-all error
14.22	27.99	17.22	2-1/2%	2-1/2%
14.90	32.65	8.99	0.3%	1%

/men

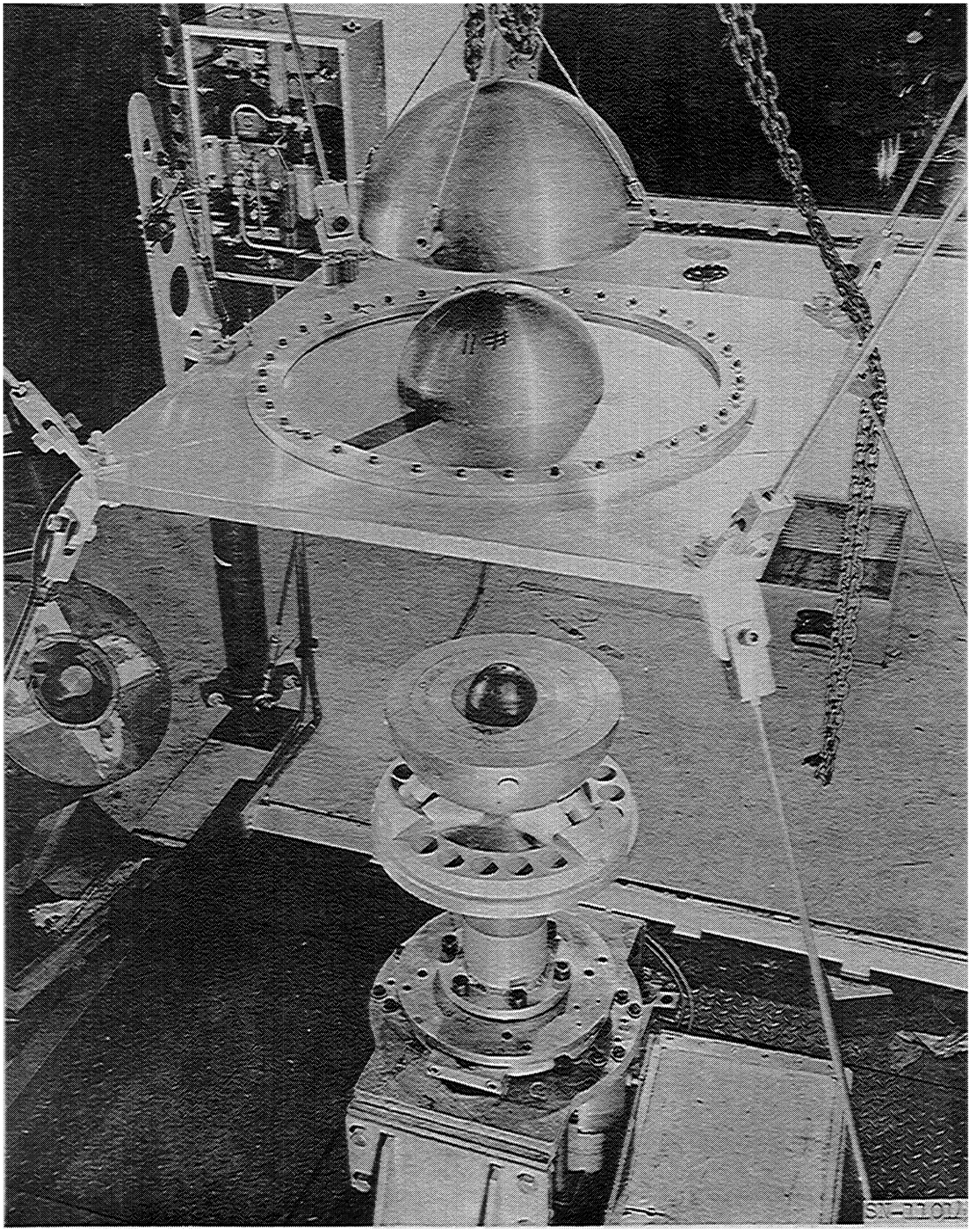
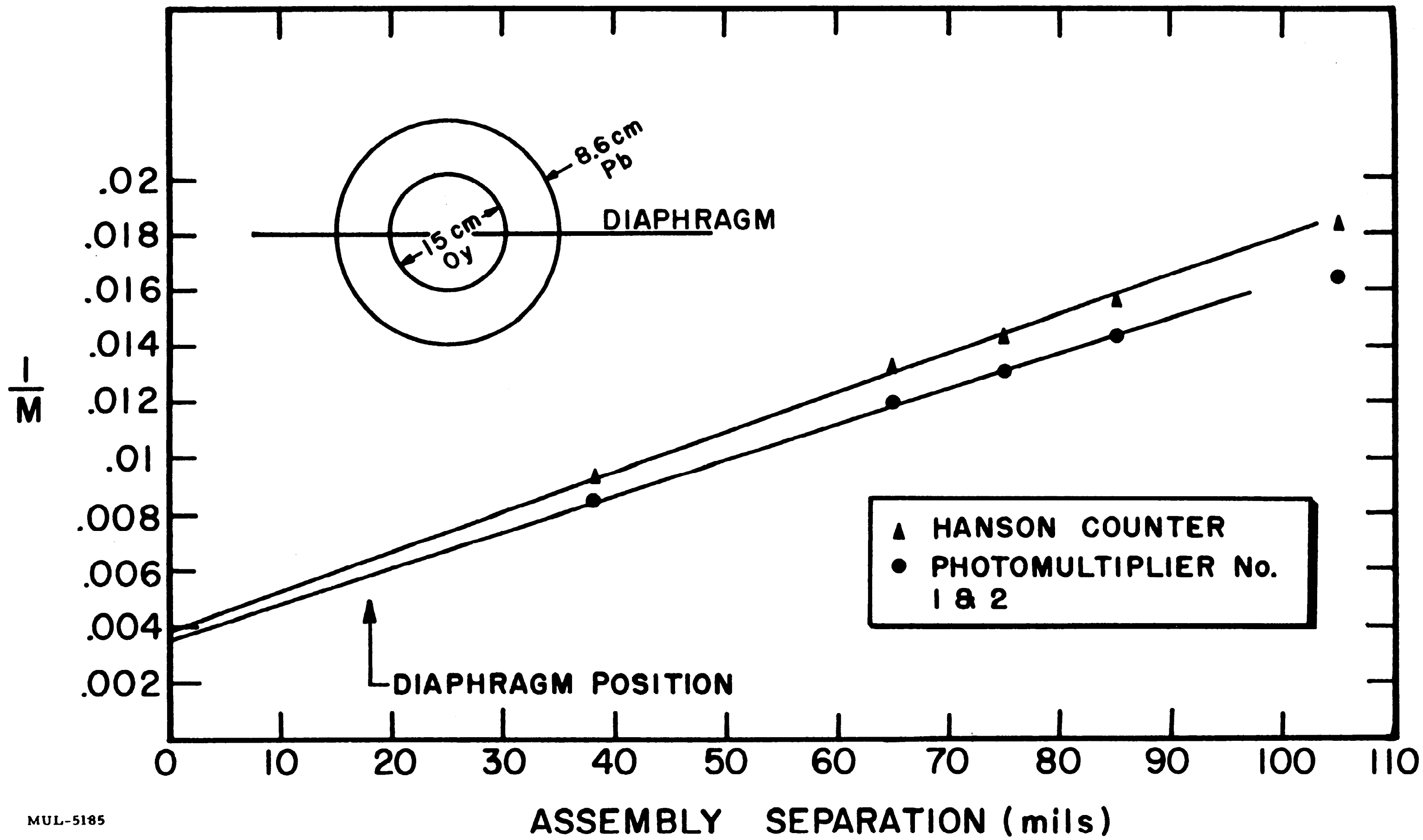


Fig. 1. Vertical assembly machine, as used with a spherical assembly.



MUL-5185

Fig. 2. Inverse multiplication vs separation.

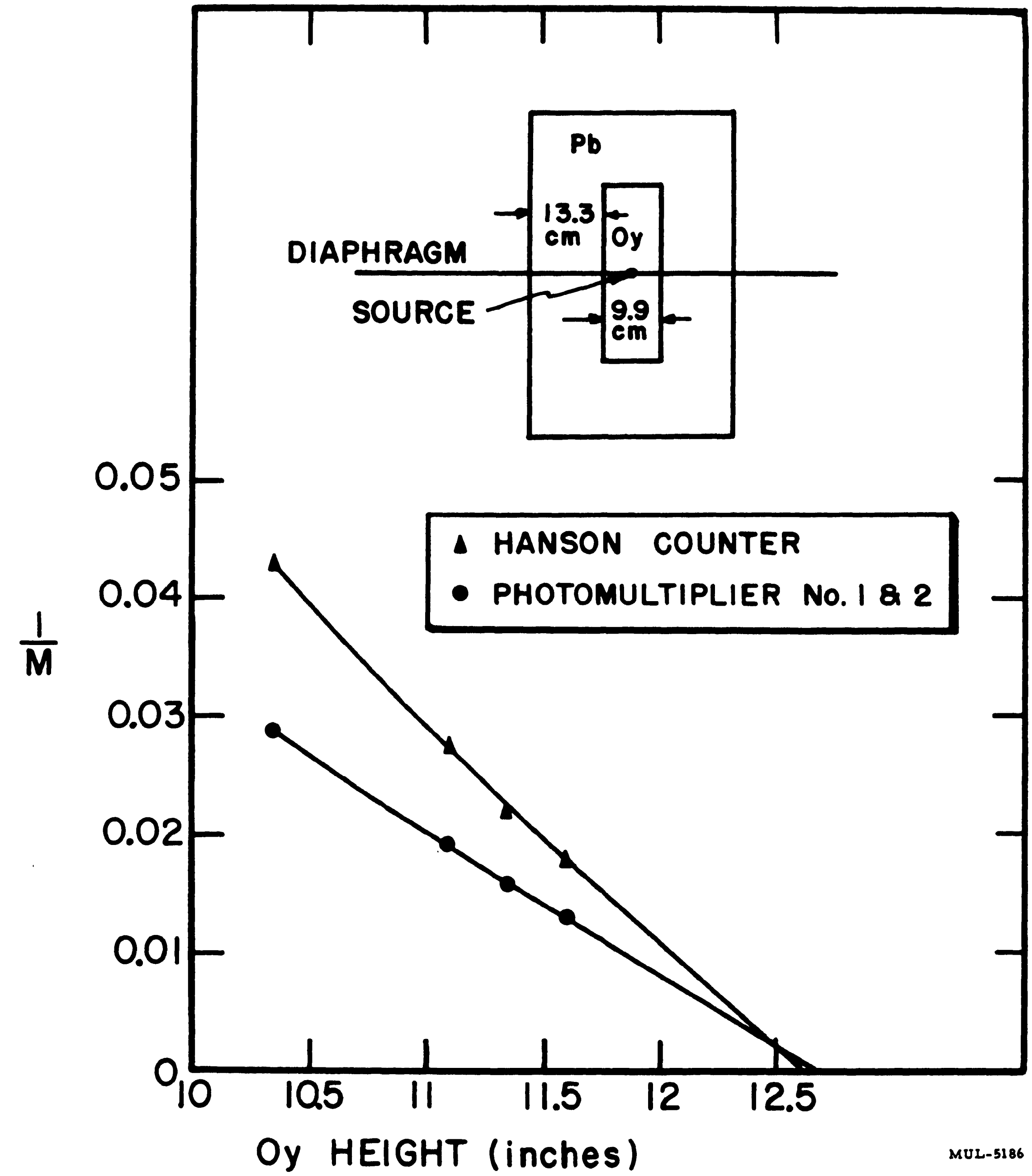
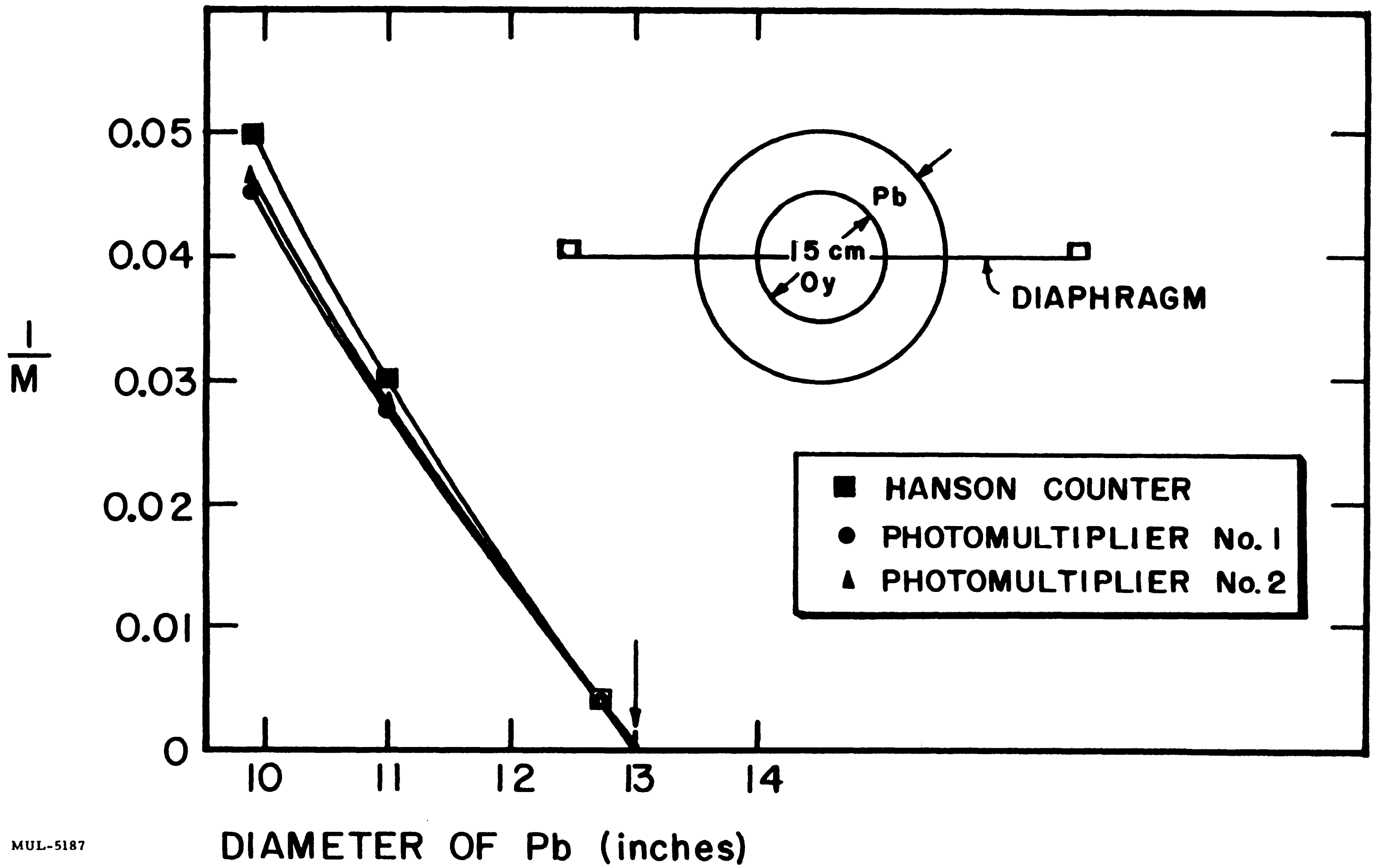
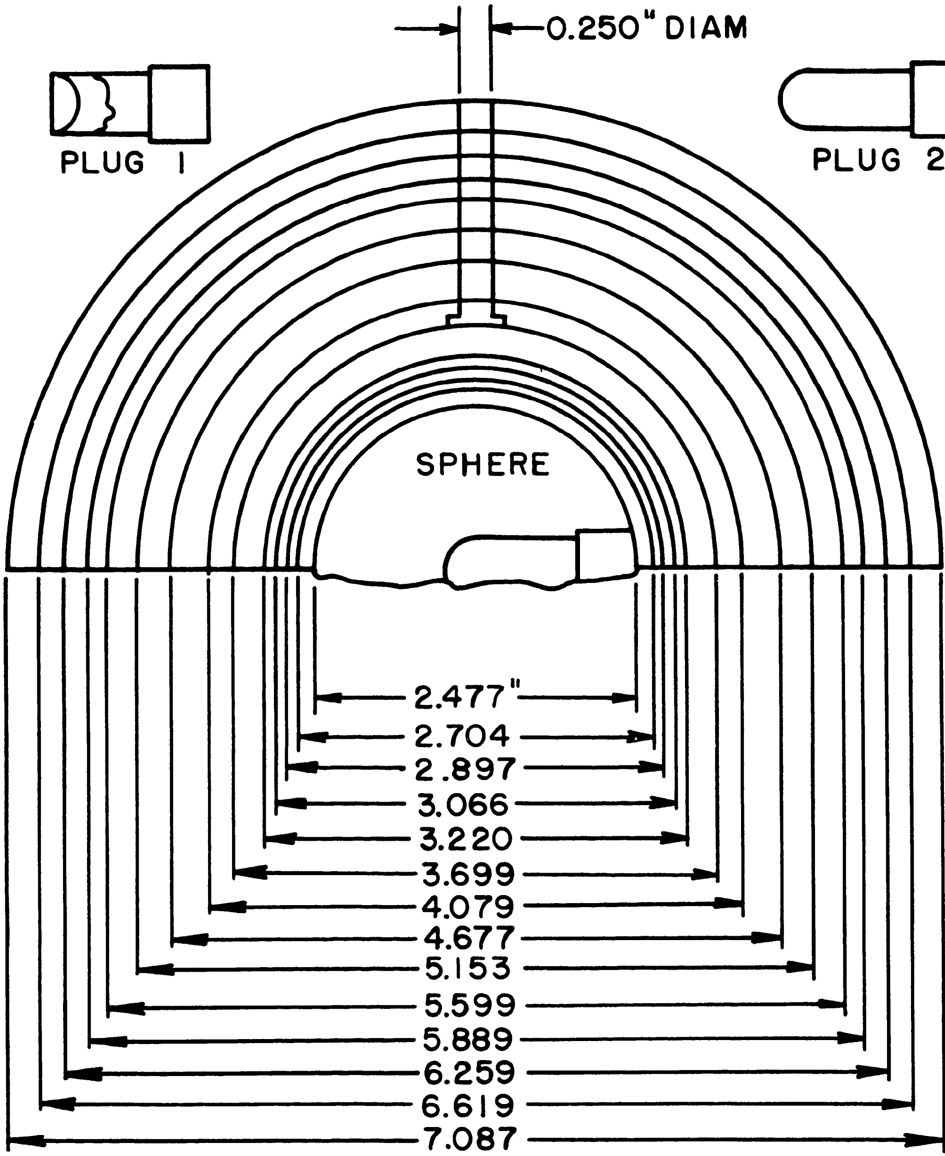


Fig. 3. Typical inverse multiplication curve for a cylindrical system.



MUL-5187

Fig. 4. Typical inverse multiplication curve for a spherical system.



MASS OF COMPLETE SPHERERICAL SHELL

SPHERE		2360.87 g
PLUG 1		63.84 g
PLUG 2		77.26 g
SHELL	2.704 O.D.	713.88 g
	2.897	714.59 g
	3.066	711.85 g
	3.220	716.51 g
	3.699	2728.91 g
	4.079	2754.59 g
SHELL	4.677 O.D.	5501.72 g
	5.153	5512.91 g
	5.599	6211.25 g
	5.889	4662.85 g
	6.259	6360.00 g
	6.619	7108.00 g
	7.087	10556.00 g

MUL-5188

Fig. 5. Spherical Oy.