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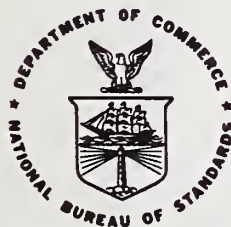
Central-Axis ^{60}CO Ionization Measurements in Graphite As A Function of Phantom Diameter, Depth, and Field Size

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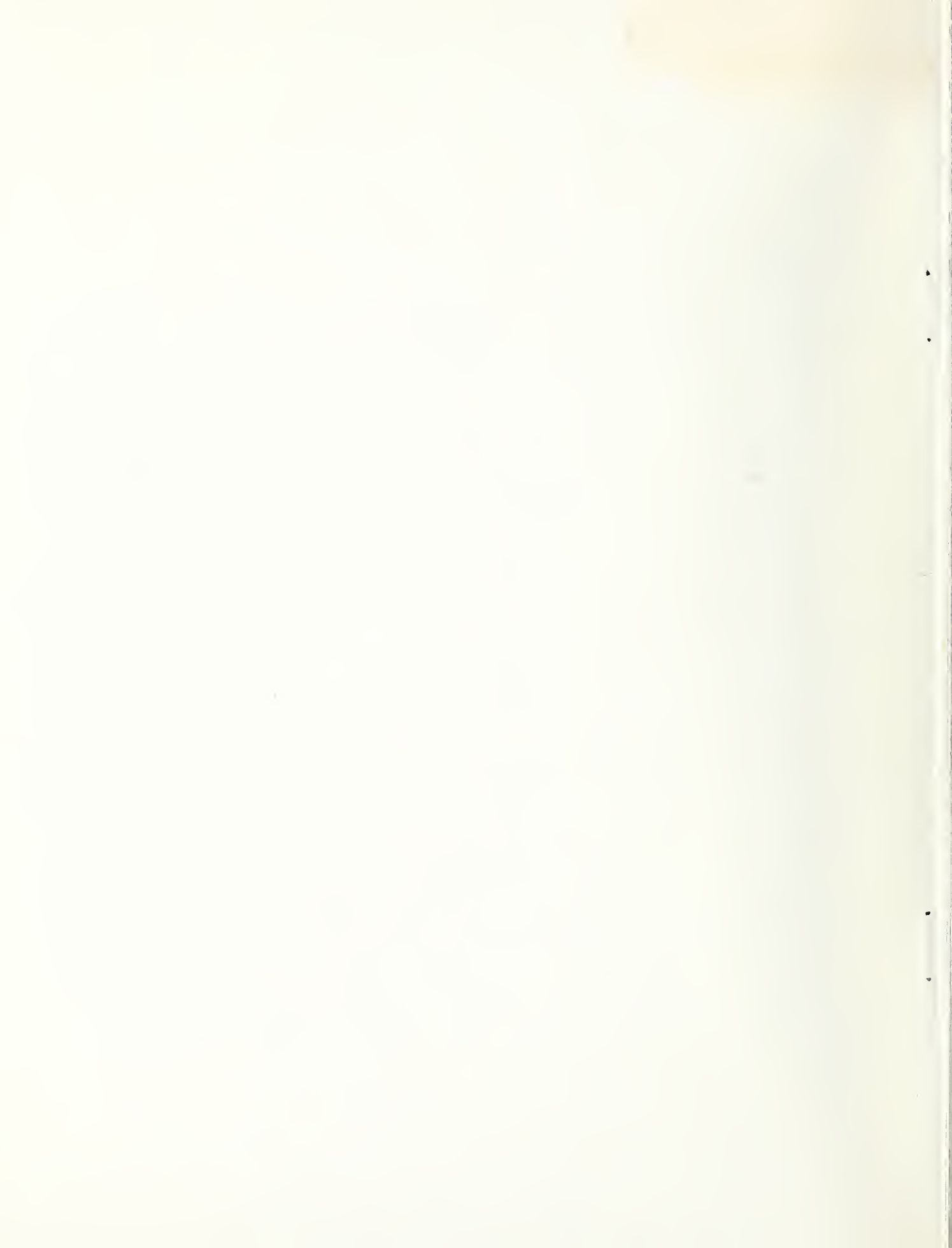
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Abstract

Ionization measurements along the central axis were made
in a graphite phantom irradiated with cobalt-60 gamma rays.
The measurements were made under the following conditions:
phantom diameters of 15, 20, and 30 cm; 15 depths from 1
to 39 g/cm^2; and square field sizes of 8.3, 10.5, 12.4, and
17.4 cm at a fixed detector position of 1 m from the
source. Empirical fits to the data aid in correcting
calorimeter comparisons to a common geometry.

Key Words: Absorbed dose; cobalt-60; graphite; calori-
meter comparisons; phantom size.

I. INTRODUCTION

In view of the importance of achieving accurate and uniform mea-

surements in radiation therapy and radiation protection, and because

those goals are linked to comparisons of calorimetric primary standards,

this investigation was initiated to aid in the comparison of calori-

meters constructed of graphite and irradiated with cobalt-60 gamma rays.

Because comparisons of those instruments will be meaningful only if they

refer to a common geometry, an investigation was made to study the vari-

ation of absorbed dose in graphite along the central axis as a function

of phantom diameter, depth of measurement, field size, and back-

scattering thickness. This investigation required ionization measure-

ments using 185 experimental setups: phantom diameters of 15, 20, and

30 cm; 15 depths from 1 to 39 g/cm^2; and square field sizes of 8.3,

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10.5, 12.4, and 17.4 cm. The data permit interpolation between those values including approximate extrapolations to an infinite diameter phantom. The smallest phantom diameter of 15 cm was that of the National Bureau of Standards (NBS) graphite calorimeter [1]. When calorimeters of different diameters are compared, correction factors must be specially determined, such as in the recent BNM-LMRI/NBS comparison [2] where a correction was applied to measurements made with a 3-cm diameter calorimeter for comparison with measurements made with the NBS 15-cm diameter calorimeter.

A program for the international comparison of absorbed-dose calorimeters has been established at the Bureau International des Poids et Mesures (BIPM). All calorimetric measurements must be compared with the BIPM graphite ionization chamber, enclosed by a 30-cm diameter phantom, which is the intermediary instrument for the calorimetric comparisons. This investigation will aid in correcting measurements to a specified, or to an infinite, diameter phantom.

II. EXPERIMENTAL SETUP

Figure 1 shows the experimental setup. A spherical graphite ionization chamber (similar to the one described in reference [3]), 1.27 cm inner diameter, was enclosed near the front surface of a graphite phantom, 15.2 cm diameter by 10.0 cm thick, which are the outside dimensions of the NBS calorimeter. The distance between the graphite ion collecting electrode and the cobalt-60 source was kept fixed at 1 m. Measurements were made at different depths by laying

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graphite discs (1.7 g/cm^3), 15.2 cm in diameter and of various thickness, on the phantom. Measurements were also made by enclosing those bodies with graphite sleeves, one 20.3 cm outside diameter by 15.3 cm inner diameter, and another of 30.5 cm outside diameter by 15.3 cm inner diameter. Height adjustment screws permitted the sleeves to be raised or lowered so that their top surfaces were at the same height as the top surface of the 15.2 cm diameter disc nearest to the source. Three 2.5 cm thick graphite rings (r_1, r_2, and r_3) were raised, one at a time, and placed against the rear of the graphite block simulating the NBS portable calorimeter to determine if the graphite behind the ion chamber provided an essentially infinite backscattering thickness. The placement and removal of all the massive pieces of graphite caused small deflections in the wooden supports. However, the distance between the source and collecting electrode was always fixed within 0.025 mm by means of an adjusting nut (not shown) until the dial indicator showed that the collecting electrode returned to its initial position.

Beam profile measurements were made of the four square field sizes by exposing film in air at 1 m from the source, and then measuring the film density along lines bisecting opposite sides. The distances (in centimeters) across the 90% and the 50% points of central density were, respectively, 5.3 and 8.3, 7.4 and 10.5, 9.5 and 12.4, and 14.3 and 17.4. The beam sizes at the 50% points are used in this report.

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III. RESULTS

Measurements showed that the backscattering ring (r_1) increased the response by (0.07 ± 0.03)%, and that there was no further significant increase in response with ring r_2 also in position. All three rings (r_1, r_2, and r_3) were in position during the following measurements.

A complicated factor that affects the detector response is geometry, such as the square field sizes that range from being larger in area to being much smaller than the circular phantom cross sections. Another is the unknown effects of collimator-scattered and leakage radiation that can vary with different source heads over the phantom front surface. These considerations, the small increase in detector response with phantom diameter, plus the fact that only three measurements made were at a given depth, make it clear that the infinite diameter response can be estimated only roughly. Fortunately, the further increase in response beyond the largest (30 cm) phantom size is quite small, and this is not an important region because phantoms of larger diameter are not in use in international comparisons. Nevertheless, it is still of some interest to estimate the correction to infinite phantom diameter, however rough that estimate may be. Empirical fits to the data points seemed adequate. The relative current is plotted against the reciprocal of the square of the phantom diameter in Figure 2. The measurements were made at a depth of 4.7 g/cm^2 and with the 10.5 cm field, close to standard conditions for international comparison of calorimeters. The increase in current is only 0.5% when the phantom diameter, D, is increased from 15 to 30 cm. A useful equation for the range of $15 \leq D \leq 30$ cm is of the type:

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$$Y_\alpha = a_0 + a_1X + a_2X^2, \text{ where } X = D^{-2}.$$

In this range, the curve has no point of inflexion which is a reasonable physical expectation. The numerical coefficients of this equation are tabulated in Tables 1 to 4. This equation with three constant coefficients passes, of course, through the three data points, but the change in detector response as a function of D (at a particular depth) is not determined from any such single curve. It is determined from results derived from the curves (Y_α) plotted as a function of depth. An illustrative example is given below.

Tables 1 to 4 summarize the results of the measurements, corrected for cobalt-60 decay. Column 1 lists the depth of measurement, and column 2 lists the diameters of the phantom as D(1), D(2), and D(3), where

$$D(1) = 15.24 \text{ cm}, \quad D(2) = 20.32 \text{ cm, and } D(3) = 30.48 \text{ cm}.$$

Column 3 lists the relative measured ionization chamber current. Column 4 shows the percent current increase relative to the 15.2 cm diameter phantom. Columns 5 to 7 list the coefficients of the equation $Y_\alpha = a_0 + a_1X + a_2X^2$ calculated from the three values of D^{-2} and Y shown in columns 2 and 3. Table 5 shows the percent increase in response calculated from equations Y_α and Y_β when the phantom is increased from 30.5 cm to infinite diameter.

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Other empirical fits to the data can be made. An equation of the type:

$$Y_\beta = b_0 + b_2 X^2 + b_4 X^4$$

also passes through the data points, but most of the curves resulted in points of inflexion in the range of $15 \le D \le 20$ cm. Mainly for this reason, the coefficients of Y_β were not included in Tables 1 to 4. However, the curves, Y_α and Y_β, were used to compare calculated response increases when a 30.5 cm diameter phantom is increased to infinite diameter.

The central axis measurements for each field and phantom size as a function of depth were least-squares fitted to the polynomial:

$$y = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4,$$

where y is the detector response and x is depth in mass per unit area, determined from micrometer and mass measurements of the 15.2 cm diameter plates. The coefficients are listed in Table 6 for the different field sizes and phantom diameters shown in columns 1 and 2, respectively.

Figure 3 is an illustrative example that shows the calculated difference in response of an 18 cm diameter calorimeter compared to one of 15 cm diameter for the 10.5 x 10.5 cm field. The percent increase in response of the former is plotted as a function of the measurement depth, x. The points were calculated from the equation for Y_α, the coefficients of which are listed in Table 2. The points are represented by the linear equation $y = 0.021x + 0.13$.

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The cobalt-60 source was in an Eldorado Super G head manufactured by Atomic Energy of Canada Limited. It is important to note that the results might have been somewhat different, if the experiment had been done with a different source head but with the same field dimensions, because of differences in scattering and energy spectral distributions incident on the phantom. Thus the results reported here are, at best, an approximation for correcting two different diameter calorimeters if they are compared in another cobalt-60 source apparatus.

IV. SUMMARY

Comparison of calorimeters requires corrections to identical irradiation conditions. This investigation aids in determining those corrections from ionization measurements made under the following conditions: phantom diameters of 15, 20, and 30 cm; 15 depths from 1 to 39 g/cm^2; square field sizes of 8.3, 10.5, 12.4, and 17.4 cm at the 50% points; a fixed source-detector distance of 1 m; and saturated back-scattering thickness.

V. ACKNOWLEDGEMENT

REFERENCES

[1] Domen, S. R. and Lamperti, P. J., A heat-loss-compensated calori-
     meter: theory, design, and performance, J. Res. Nat. Bur. Stand.
     (U.S.), 78A (Phys. and Chem.) No. 5, 595610, (Sept.-Oct. 1974).

[2] Guiho, J.-P., Simoen, J.-P., and Domen, S. R., Comparison of
     BNM-LMRI and NBS absorbed-dose standards for ^{60}Co gamma rays,
     Metrologia, No. 2, 63-68, (1978).

[3] Loftus, T. P., and Weaver, J. T., Standardization of ^{60}Co and ^{137}Cs
     Gamma-ray Beam in Terms of Exposure, J. Res. Nat. Bur. Stand.

<p style="text-align:center">Table 1. Results with an 8.3 x 8.3 cm ^{60}Co field</p>

Graphite Depth (g/cm^2)	Phantom Diameter (cm)	Relative Current Y*		Increase from a 15.2 cm dia. Phantom (%)	Coefficients of $Y_c = a_0 + a_1X + a_2X^2$		
					a_0	a_1	a_2
1.4	D(1) = 15.24	28.710	05 4	0.00			
	D(2) = 20.32	28.748	16 5	0.13	28.768	-17.2	-2700
	D(3) = 30.48	28.763	09 4	0.18			
2.0	D(1)	28.255	08 4	0.00			
	D(2)	28.289	10 3	0.12	28.301	2.0	-2900
	D(3)	28.300	12 6	0.16			
2.9	D(1)	27.631	19 4	0.00			
	D(2)	27.670	08 3	0.14	27.702	-9.6	-1600
	D(3)	27.690	05 4	0.21			
4.7	D(1)	26.079	19 4	0.00			
	D(2)	26.126	06 3	0.18	26.146	1.2	-3900
	D(3)	26.143	15 3	0.24			
6.4	D(1)	24.559	02 2	0.00			
	D(2)	24.596	01 2	0.15	24.650	-21.4	0
	D(3)	24.629	08 3	0.28			
8.8	D(1)	22.485	08 3	0.00			
	D(2)	22.539	12 3	0.24	22.588	-15.6	-1930
	D(3)	22.569	00 3	0.37			
11.3	D(1)	20.162	28 3	0.00			
	D(2)	20.241	07 3	0.39	20.300	-14.9	-4000
	D(3)	20.280	12 3	0.58			
14.0	D(1)	18.066	14 3	0.00			
	D(2)	18.123	18 3	0.32	18.181	-20.1	-1560
	D(3)	18.158	03 3	0.51			
17.5	D(1)	15.237	04 3	0.00			
	D(2)	15.303	20 4	0.44	15.368	-21.9	-1990
	D(3)	15.342	02 3	0.69			
21.4	D(1)	12.614	22 3	0.00			
	D(2)	12.673	02 3	0.47	12.750	-31.8	0
	D(3)	12.716	08 3	0.81			
24.7	D(1)	10.642	06 3	0.00			
	D(2)	10.704	20 3	0.59	10.763	-19.6	-2000
	D(3)	10.740	09 3	0.92			
28.1	D(1)	8.937	21 4	0.00			
	D(2)	8.996	14 3	0.66	9.067	-23.4	- 430
	D(3)	9.036	26 3	1.11			
31.9	D(1)	7.264	17 3	0.00			
	D(2)	7.314	26 3	0.70	7.381	-27.5	0
	D(3)	7.352	10 3	1.22			
35.7	D(1)	5.978	10 2	0.00			
	D(2)	6.021	03 2	0.72	6.081	-24.1	0
	D(3)	6.056	11 3	1.30			
39.1	D(1)	4.950	09 3	0.00			
	D(2)	4.990	18 3	0.81	5.044	-21.9	0
	D(3)	5.021	11 5	1.43			

* The first entry is 28.710 with a mean error of 0.006% for the mean of 4 measurements.

Table 2. Results with a 10.5 x 10.5 cm ^{60}Co Field

Graphite Depth (g/cm^2)	Phantom Diameter (cm)	Relative Current Y			Increase from a 15.2 cm dia. Phantom (%)	Coefficients of $Y_\alpha = a_0 + a_1 X + a_2 X^2$		
						a_0	a_1	a_2
1.4	D(1) = 15.24	29.332	12	3	0.00	29.435	-8.7	-3500
	D(2) = 20.32	29.393	14	5	0.21			
	D(3) = 30.48	29.421	05	3	0.30			
2.0	D(1)	28.893	22	4	0.00	29.021	-27.7	-460
	D(2)	28.951	10	3	0.20			
	D(3)	28.991	14	4	0.34			
2.9	D(1)	28.305	08	3	0.00	28.400	3.9	-6050
	D(2)	28.374	12	4	0.25			
	D(3)	28.398	22	3	0.33			
4.7	D(1)	26.816	11	4	0.00	26.963	-16.4	-4140
	D(2)	26.899	04	3	0.31			
	D(3)	26.941	13	3	0.47			
6.4	D(1)	25.356	16	4	0.00	25.521	-24.2	-3290
	D(2)	25.443	27	3	0.34			
	D(3)	25.491	07	3	0.53			
8.8	D(1)	23.366	12	3	0.00	23.543	-17.2	-5570
	D(2)	23.469	05	3	0.44			
	D(3)	23.518	25	4	0.65			
11.3	D(1)	21.127	05	3	0.00	21.337	-49.0	0
	D(2)	21.216	25	4	0.42			
	D(3)	21.286	19	3	0.75			
14.0	D(1)	19.042	07	4	0.00	19.245	-37.2	-2320
	D(2)	19.141	25	3	0.52			
	D(3)	19.202	02	3	0.84			
17.5	D(1)	16.202	03	3	0.00	16.415	-36.8	-2960
	D(2)	16.309	09	3	0.66			
	D(3)	16.372	07	3	1.05			
21.4	D(1)	13.527	22	3	0.00	13.746	-34.4	-3830
	D(2)	13.640	17	3	0.84			
	D(3)	13.705	09	3	1.31			
24.7	D(1)	11.495	11	3	0.00	11.706	-36.2	-3000
	D(2)	11.601	07	3	0.92			
	D(3)	11.664	10	3	1.47			
28.1	D(1)	9.707	12	3	0.00	9.904	-34.3	-2670
	D(2)	9.806	08	3	1.01			
	D(3)	9.864	07	3	1.62			
31.9	D(1)	7.940	09	3	0.00	8.139	-46.6	0
	D(2)	8.024	21	3	1.06			
	D(3)	8.091	22	3	1.90			
35.7	D(1)	6.567	10	3	0.00	6.740	-40.1	0
	D(2)	6.642	11	3	1.14			
	D(3)	6.697	15	3	1.97			
39.1	D(1)	5.458	11	3	0.00	5.618	-37.3	0
	D(2)	5.527	11	3	1.26			
	D(3)	5.579	29	4	2.21			

Table 3. Results with a 12.4 x 12.4 cm ^{60}Co Field

Graphite Depth (g/cm^2)	Phantom Diameter (cm)	Relative Current Y			Increase from a 15.2 cm dia. Phantom (%)	Coefficients of $Y_\alpha = a_0 + a_1 X + a_2 X^2$		
						a_0	a_1	a_2
1.4	D(1) = 15.24	29.675	14	8	0.00	29.817	-3.8	-6790
	D(2) = 20.32	29.768	06	7	0.31			
	D(3) = 30.48	29.805	13	7	0.44			
2.0	D(1)	29.246	13	9	0.00	29.389	4.5	-8740
	D(2)	29.349	07	7	0.35			
	D(3)	29.384	09	8	0.47			
2.9	D(1)	28.672	10	9	0.00	28.838	-12.2	-6100
	D(2)	28.772	36	9	0.35			
	D(3)	28.818	06	7	0.51			
4.7	D(1)	27.218	06	6	0.00	27.428	-27.4	-4950
	D(2)	27.333	11	8	0.42			
	D(3)	27.393	08	7	0.64			
6.4	D(1)	25.788	13	7	0.00	25.986	-4.2	-9660
	D(2)	25.919	13	8	0.51			
	D(3)	25.970	05	4	0.70			
8.8	D(1)	23.821	17	5	0.00	24.053	-8.8	-10500
	D(2)	23.970	17	5	0.63			
	D(3)	24.031	03	4	0.88			
11.3	D(1)	21.614	14	4	0.00	21.869	-21.6	-8740
	D(2)	21.765	10	4	0.70			
	D(3)	21.835	06	4	1.03			
14.0	D(1)	19.538	12	4	0.00	19.834	-32.0	-8540
	D(2)	19.706	05	4	0.86			
	D(3)	19.790	08	7	1.29			
17.5	D(1)	16.705	11	4	0.00	16.995	-34.5	-7620
	D(2)	16.867	23	5	0.97			
	D(3)	16.949	14	4	1.46			
21.4	D(1)	14.024	05	4	0.00	14.310	-37.4	-6790
	D(2)	14.180	03	4	1.12			
	D(3)	14.262	24	5	1.70			
24.7	D(1)	11.955	05	4	0.00	12.203	-15.5	-9750
	D(2)	12.107	09	4	1.27			
	D(3)	12.175	18	6	1.84			
28.1	D(1)	10.134	06	5	0.00	10.390	-35.8	-6520
	D(2)	10.271	07	5	1.36			
	D(3)	10.346	14	5	2.09			
31.9	D(1)	8.318	06	4	0.00	8.559	-35.7	-4740
	D(2)	8.444	07	4	1.52			
	D(3)	8.516	09	4	2.37			
35.7	D(1)	6.908	12	4	0.00	7.112	-44.1	-1770
	D(2)	7.014	08	4	1.54			
	D(3)	7.082	14	4	2.51			
39.1	D(1)	5.762	10	4	0.00	5.955	-35.4	-2220
	D(2)	5.856	11	6	1.64			
	D(3)	5.914	02	4	2.65			

Table 4. Results with a 17.4 x 17.4 cm ^{60}Co Field

Graphite Depth (g/cm^2)	Phantom Diameter (cm)	Relative Current Y			Increase from a 15.2 cm dia Phantom (%)	Coefficients of $Y_a = a_0 + a_1 X + a_2 X^2$		
						a_0	a_1	a_2
1.4	D(1) = 15.24	30.661	09	3	0.00			
	D(2) = 20.32	30.944	12	4	0.92	31.151	-49.2	-15000
	D(3) = 30.48	31.081	04	3	1.37			
2.0	D(1)	30.234	21	3	0.00			
	D(2)	30.565	09	3	1.09	30.722	-2.9	-25700
	D(3)	30.690	18	4	1.51			
2.9	D(1)	29.674	17	4	0.00			
	D(2)	30.025	09	3	1.18	30.235	-30.8	-23100
	D(3)	30.175	01	3	1.69			
4.7	D(1)	28.239	11	4	0.00			
	D(2)	28.654	07	3	1.47	28.912	-42.7	-26400
	D(3)	28.835	06	3	2.11			
6.4	D(1)	26.822	08	3	0.00			
	D(2)	27.283	20	5	1.72	27.571	-47.7	-29300
	D(3)	27.486	09	3	2.48			
8.8	D(1)	24.887	07	3	0.00			
	D(2)	25.416	11	3	2.13	25.699	-24.7	-38100
	D(3)	25.628	13	3	2.98			
11.3	D(1)	22.689	11	3	0.00			
	D(2)	23.302	10	3	2.70	23.593	-4.3	-47800
	D(3)	23.533	09	3	3.72			
14.0	D(1)	20.653	12	3	0.00			
	D(2)	21.295	21	4	3.11	21.582	6.6	-51600
	D(3)	21.529	09	3	4.24			
17.5	D(1)	17.823	07	3	0.00			
	D(2)	18.509	00	3	3.85	18.820	4.1	-54800
	D(3)	18.761	04	3	5.26			
21.4	D(1)	15.107	20	3	0.00			
	D(2)	15.793	04	3	4.54	16.076	21.9	-57360
	D(3)	16.033	23	3	6.13			
24.7	D(1)	12.996	04	3	0.00			
	D(2)	13.656	19	4	5.08	13.947	9.3	-53500
	D(3)	13.895	25	4	6.92			
28.1	D(1)	11.116	08	3	0.00			
	D(2)	11.728	07	3	5.51	12.012	0.1	-48320
	D(3)	11.956	33	3	7.56			
31.9	D(1)	9.222	08	3	0.00			
	D(2)	9.778	04	3	6.03	10.035	0.4	-44000
	D(3)	9.985	11	3	8.27			
35.7	D(1)	7.721	06	3	0.00			
	D(2)	8.207	19	3	6.29	8.452	-13.6	-36300
	D(3)	8.396	08	3	8.74			
39.1	D(1)	6.493	04	3	0.00			
	D(2)	6.921	16	4	6.59	7.122	-1.5	-33600
	D(3)	7.081	12	4	9.06			

Table 5. Percent increase in detector response when a 30.5 cm diameter
phantom is increased to infinite diameter*

Depth (g/cm^2)	Side of square field (cm)							
	8.3		10.5		12.4		17.4	
	Y_α (%)	Y_β (%)	Y_α (%)	Y_β (%)	Y_α (%)	Y_β (%)	Y_α (%)	Y_β (%)
1.4	0.08	0.01	0.05	0.03	0.04	0.03	0.23	0.13
2.0	0.00	0.01	0.11	0.04	0.02	0.03	0.11	0.11
2.9	0.04	0.02	0.01	0.02	0.07	0.04	0.20	0.14
4.7	0.01	0.02	0.08	0.04	0.13	0.06	0.27	0.17
6.4	0.09	0.04	0.12	0.05	0.06	0.05	0.31	0.20
8.8	0.08	0.04	0.11	0.06	0.09	0.07	0.28	0.22
11.3	0.10	0.05	0.25	0.10	0.15	0.09	0.26	0.26
14.0	0.13	0.06	0.22	0.09	0.22	0.11	0.25	0.28
17.5	0.17	0.07	0.26	0.11	0.27	0.13	0.32	0.35
21.4	0.27	0.11	0.30	0.13	0.34	0.16	0.28	0.39
24.7	0.22	0.10	0.36	0.16	0.23	0.14	0.37	0.45
28.1	0.34	0.14	0.41	0.18	0.44	0.20	0.47	0.50
31.9	0.40	0.15	0.62	0.25	0.52	0.23	0.51	0.54
35.7	0.43	0.17	0.65	0.25	0.70	0.27	0.68	0.60
39.1	0.47	0.18	0.72	0.29	0.69	0.27	0.57	0.59

* Calculated from $Y_\alpha = a_0 + a_1 X + a_2 X^2$ and $Y_\beta = b_0 + b_2 X^2 + b_4 X^4$, where $X = D^{-2}$.

Table 6. Summary of central axis detector response

Field Size	Phantom Diameter	Equation Coefficients*				
(cm)	(cm)	c_0	$10\,c_1$	$10^2 c_2$	$10^4 c_3$	$10^6 c_4$
8.3	D(1) = 15.24	29.855	-7.481	-1.775	9.125	-9.878
"	D(2) = 20.32	29.883	-7.446	-1.777	9.080	-9.800
"	D(3) = 30.48	29.889	-7.399	-1.802	9.141	-9.861
10.5	D(1)	30.389	-6.946	-1.912	8.843	-9.163
"	D(2)	30.441	-6.881	-1.933	8.852	-9.153
"	D(3)	30.460	-6.820	-1.962	8.914	-9.206
12.4	D(1)	30.702	-6.736	-1.947	8.650	-8.794
"	D(2)	30.780	-6.635	-1.976	8.629	-8.716
"	D(3)	30.807	-6.574	-1.997	8.646	-8.708
17.4	D(1)	31.677	-6.677	-1.848	7.999	-7.976
"	D(2)	31.916	-6.288	-1.871	7.561	-7.278
"	D(3)	32.017	-6.084	-1.971	7.769	-7.475

* $y = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4$, where x is the depth in g/cm^2.

FIGURE LEGENDS

Fig. 1 Experimental setup for determining the ionometric response as a
function of phantom diameter, depth, field size, and back-
scattering thickness. The ion chamber was fixed at 1 m from
the source and centered on the beam axis.

Fig. 2 Relative current as a function of phantom diameter at a depth of
4.7 g/cm^2, with a field size of 10.5 x 10.5 cm in air at 1 m.

Fig. 3 Illustrative example showing the percent increase in central
axis absorbed-dose rate in an 18 cm diameter calorimeter
compared to one of 15 cm diameter, for a 10.5 x 10.5 cm field
in air at 1 m, in a cobalt-60 γ-ray beam.

BEAM DIRECTION

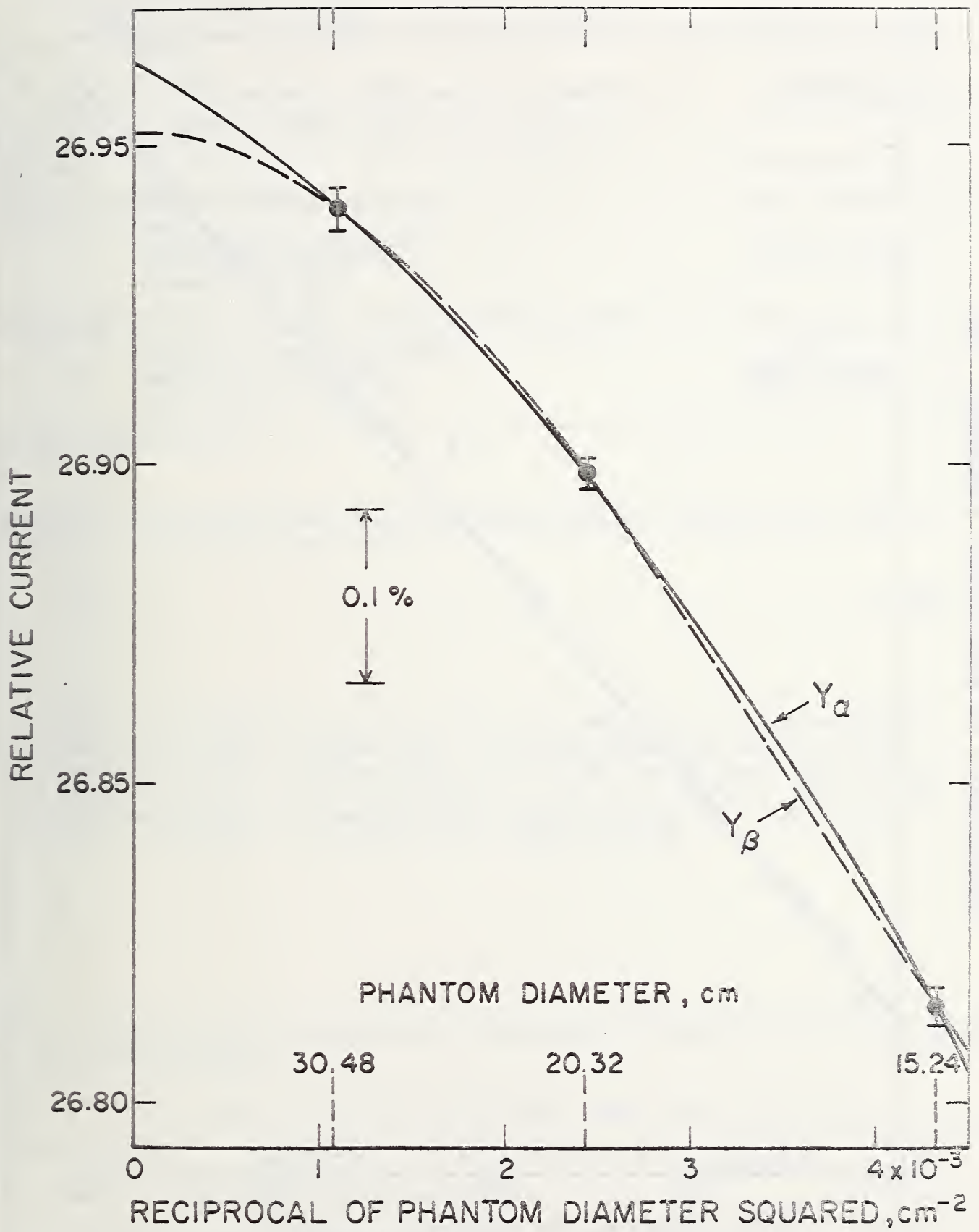GRAPHITE SLEEVES

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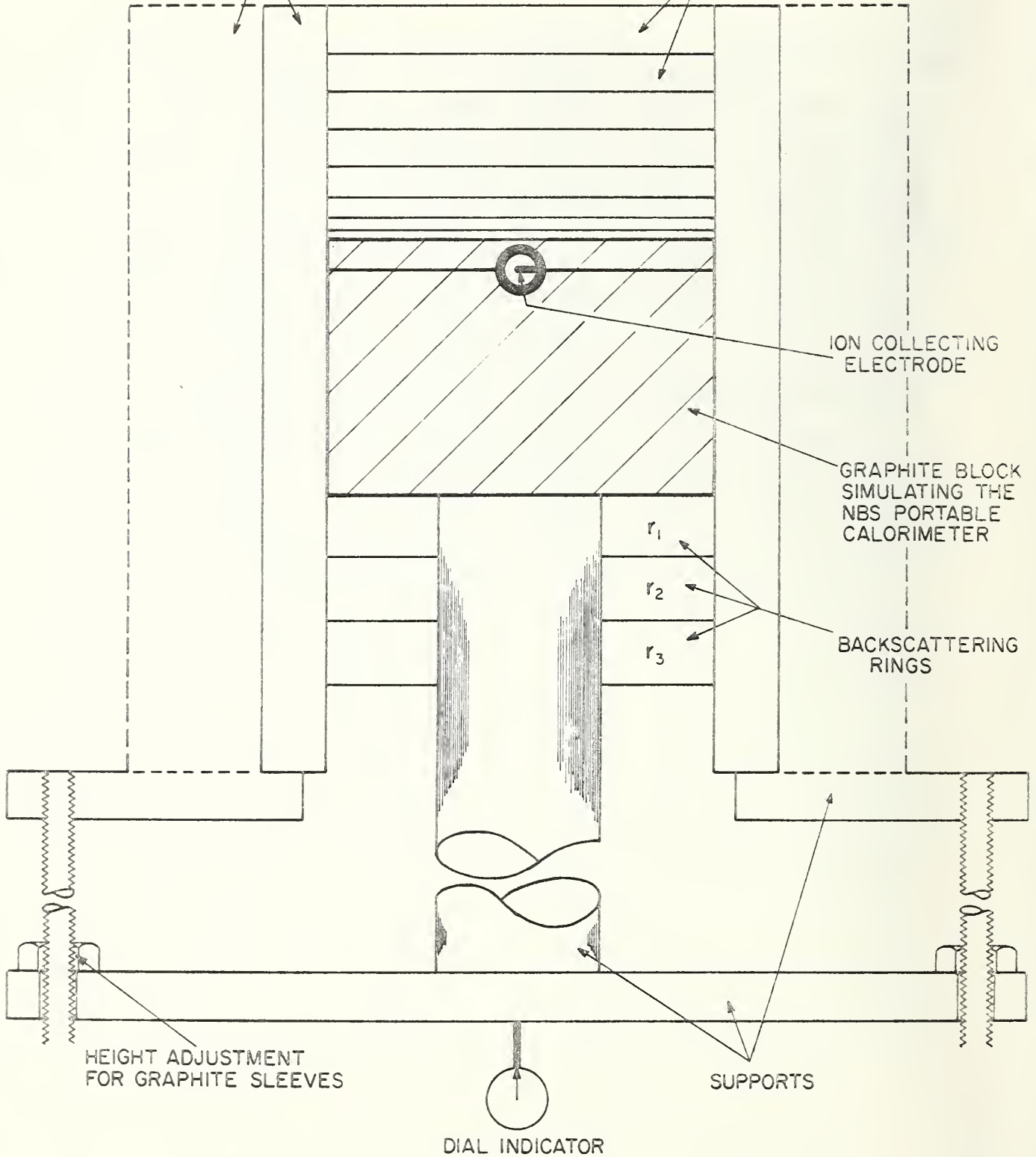
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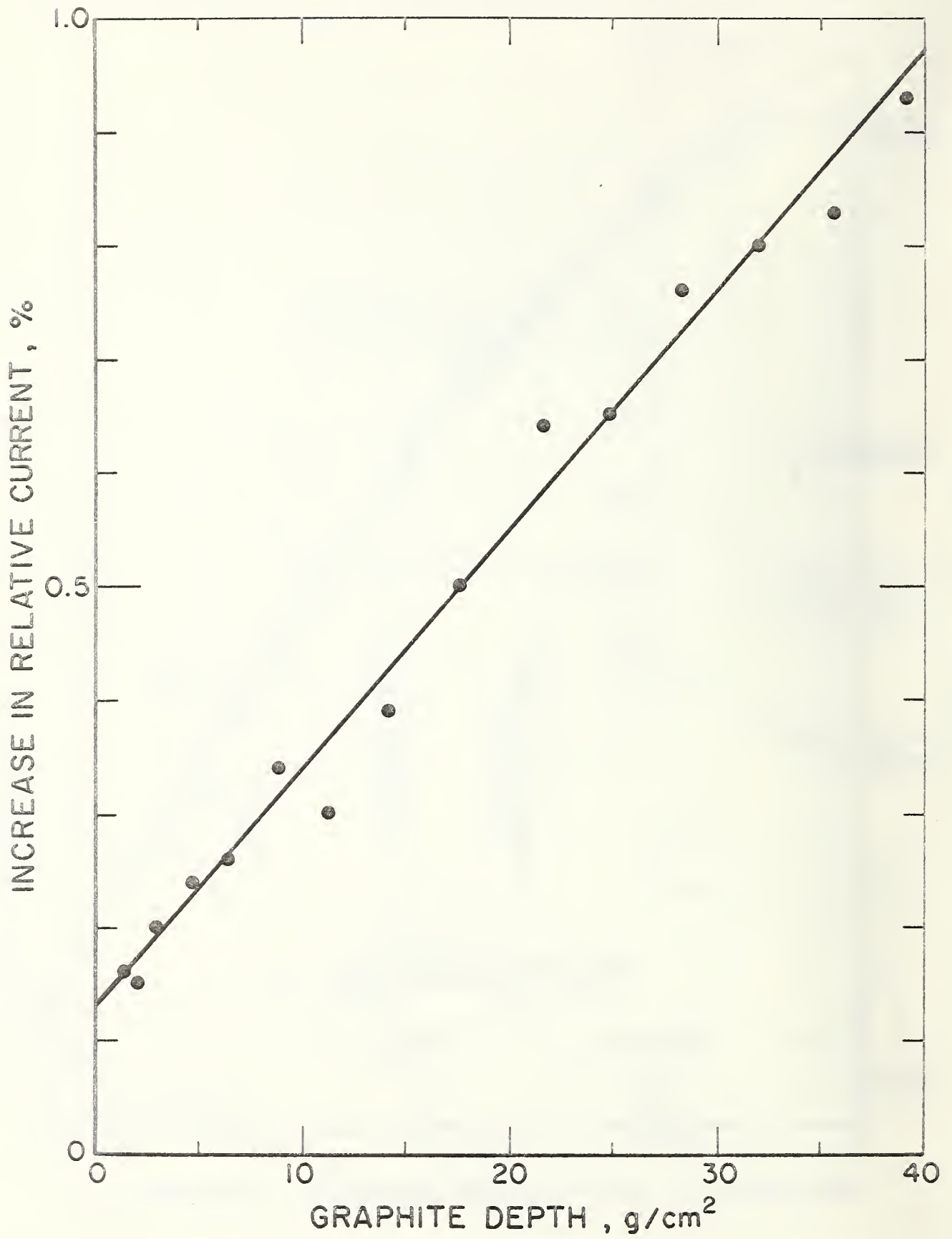
GRAPHITE BLOCK SIMULATING THE NBS PORTABLE CALORIMETER

r_1

r_2

r_3

BACKSCATTERING RINGS

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SUPPORTS

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15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

Ionization measurements along the central axis were made in a graphite phantom irradiated with cobalt-60 gamma rays. The measurements were made under the following conditions: phantom diameters of 15, 20, and 30 cm; 15 depths from 1 to 39 g/cm^2; and square field sizes of 8.3, 10.5, 12.4, and 17.4 cm at a fixed detector position of 1 m from the source. Empirical fits to the data aid in correcting calorimeter comparisons to a common geometry.

17. KEY WORDS (six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)

Absorbed dose; cobalt-60; graphite; calorimeter comparisons; phantom size.

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