Rapport BIPM-90/4

Revision of the results of international comparisons of absorbed dose in graphite, in a ^{60}Co beam

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Abstract

The results of the past comparisons of absorbed dose in graphite, in a ^{60}Co beam, have been revised by including new available data for some of the correction factors. The change in the absorbed dose determination can reach 1 % at large depths in graphite.

1. Introduction

International comparisons of absorbed dose in graphite, with ^{60}Co radiation, have been performed during the past decade between the ionometric standard of the Bureau International des Poids et Mesures (BIPM) and the calorimetric standards of the following national laboratories:

NIST	National Institute of Standards and Technology, United States of America
LMRI	Laboratoire de Métrologie des Rayonnements Ionisants, France
RIVM	Rijksinstituut voor Volksgezondheid en Milieuhygiëne, the Netherlands
PTB	Physikalisch-Technische Bundesanstalt, Federal Republic of Germany
OMH	Országos Mérésügyi Hivatal, Hungary
NPL	National Physical Laboratory, United Kingdom.
IRA	Institut de Radiophysique Appliquée, Switzerland.

The agreement between the results was found to be good and consistent with the estimated uncertainties. However, during the first four comparisons two effects had been disregarded. They concern the influence of the lateral non-uniformity of the BIPM beam and the influence of the gaps inside the calorimeters (only NIST applied a correction for the influence of the gap between its calorimeter and the added graphite plate). Recent work concerning these questions shows that substantial corrections are needed to take into account these effects (Owen and DuSautoy, 1988; Boutillon, 1989; Boutillon and Perroche, 1989) and the results of the first four comparisons have to be revised accordingly. The perturbation correction factor pertinent to the standard used at BIPM has also been revised and all the corrections are given for the geometrical conditions of the comparisons (Fig. 1).

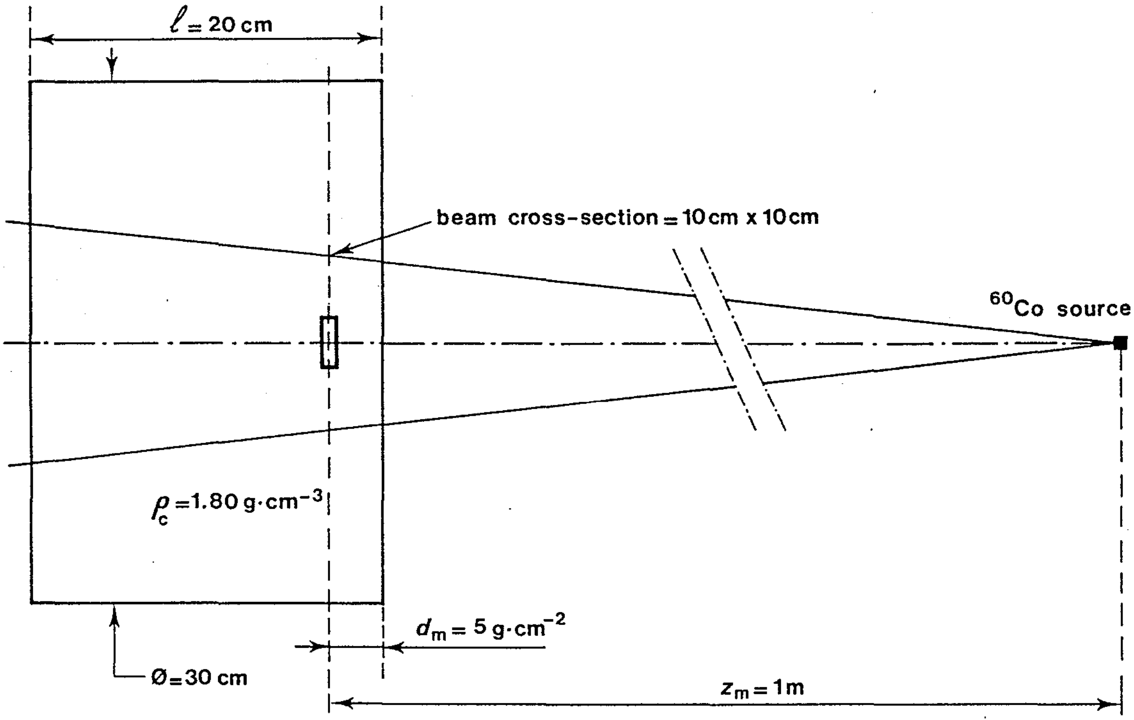

Fig. 1 - Geometrical conditions chosen for the comparisons.

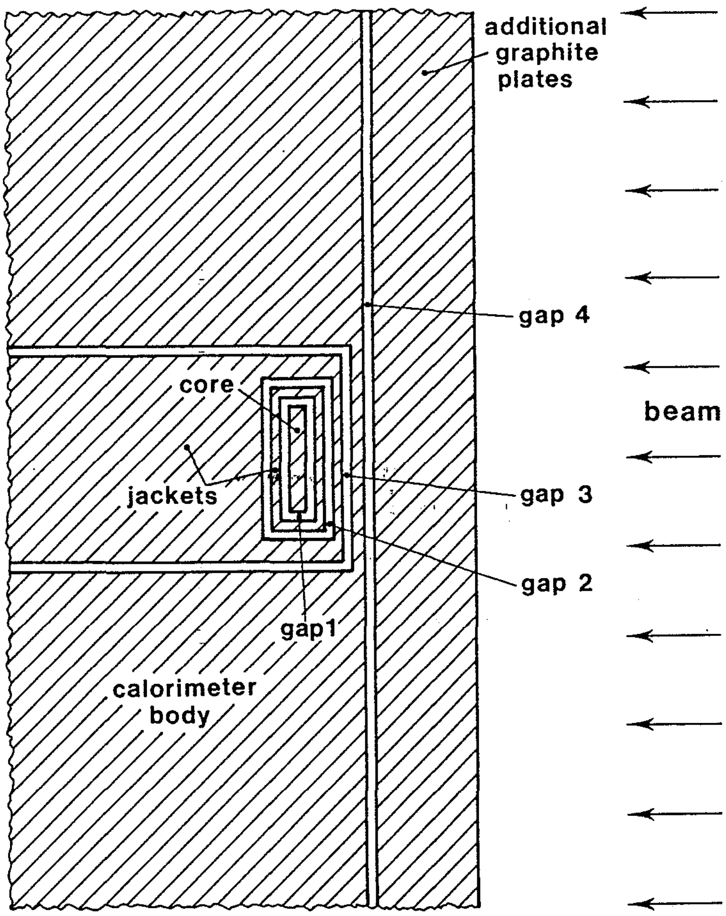

Fig. 2 - Schematic view of the gaps in a calorimeter.

2. Gap correction factor

The positions of the four gaps inside a calorimeter are shown schematically in Figure 2 and their widths are listed in Table 1. The correction factor for each of the four gaps, as a function of depth in graphite, is given in Table 2 and the total gap correction factor, k_{gap}, for each calorimeter is given in Table 3.

Table 1 - Widths (mm) of the calorimeter gaps

Laboratory	gap 1	gap 2	gap 3	gap 4
NIST	0.53	0.79	0.73	0.4
PTB	1.	1.	1.	1.
LMRI	1.1	1.1	1.1	0.
RIVM	0.520	0.966	0.998	0.15
OMH	0.5	0.5	0.5	4 or 8
NPL	0.65	0.48	0.73	0.73
IRA	0.5	0.5	1.0	0.1

Table 2 - Gap correction factor* (gap width: 1 mm)

depth (g cm^{-2})	gap 1	gap 2	gap 3	gap 4
3	1.000 8	1.001 1	1.000 9	1.001 0
5	1.001 5 1.002 5**	1.001 9 1.001 8**	1.001 3 1.001 2**	1.001 6 1.002 6** 1.001 6***
11	1.003 1	1.003 3	1.002 3	1.003 2
17	1.003 7	1.004 2	1.003 0	1.004 0

* Calculated values (Boutillon, 1989)
** NPL experimental values (Owen and DuSautoy, 1988)
*** NIST experimental value (Domen, 1977).

Table 3 - Revised results of comparisons of absorbed dose to graphite
(1) Values used during the comparisons*, (2) Corrected values

Laboratory	Depth in graphite	Calorimeters			BIPM standard			D_{lab}/D_{BIPM}	
		k_{gap}		k_{rn}	k_p		k_{rn}		
	($g\ cm^{-2}$)	(1)	(2)	(2)	(1)	(2)	(2)	(1)	(2)
NIST 1977	1	1.0000	1.0007	1.0003	0.9949	0.9932	1.0020	0.9996	1.0003
	3	1.0003	1.0023	1.0003	0.9907	0.9912	1.0025	0.9976	0.9969
	5	1.0006	1.0038	1.0004	0.9889	0.9896	1.0032	0.9990	0.9987
	7	1.0008	1.0052	1.0006	0.9877	0.9885	1.0041	0.9988	0.9989
	10	1.0011	1.0067	1.0009	0.9863	0.9871	1.0058	1.0011	1.0010
	12	1.0014	1.0075	1.0011	0.9857	0.9865	1.0072	1.0019	1.0011
	15	1.0017	1.0085	1.0017	0.9850	0.9856	1.0096	1.0022	1.0005
PTB 1977	5	1.	1.0062	1.0004	0.9889	0.9896	1.0032	1.0053	1.0080
	7	1.	1.0083	1.0006	0.9877	0.9885	1.0041	1.0029	1.0069
	8	1.	1.0093	1.0007	0.9872	0.9880	1.0046	0.9993	1.0039
LMRI 1977	3	1.	1.0030	1.0003	0.9907	0.9912	1.0025	0.9972	0.9975
	5	1.	1.0051	1.0004	0.9889	0.9896	1.0032	0.9983	0.9999
	6	1.	1.0060	1.0005	0.9883	0.9890	1.0036	0.9986	1.0008
	7	1.	1.0068	1.0006	0.9877	0.9885	1.0041	1.0004	1.0029
	8	1.	1.0076	1.0007	0.9872	0.9880	1.0046	0.9985	1.0014
	10	1.	1.0088	1.0009	0.9863	0.9871	1.0058	0.9980	1.0011
	12	1.	1.0099	1.0011	0.9857	0.9865	1.0072	0.9987	1.0017
	15	1.	1.0112	1.0017	0.9850	0.9856	1.0096	1.0029	1.0056
	17	1.	1.0120	1.0021	0.9847	0.9852	1.0114	0.9969	0.9991
RIVM 1979	1	1.	1.0010	1.0003	0.9949	0.9932	1.0020	0.9962	0.9972
	3	1.	1.0028	1.0003	0.9907	0.9912	1.0025	0.9988	0.9989
	4.6	1.	1.0039	1.0004	0.9896	0.9902	1.0030	1.0009	1.0016
	5	1.	1.0041	1.0004	0.9889	0.9896	1.0032	0.9992	0.9998
	6	1.	1.0048	1.0005	0.9883	0.9890	1.0036	0.9971	0.9981
	7	1.	1.0055	1.0006	0.9877	0.9885	1.0041	1.0024	1.0036
	8	1.	1.0061	1.0007	0.9872	0.9880	1.0046	0.9995	1.0009
	10	1.	1.0071	1.0009	0.9863	0.9871	1.0058	1.0035	1.0049
	11.9	1.	1.0080	1.0011	0.9857	0.9865	1.0072	0.9973	0.9984
	12	1.	1.0080	1.0011	0.9857	0.9865	1.0072	1.0006	1.0017
	15	1.	1.0091	1.0017	0.9850	0.9856	1.0096	1.0027	1.0033
OMH 1986	1.76		1.0055	1.0003		0.9924	1.0021		0.9977
	2.64		1.0045	1.0003		0.9915	1.0024		0.9967
	3.53		1.0013	1.0003		0.9907	1.0027		0.9953
	5.32		1.0024	1.0004		0.9894	1.0033		1.0003
	7		1.0031	1.0006		0.9885	1.0041		0.9988
NPL 1987	5.5		1.0053**	-		0.9896	1.0032		1.0014
IRA 1989	3		1.0020	1.0002		0.9912	1.0025		0.9984
	5		1.0032	1.0002		0.9896	1.0032		0.9985
	8		1.0047	1.0004		0.9880	1.0046		0.9995
	10		1.0054	1.0006		0.9871	1.0058		1.0009
	16		1.0072	1.0012		0.9854	1.0104		1.0010

* k_{rn} was set to 1. during the first four comparisons

** experimental value

3. Correction for the radial non-uniformity of the beam

The radial non-uniformity of the beam, which is small in air, has been found to be of real importance in the graphite phantom (Boutillon and Perroche, 1989), and a correction factor, k_{rn}, has to be applied to the detector response to take into account the effect of its lateral size. The numerical values of k_{rn} are given in Table 3, both for the calorimeters ($\emptyset$ = 2.0 cm) and for the BIPM standard ($\emptyset$ = 4.5 cm).

4. Perturbation correction factor for the BIPM standard

In the revision of the correction for the perturbation, k_p, pertinent to the ionometric standard of the BIPM, attention has been focussed on a more accurate determination of the photon field in graphite (obtained by a Monte-Carlo calculation). The new values of k_p (Table 3) do not differ by more than 0.07 % from the previous ones.

5. Corrected results

Table 3 gives a summary of the numerical values used for the correction factors, whereas the relative change in the absorbed dose value for each laboratory is given in Table 4 for two depths in graphite. At the reference depth this change is significantly higher than the estimated uncertainties for most of the laboratories and it can reach a value of up to 1 % at large depths in graphite, both for calorimeters and the BIPM standard. The corrected results of the comparison, together with the previous ones, are given in Figure 3.

The experimental value of W (the mean energy required by electrons to produce an ion pair in dry air), deduced from the results of the comparisons (Niatel et al., 1985), has been revised by taking into account the above re-adjustment and the results of three recent comparisons (BIPM-OMH, BIPM-NRC and BIPM-IRA). This leads to a change of 0.15 % and the mean W value obtained by an analysis of all the available experimental data (Boutillon and Perroche, 1987) does not undergo any significant change (Table 5).

Table 4 - Relative change (in %) in the absorbed dose determination due to the present revision

depth ($g\ cm^{-2}$)	BIPM	NIST	LMRI	RIVM	PTB
5	0.39	0.09	0.70	0.45	0.66
15	1.02	0.67	1.67	1.08	-

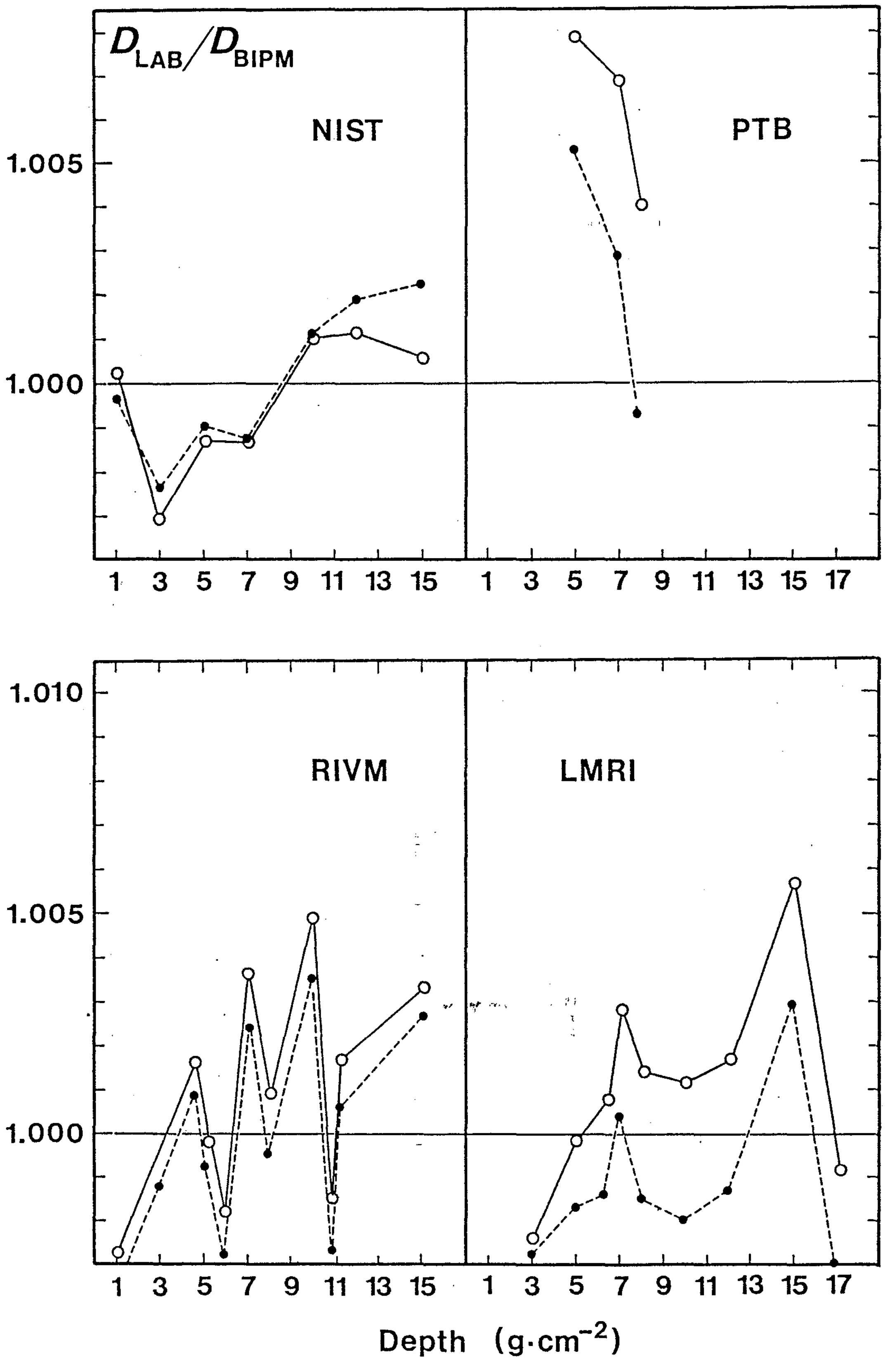

Fig. 3 - Results of four comparisons
● previous values, o corrected values.

Table 5

- Experimental determination of W/e

(from comparisons of absorbed dose measurements)

$$W/e\ (1985) = (33.96 \pm 0.08)\ J\ C^{-1}$$

$$W/e\ (1989) = (33.99 \pm 0.08)\ J\ C^{-1}.$$

- Compiled value of W/e

(from published values)

$$W/e\ (1987) = (33.97 \pm 0.05)\ J\ C^{-1}$$

$$W/e\ (1989) = (33.98 \pm 0.05)\ J\ C^{-1}.$$

6. Conclusion

The two corrections discussed above (gap correction and correction for radial non-uniformity) of the beam, which both increase the absorbed dose measured either with a calorimeter or with the ionometric standard, are of the same order of magnitude. As a consequence, and despite the fact that the previous values of the absorbed dose were in error by an amount of up to 1 % for the first comparisons, the absorbed dose ratios thus obtained - and the W value deduced therefrom - were only biassed to a much smaller extent.

References

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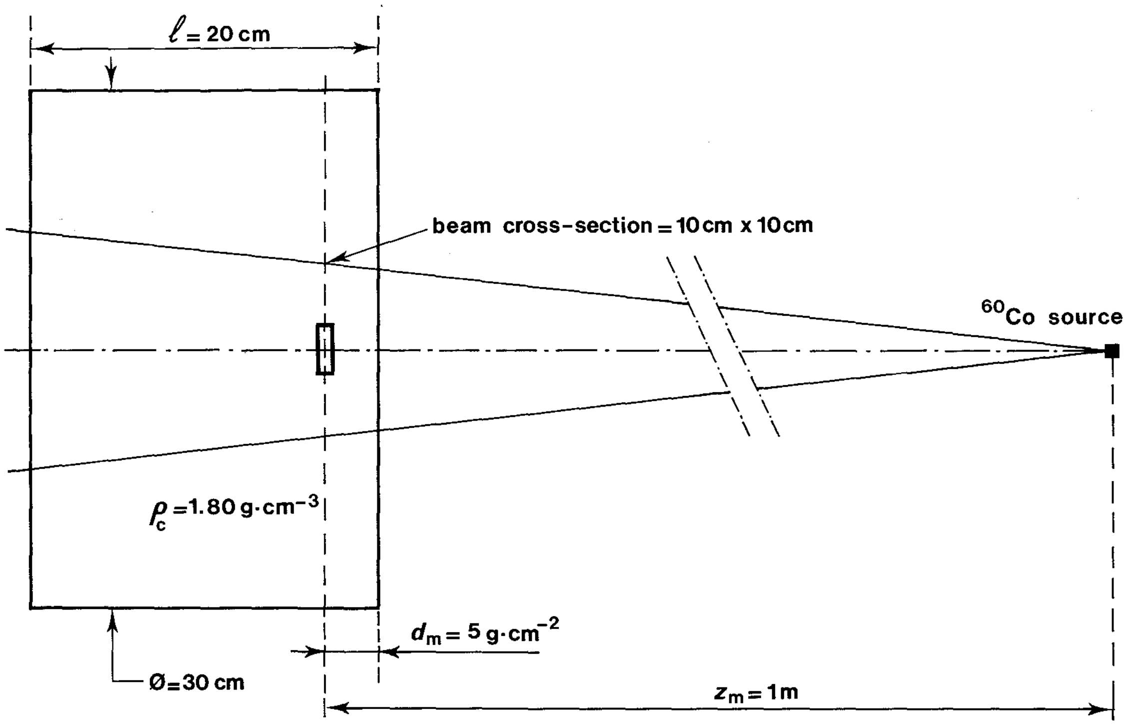
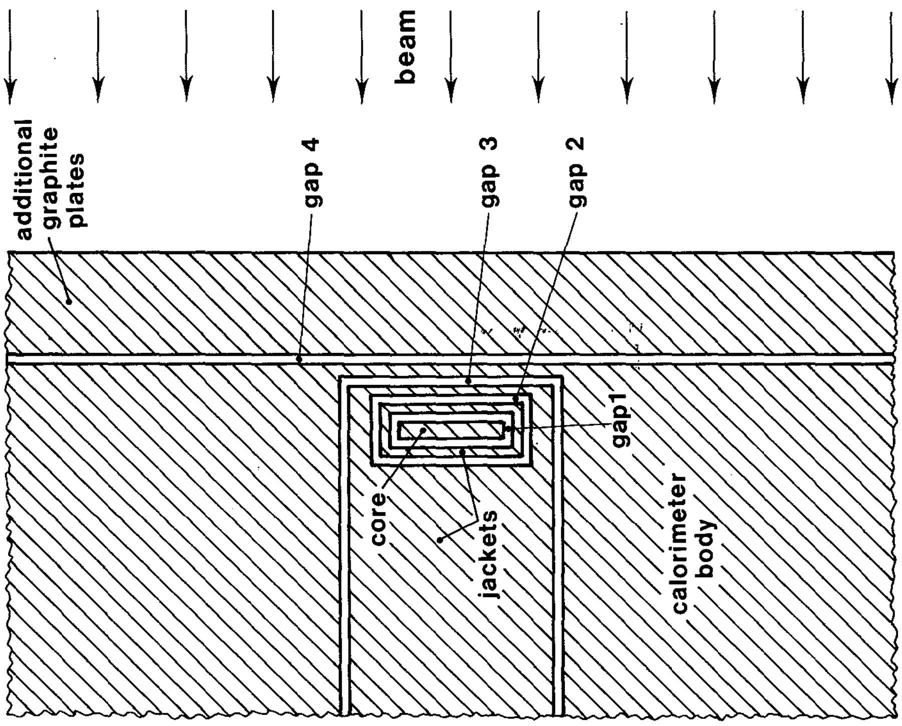


$\ell = 20$ cm
beam cross-section = 10cm x 10cm
^{60}Co source
$\rho_c = 1.80$ g·cm^{-3}
$d_m = 5$ g·cm^{-2}
Ø=30 cm
$z_m = 1$m



beam
additional graphite plates
gap 4
gap 3
gap 2
gap1
core
jackets
calorimeter body