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DETERMINATION OF THE K_{wall} CORRECTION FACTOR FOR CYLINDRICAL IONISATION CHAMBERS OF VARIOUS DIMENSIONS: REPORT TO THE 2003 CCRI SECTION I MEETING

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Introduction

In 2001 the factor K_{wall} to correct for photon attenuation and scatter in the wall of the ENEA-INMRI standard ionization chamber for Co-60 air-kerma measurement was re-determined by an experimental/analytical method [1] other than that based on the traditional extrapolation procedure of the chamber current to zero wall thickness. This re-determination agreed with previous Monte Carlo results [2] for chambers of the same geometry (OMH cylindrical type). To increase the robustness of such results and give more confidence to their applicability to chambers of different type the same analytical/experimental procedure was also extended to cylindrical chambers of different shape and wall thickness. As described below, the factor K_{wall} was then determined for each of these chambers by: a) the experimental/analytical method [1] and the Monte Carlo calculation, to be able to furtherly confirm the coherence of these two methods and b) the traditional linear extrapolation procedure, to furtherly confirm the inadequacy of this method.

Methods

Four cylindrical ionisation chambers of different size and shape were built to check the coherence of results when the method [1] is applied to chambers of different height to diameter ratio and wall thickness. These are just the parameters on which the correction factor K_{wall} mainly depends. The geometry and dimensions of these four graphite chambers are described in Fig.1 and Table 1. One of these chambers (chamber D in Table 1) is similar to the standard cavity chamber (OMH type). The dimensions and shape of the four chambers were deliberately designed very different from each other to be able to check accuracy and coherence of all the three methods used to determine K_{wall} in the present investigation. The air cavity volume of each chamber was accurately determined because absolute measurements were required for the purpose of this investigation. Measurements of attenuation and scatter effects were then made for each of these chambers according to both the analytical/experimental method described in [1] and the traditional linear extrapolation procedure. To this end four sets of shaped graphite shells and caps like those described in [1] were built to accurately fit with each chamber. A Monte Carlo calculation of the same attenuation and scatter effects in the different chambers was also made by the EGSnrc code as in the previous work [1]. For each of the four chambers three sets of results (one from calculation and two from measurements) were finally obtained and compared with each other.

Absolute air-kerma measurements were made by each of the four chambers to verify that the same air-kerma values are obtained irrespective of the chamber type used, only if the correct K_{wall} factor is applied to any chamber. On the other hand not consistent air-kerma results have to be expected among the different chambers if the K_{wall} factors used are wrong.

Results

The results regarding calculation and experimental determination of the K_{wall} factor for the different chambers considered in this work are summarized in Table 2. As can be seen in Table 2 the deviations between experimental and Monte Carlo results are within 0.2% for the K_{wall} values obtained by the analytical/experimental method described in [1]. The above deviations should be compared with those occurring, up to 2.2%, between the K_{wall} factors obtained by Monte Carlo and the linear extrapolation method. It also results from the data in Table 2 that the traditional linear extrapolation method yields nearly the same value for the K_{wall} factor of different chambers, i.e. chambers with equal wall thickness but different diameter to height ratio (chambers A, B and C).

The traditional extrapolation method is then insensitive to chamber shape and dimension, whereas one expects the K_{wall} factor to change for chambers with similar wall thickness but different diameter to height ratio.
A further confirmation of the need to replace the old K_{wall} factors (as determined by the linear extrapolation procedure) by those calculated by the Monte Carlo method, is given by the results shown in Figure 2. The air-kerma values as measured by chambers of different shape are consistent with each other (within 0.2%) if the K_{wall} factor for each of the four chambers is determined by the Monte Carlo method. A rather good consistency is also observed in the Fig. 2 when comparing the air-kerma values obtained by the different size chambers whose K_{wall} factors are determined by the analytical/experimental method described in [1]. Deviations up to 1.2% are instead observed among the air-kerma values obtained by all of the four chambers whose K_{wall} factors are determined by the traditional extrapolation method (Fig 2). Moreover deviations up to about 2% (see Fig 2) occur between the air-kerma values determined by the same type of chamber with a K_{wall} factor determined alternatively by the traditional extrapolation method and by the Monte Carlo calculation. To obtain the results shown in Fig 2 it was necessary to perform absolute air-kerma measurements after determining accurately the air cavity volume of the four chambers considered for this investigation.

In conclusion the present study confirms the recommendation that for the standard chambers of cylindrical geometry the K_{wall} factor as determined by the traditional linear extrapolation procedure should be revised. The correct K_{wall} factors may be obtained by both the Monte Carlo and the analytical/experimental methods referred to above. Of the two alternatives the Monte Carlo calculation is certainly that less time consuming.

References

[1] Laitano RF, Toni MP, Pimpinella M and Bovi M 2002 Determination of the Kwall correction factor for a cylindrical ionisation chamber to measure air-kerma in Co-60 gamma beams *Phys. Med. Biol.* **47** 2411-2431.
[2] Rogers DWO and Bielajew AF 1990 Wall attenuation and scatter corrections for ion chambers: measurements versus calculations *Phys. Med. Biol.* **35** 1065-1078.

Table 1. Characteristics of the cylindrical ionization chambers considered in the present analysis.

	Chamber code			
	A	B	C	D
Chamber dimensions (mm)				
Inner diameter	7.98	10.87	16.01	11.00
Inner length	15.98	10.86	7.97	11.02
Wall thickness	2.97	2.99	3.00	3.88
Central electrode diameter	1.96	1.99	1.99	1.98
Central electrode length	14.98	10.07	7.01	10.00
Volume (cm^3)	0.772	0.988	1.598	1.032
Chamber material				
Wall and central electrode	Graphite (1.75 g cm^{-3})			

Table 2. K_{wall} factors for the different chambers A, B, C, D described in Table 1 and Fig. 1. The deviations (Δ) between the methods 1 and 2 and between the methods 1 and 3 are also reported.

K_{wall}	Chamber code			
	A	B	C	D
(1)	1.0119 (15)	1.0171 (15)	1.0277 (15)	1.0220 (15)
(2)	1.0035 (20)	1.0044 (20)	1.0048 (20)	1.0081 (20)
(3)	1.0108 (25)	1.0184 (25)	1.0293 (26)	1.0235 (26)
Δ(1-2) %	0.83	1.30	2.23	1.38
Δ(1-3) %	0.11	-0.13	-0.16	-0.15

(1) Monte Carlo calculation
(2) Linear extrapolation method
(3) Analytical/experimental method

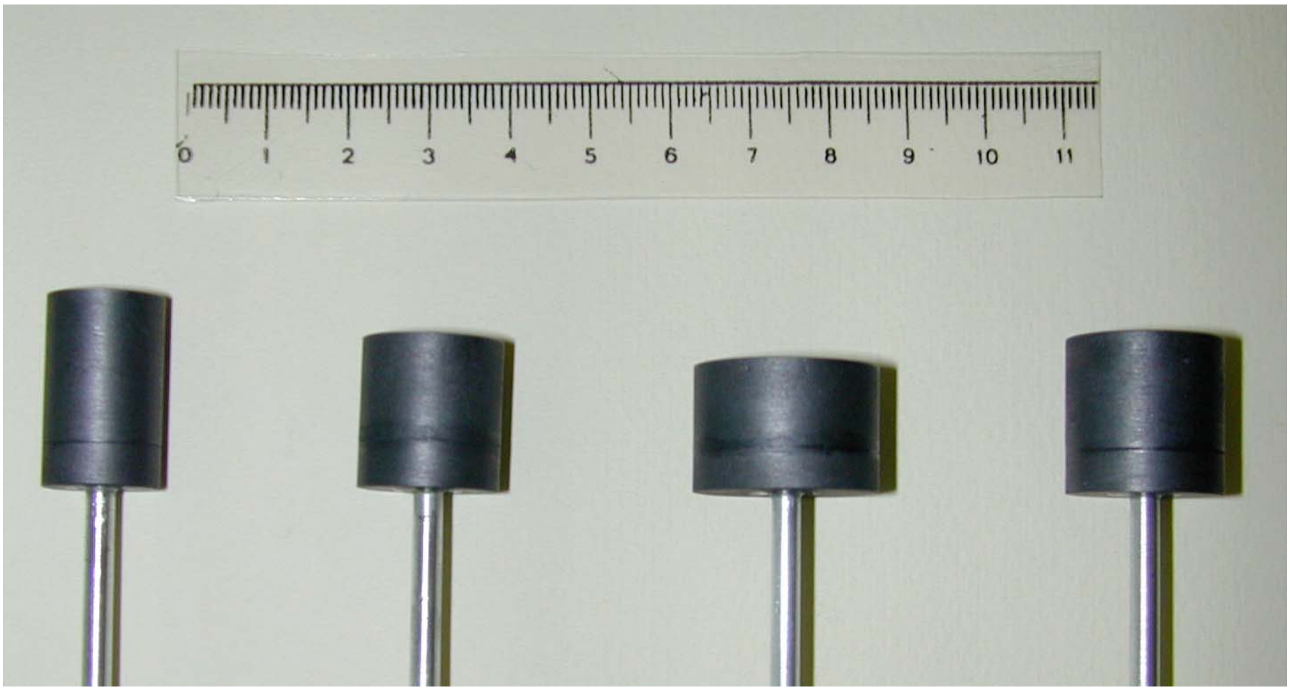

Figure 1 – Photo of the four ionization chambers (from the left, chamber code A, B, C, D) of various shape and size built for the present study.

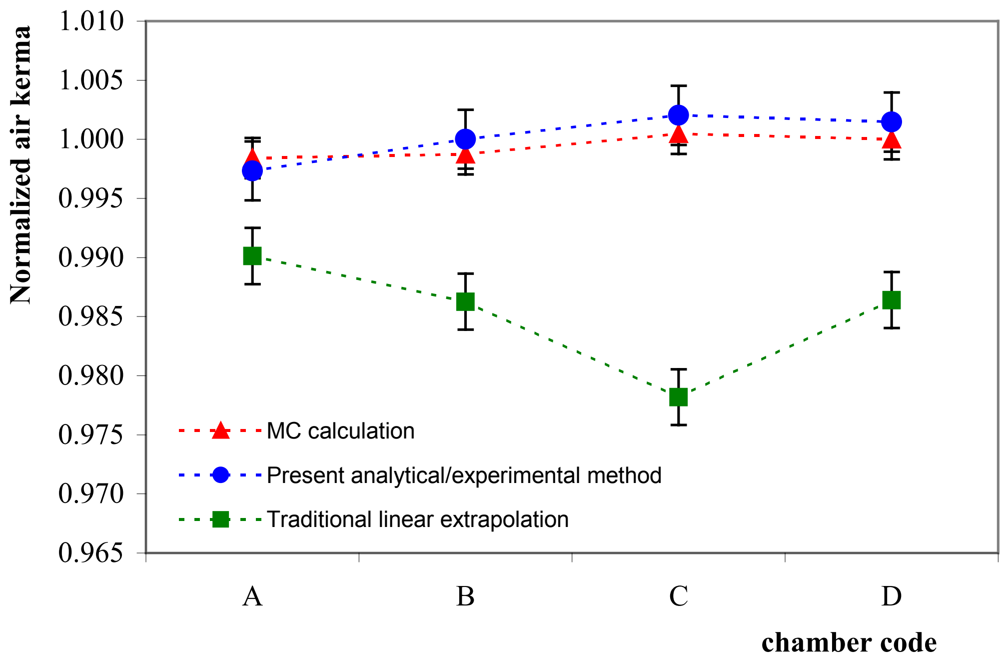

Figure 2. Air kerma values determined by the different ion chambers (A, B, C and D) using K_{wall} factors obtained by the three methods specified in the graph (triangles, circles and squares). The data are normalized to the MC value of the chamber D.