Sensitivity of x-ray comparisons and calibrations to radiation field size

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Introduction

BIPM comparisons for medium-energy x-rays are carried out indirectly, using transfer ionization chambers calibrated at each laboratory. This is necessary because the primary standards are not transportable. However, in contrast to the practice in ^{60}Co gamma-ray dosimetry, there is no common field size for x-ray comparisons and the values used in different laboratories vary significantly.

As a result of x-ray scattering from the chamber body and stem or other support, the response of a transfer chamber generally shows some sensitivity to the radiation field size, a sensitivity that is not reflected in the response of a free-air ionization chamber standard when subject to different field sizes. This leads to differences in transfer chamber calibration coefficients that can be interpreted erroneously, during an indirect comparison, as differences in the free-air chamber standards themselves.

This problem is normally avoided in low-energy x-ray dosimetry by making direct comparisons of the primary standards in the same radiation field. However, problems related to field size re-surface when calibrations are made in each laboratory for the purpose of disseminating each standard. Thus two primary standards that agree when compared directly may not give the same calibration coefficient for a given chamber subsequently calibrated in each laboratory if the field sizes are not matched.

This work aims to quantify these effects for the ionization chamber types most commonly used for comparisons and calibrations at the BIPM. The present report presents results for low-energy x-rays; a similar study for medium-energy x-rays is planned.

Radiation fields

The radiation qualities used for all comparisons and calibrations at the BIPM are those defined by the CCRI and listed in [1]. A series of tungsten apertures was fabricated, each 5 mm in thickness and with aperture diameters in the range from 20 mm to 50 mm. For most of the measurements, each aperture was positioned in turn approximately mid-way between the focal spot of the x-ray tube and the reference plane, 500 mm from the focal spot. In this way, a series of circular fields was generated, with diameters in the range from 30 mm to 90 mm. Field size refers to the diameter defined by a reduction of the air-kerma rate to half of its value on the beam axis. However, the values given in this report are approximate and were determined by calculation from the aperture diameter and the position of the aperture relative to the focal spot and the reference plane.

Some measurements were made at field sizes greater than 90 mm. These were produced by increasing the distance from the focal spot to the reference plane, while keeping the aperture position fixed with respect to the focal spot.

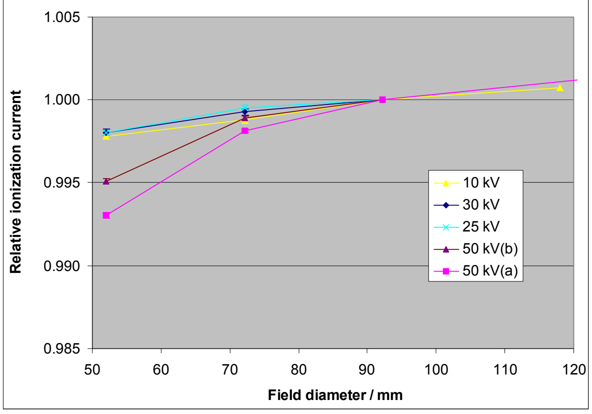
Results

Measurements were made for the two parallel-plate chamber types most commonly measured at the BIPM, the PTW 23344 (serial number 866) and the Radcal RC6M (serial number 9112). The results for these two chambers at the CCRI reference qualities are shown in Figures 1 and 2, respectively. For each set of data, the measured ionization current is normalized to that measured for a field size of 90 mm. The Radcal RC6M shows a small effect, the response changing by 2 or 3 parts in 10^{-3} for field sizes in the range from 50 mm to

120 mm. This effect does not change significantly with energy. In contrast, the field-size effect for the PTW 23344 increases with radiation quality (characterized by the half-value layer), reaching 8×10^{-3} in relative value at 50 kV(a) over the same range of field sizes.

To estimate the effect that such changes would have on calibration coefficients, the same series of measurements was made for the BIPM free-air chamber. The results are shown in Figure 3. It can be seen that for radiation fields greater than around 40 mm in diameter the field-size effect is negligible at the level of the statistical uncertainty (typically 2 parts in 10^{-4}).

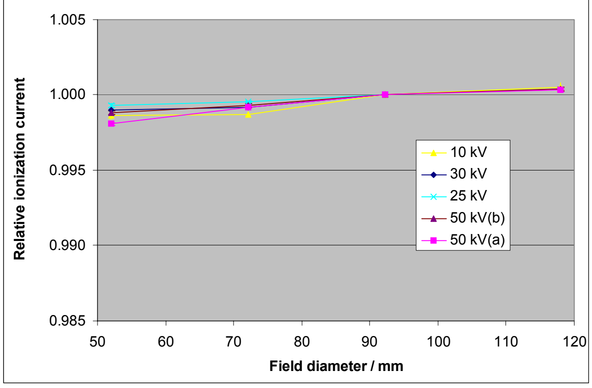
Figure 1. Relative ionization current measured by chamber PTW 23344-866 for different radiation qualities and field diameters



Discussion

The field sizes in use in laboratories holding free-air chambers for low-energy x-rays range from 60 mm to 100 mm, the value at the BIPM being around 85 mm. Over this range of field sizes, it is clear that a transfer chamber response can change by several tenths of one percent and at this level field-size effects should not be neglected. The effect may be even larger for the medium-energy x-ray qualities, although different chamber types are used. These measurements are planned for the near future.

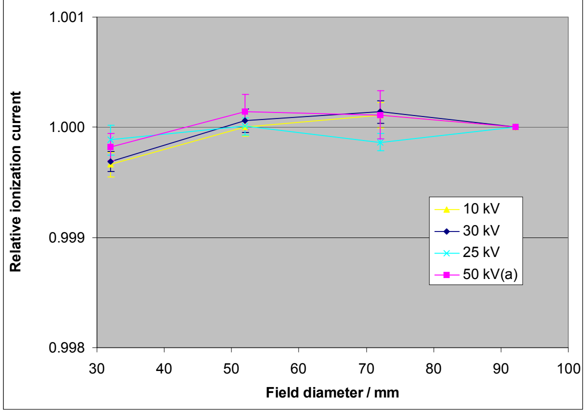
Figure 2. Relative ionization current measured by chamber Radcal RC6M-9112 for different radiation qualities and field diameters



The optimum choice of field size depends on the circumstances. For indirect comparisons made using transfer instruments, the field sizes at the participating laboratories should be matched, or at least field-size effects taken into account in the data analysis using information of the type presented in this paper. For the calibration of instruments for customers, the field size should match that of the reference conditions used by the customer (or an appropriate correction factor applied to the calibration coefficient).

The direct BIPM comparisons made in low-energy x-rays are designed to compare the primary standards themselves, rather than the calibration coefficients disseminated by each laboratory. In order to gain information on the latter, BIPM comparisons now generally involve transfer chamber calibrations as well as, whenever possible, a direct comparison of the primary standards. In this way, direct and indirect comparisons are made with each laboratory. This should help to quantify any problems related to field size and other effects.

Figure 3. Relative ionization current measured by BIPM primary standard for different radiation qualities and field diameters



[1] Allisy-Roberts P.J., Burns D.T. and Kessler C., Rapport BIPM-2004/17.