A correction for scattered x-ray contribution in air kerma calibration

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Abstract: The contribution of scattered x-rays in dosimetry measurements using a parallel-plate ionization chamber is estimated and applied as a correction factor with respect to a free-air ionization chamber. The effect of photons scattered by the source collimator, filter and ambient atmosphere is investigated by inserting a thick copper collimator between the x-ray source and ionization chambers. The measurements indicate the correction factor required in the calibration of window-type chambers for x-ray dosimetry increases from 0.5 % at an effective energy of 8 keV to 1.0 % at 35 keV.

1. Introduction

In x-ray field for calibration, there are photons scattered by the collimator, filter and ambient atmosphere as well as direct photons emitted by the x-ray tube. The sensitivity of the ionization chambers used for dosimetry to these scattered photons arriving at various incidence angles is dependent on the type and configuration of the ionization chamber. Free-air ionization chambers, which typically have a thick diaphragm with an aperture for confining the x-ray beam, are relatively insensitive to these scattered photons. At calibration of ionization chambers, it is necessary to take into account the differences in the sensitivity for scattered photons. In the present study, the effects of scattered x-rays on the response of parallel-plate and free-air ionization chambers is investigated in order to obtain correction factors for calibration of the parallel-plate ionization chamber.

2. Experiment

A parallel-plate ionization chamber (CE-60, Applied Engineering) with a thin window of 110 mm diameter was entirely shrouded with 1 mm-thick lead sheets, exposing only an aperture of 20 mm in diameter (Fig. 1). The chamber was placed 1 m from an x-ray source. The signal outputs from the chamber were measured with and without a 15 mm-thick copper collimator (hole diameter: 15 mm) inserted midway between the x-ray source and the ionization chamber. The collimator was sufficiently thick to prevent the transmission of x-rays under the present conditions. The diameter of the x-ray field at the window of the CE-60 was 30 mm with the collimator and 150 mm without. The increase in the signal current without the collimator can therefore be attributed to scattered photons that were shadowed by the collimator. Similar measurements using the same collimator were also made for a free-air ionization chamber (denoted FAC later on) using low-energy x-rays to determine the correction factor. The free-air ionization chamber had a 12 mm-thick diaphragm with an aperture of 6 mm diameter. A schematic diagram of the chamber is shown in Fig. 2.

3. Results and discussion

Measurements were made at various effective energies (E_{eff}) in the range 8–35 keV, with tube voltages of 20–50 kV. The results of measurements are shown in Fig. 3, where I_{small} is the current obtained with the copper collimator in place, and I_{large} is that without the collimator. The contribution of scattered photons increases with E_{eff} for both the CE-60 and FAC, although the contribution is notably smaller in the latter case, as expected. The ratio of $(I_{large}/I_{small})_{CE\text{-}60}$ to $(I_{large}/I_{small})_{FAC}$ can be used to correct the calibration factor to account for the effects of scattered photons.

The calibration factor for the CE-60 ionization chamber without lead sheets was determined for each E_{eff}, and was multiplied by the ratio $(I_{large}/I_{small})_{CE\text{-}60}$ / $(I_{large}/I_{small})_{FAC}$. The ratio increases from 0.5 % to 1.0 % with increasing E_{eff} from 8 to 35 keV. It should be noted, however, that this calculation assumes that the contribution of scattered photons is uniform over the entire CE-60 window area. To obtain more accurate correction factors, it will therefore be necessary to measure using copper collimators with various hole diameters and also lead sheets with various aperture sizes.

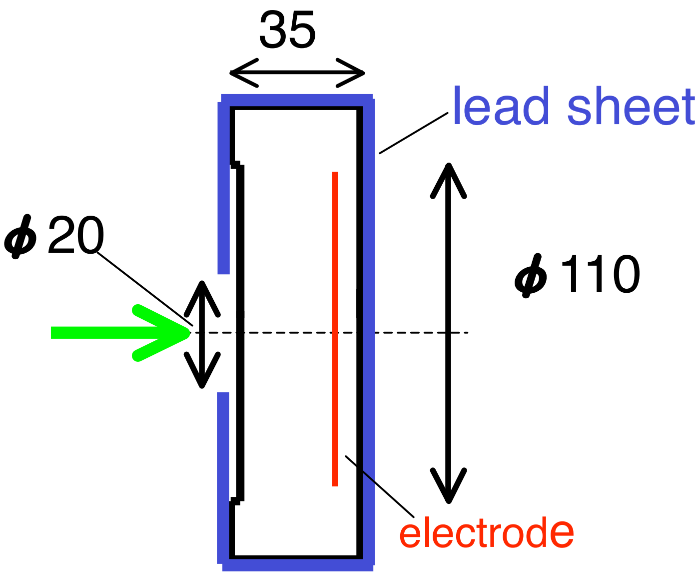

Fig. 1 Schematic diagram of parallel-plate (CE-60) ionization chamber with lead sheets.

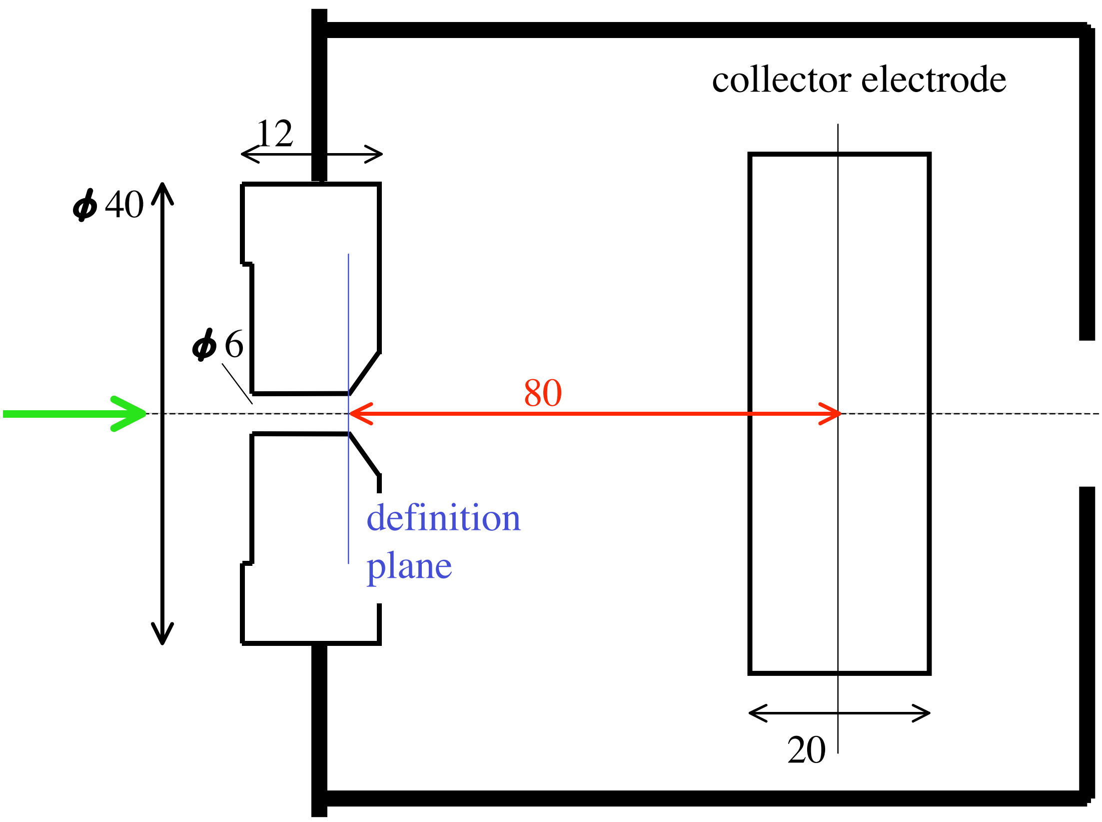

Fig. 2 Schematic diagram of free air ionization chamber of NMIJ.

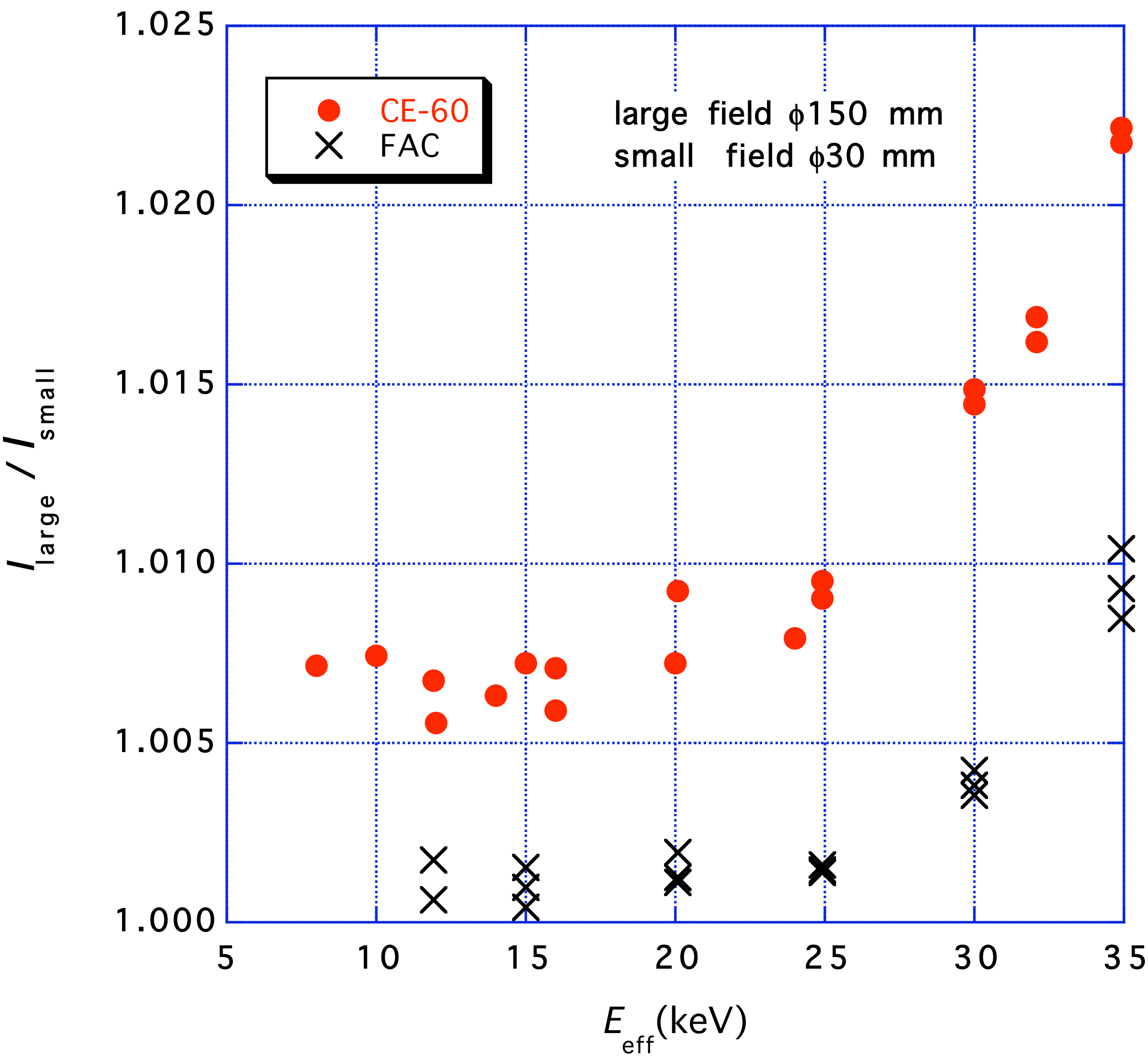

Fig. 3 Ratio between signal currents measured with (I_{small}) and without (I_{large}) the copper collimator in place.