Changes to the magnitude of the unit of Gray according to ICRU Report 90

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1. Background

In October 2016 the International Commission on Radiation Units and Measurements (ICRU) published its Report 90[1)] titled “Key Data for Ionizing-Radiation Dosimetry: Measurement Standards and Applications”. Amongst other things the recommendations in this report have implications on the magnitude and uncertainties of the unit of Gray realized by primary air kerma standards. On its 26th meeting in June 2017 the Consultative Committee for Ionizing Radiation (CCRI) decided to adopt the ICRU 90 recommendations and implications to the measurement standards on 1st January 2018.

The Physikalisch-Technische Bundesanstalt (PTB), the national metrology institute of Germany, followed the CCRI recommendation and introduced the changes in the magnitude and uncertainties of the unit of gray measured by their primary air kerma standards in fields of ^{60}Co, ^{137}Cs and x-rays according to the data published in ICRU 90. This document summarizes the implications of these changes on the calibration factors in PTB calibration certificates issued since 1st January 2018. The data given in this document enable the applicants to correct the calibration factors N_{old} and N_{new} shown in certificates issued before and after the 1st January 2018 for the changes in the primary air kerma standards. The correction can be estimated by the factor f_c according to the following equation:

$$N_{new} = f_c * N_{old}$$

2. Changes of air kerma calibration factors in fields of ^{60}Co and ^{137}Cs

Changes are caused by new values of the product $W_{air}*s_{g,air}$ recommended in ICRU 90. Detailed information on this product are given in ICRU 90 and references therein. Thus, the changes can be expressed by $f_c = (W_{air}*s_{g,air})_{new} / (W_{air}*s_{g,air})_{old}$.

Radiation field	f_c =
Co-60	0.9916
Cs-137	0.9918

3. Changes of air kerma calibration factors in fields of x-rays

Changes are caused by the introduction of the new correction factor $k_{ii}k_w$ to be applied for free-air ionization chambers. Detailed information on the correction factors k_{ii} and k_w are given in ICRU 90 and references therein. Thus, the changes can be expressed by $f_c = k_{ii}k_w$. The factor f_c depends on the radiation quality and can be calculated from the aluminum or copper half-value layer (HVL) as shown in the following sections 3.1 and 3.2.

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3.1 f_c as a function of the aluminum half-value layer (Al-HVL)

Al-HVL / mm	f_c =
0.02 – 1	0.9978 + 0.0017*log(Al-HVL)
1 - 15	0.9980
15 - 25	0.9955 + 0.00017*(Al-HVL)
>25	1

3.2 f_c as a function of the copper half-value layer (Cu-HVL)

Cu-HVL / mm	f_c =
0.03 – 2	0.9980
2 - 7	0.9976 + 0.0003*(Cu-HVL)
>7	1

4. Changes of absorbed dose to water calibration factors in fields of low-energy x-rays

The absorbed dose to water of low-energy x-rays (PTB radiation qualities T10 – T100) is based on air kerma measurements. The factor f_c can therefore be calculated according to section 3.1.

5. Changes in the uncertainties

The relative standard uncertainty of W_{air}, the mean energy expended to produce an ion pair in dry air, was increased from 0.15% to 0.35% (except for the special case of ^{60}Co, and thus for ^{137}Cs, see below). The relative uncertainties of the correction factor $k_{ii}k_w$ to be applied for free-air ionization chambers ranges from 0.14% to 0.02% for radiation qualities characterized by aluminum half-values layers ranging from 0.02 mm to 25 mm. The uncertainties of the air kerma calibration factors in the fields of x-rays increase accordingly.

The values and relative standard uncertainties of the product $W_{air}*s_{g,air}$ are recommended as 33.72 eV and 0.08% for ^{60}Co and estimated as 34.04 eV and 0.15% for ^{137}Cs. The changes in the magnitudes compared to the old values used before 1st January 2018 are reflected by the f_c values given in section 2. The relative standard uncertainties of these values as used before were 0.11% in both fields and thus the change in the estimated uncertainty on the air kerma and calibration factors is nearly negligible.

6. References

1. International Commission on Radiation Units and Measurements. ICRU Report No. 90: *Key Data for Ionizing-Radiation Dosimetry: Measurement Standards and Applications.* Journal of the ICRU Volume 14, No 1 (2014). (Published October 2016)