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CHANGES TO THE UK NATIONAL PRIMARY STANDARDS OF AIR KERMA AND ABSORBED DOSE INCORPORATING ICRU REPORT 90 RECOMMENDATIONS

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Changes to the UK national primary standards of air kerma and absorbed dose incorporating ICRU Report 90 recommendations

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ABSTRACT

Changes to the UK national primary standards of air kerma and absorbed dose will take effect from 1st of September 2019. The changes are due to (i) the UK adoption of the recommendations of the International Commission on Radiation Units and Measurements Report No. 90 and (ii) the recent introduction of new or re-evaluated primary standards as part of NPL's ongoing programme of research and development.

This report summarises the total changes to the primary standards and the resulting effect on the calibration coefficients of secondary standard ionisation chambers calibrated at NPL.

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1 INTRODUCTION

The International Commission on Radiation Units and Measurements Report No. 90 *Key data for ionizing-radiation dosimetry: measurement standards and applications* (ICRU 2016) makes certain recommendations that, when adopted, may result in changes to the realisation of air kerma and absorbed dose. A review of the UK national primary standards of air kerma and absorbed dose at NPL was therefore initiated to assess and implement the recommendations as necessary. The review coincided with the introduction of new primary standards in some cases and the re-evaluation of other factors unrelated to ICRU 90, also resulting in some changes to the NPL standards and the associated uncertainties.

Changes to the UK national primary standards of air kerma and absorbed dose will take effect from 1st of September 2019. This report summarises the effects of these changes on the calibration coefficients of secondary standards.

2 USE OF THIS REPORT

All NPL secondary standard calibrations issued after 1st of September 2019 contain the revised factors and so no additional correction is necessary.

An NPL secondary standard calibration issued prior to 1st of September 2019 may be revised to reflect a change in the primary standard by multiplying the calibration coefficient by the factor F_Q. Values for F_Q are presented in the following tables for the different beam quality ranges used at NPL for the calibration of secondary standard ionisation chambers, and the associated uncertainty in the calibration coefficients. The uncertainty values have been estimated according to ISO recommendations (Bentley 2005 and ISO 1995).

Example:

Calibration coefficient issued for therapy level absorbed dose to water at 6 MV in NPL certificate dated 1 May 2019: 10.00×10^7 Gy/C. F_Q for this beam quality: 1.004.

Revised calibration coefficient $= 10.00 \times 10^7$ Gy/C $\times$ 1.004
$= 10.04 \times 10^7$ Gy/C.

3 VERY LOW ENERGY THERAPY LEVEL AIR KERMA

Table 1 lists values of the multiplying factor F_Q for very low energy therapy level x-ray air kerma beam qualities in the range 0.024 mm Al HVL to 1.00 mm Al HVL (nominal generating potential 8.5 kV to 50 kV). F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Kelly *et al.* 2019: NPL Report IR 51). The reviewed uncertainty for air kerma calibration coefficients N_K in this energy range is also given.

Table 1: Very low energy therapy level air kerma

Nominal generating potential (kV)	HVL (mm Al)	F_Q
8.5	0.024	1.003
10	0.036	1.003
11.5	0.050	1.003
14	0.070	1.004
16	0.10	1.004
20	0.15	1.005
25	0.25	1.005
34	0.35	1.005
41	0.50	1.006
44	0.70	1.006
50	1.00	1.006
Uncertainty in N_K = ± 1.3 % (k = 2)		

4 MAMMOGRAPHIC X-RAY AIR KERMA

Table 2 lists values of the multiplying factor F_Q for mammographic x-ray air kerma beam qualities designated RQR-M2 and RQN-M2 (nominal generating potential 28 kV). F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Kelly *et al.* 2019: NPL Report IR 51). The reviewed uncertainty for air kerma calibration coefficients N_K for these beam qualities is also given.

Table 2: Mammographic x-ray air kerma RQR and RQN

Quality	Nominal generating potential (kV)	HVL (mm Al)	F_Q
RQR-M2	28	0.31	1.005
RQN-M2	28	0.62	1.005
Uncertainty in N_K = ± 1.4 % (k = 2)			

5 DIAGNOSTIC X-RAY AIR KERMA

Tables 3, 4, 5 and 6 list values of the multiplying factor F_Q for diagnostic x-ray air kerma beam qualities designated RQC, RQT, RQR and RQA respectively. F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Bass *et al.* 2019: NPL Report IR 54). The reviewed uncertainty for air kerma calibration coefficients N_K in this energy range is also given.

Table 3: Diagnostic x-ray air kerma RQC

Quality	Nominal generating potential (kV)	HVL (mm Al)	F_Q
RQC 3	50	4.5	0.998
RQC 5	70	8.4	0.998
RQC 8	100	11.5	0.998
Uncertainty in N_K = ± 1.4 % (k = 2)			

Table 4: Diagnostic x-ray air kerma RQT

Quality	Nominal generating potential (kV)	HVL (mm Al)	F_Q
RQT 8	100	0.2	0.998
RQT 9	120	0.25	0.998
RQT 10	150	0.3	0.998
Uncertainty in N_K = ± 1.4 % (k = 2)			

Table 5: Diagnostic x-ray air kerma – entrance qualities

Quality	Nominal generating potential (kV)	HVL (mm Al)	F_Q
RQR 2	40	1.42	0.998
RQR 3	50	1.78	0.998
RQR 4	60	2.19	0.998
RQR 5	70	2.58	0.998
RQR 6	80	3.01	0.998
RQR 7	90	3.48	0.998
RQR 8	100	3.97	0.998
RQR 9	120	5.00	0.998
RQR 10	150	6.57	0.998
Uncertainty in N_K = ± 1.4 % (k = 2)			

Table 6: Diagnostic x-ray air kerma – exit qualities

Quality	Nominal generating potential (kV)	HVL (mm Al)	F_Q
RQA 2	40	2.2	0.998
RQA 3	50	3.8	0.998
RQA 4	60	5.4	0.998
RQA 5	70	6.8	0.998
RQA 6	80	8.2	0.998
RQA 7	90	9.2	0.998
RQA 8	100	10.1	0.998
RQA 9	120	11.6	0.998
RQA 10	150	13.3	0.998
Uncertainty in N_K = ± 1.4 % (k = 2)			

6 THERAPY LEVEL X-RAY AIR KERMA

Table 7 lists values of the multiplying factor F_Q for therapy level x-ray air kerma beam qualities in the range 1.00 mm Al HVL to 20.0 mm Al HVL (nominal generating potential 50 kV to 280 kV). F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Bass *et al.* 2019: NPL Report IR 54). The reviewed uncertainty for air kerma calibration coefficients N_K in this energy range is also given.

Table 7: Therapy level x-ray air kerma

Nominal generating potential (kV)	HVL (mm Al)	HVL (mm Cu)	F_Q
50	1.00	0.030	0.997
70	2.0	0.062	0.998
100	4.0	0.15	0.999
105	5.0	0.20	0.999
135	8.8	0.50	0.999
180	12.3	1.0	1.001
220	16.1	2.0	1.001
280	20.0	4.0	1.002
Uncertainty in N_K = ± 1.4 % (k = 2)			

7 PROTECTION LEVEL X-RAY AIR KERMA

Table 8 lists values of the multiplying factor F_Q for protection level x-ray air kerma beam qualities in the nominal generating potential range 10 kV to 300 kV. F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Kelly *et al.* 2019: NPL Report IR 51 and Bass *et al.* 2019: NPL Report IR 54). The reviewed uncertainty for air kerma calibration coefficients N_K in this energy range is also given.

Table 8: Protection level x-ray air kerma

Nominal generating potential (kV)	HVL (mm Al)	HVL (mm Cu)	F_Q
10	0.058	-	0.996
15	0.17	-	0.997
20	0.36	-	0.997
25	0.69	-	0.998
30	1.21	-	0.998
40	-	0.085	0.998
60	-	0.234	0.998
80	-	0.581	0.999
100	-	1.12	0.998
120	-	1.73	0.998
150	-	2.42	0.998
200	-	4.10	0.999
250	-	5.33	0.999
300	-	6.26	0.999
Uncertainty in N_K = ± 1.6 % (k = 2)			

8 HDR ^{192}Ir BRACHYTHERAPY REFERENCE AIR KERMA RATE

Table 9 gives the value of the multiplying factor F_Q for HDR ^{192}Ir brachytherapy reference air kerma rate. F_Q must be applied to pre-1st of September 2019-certificated reference air kerma rate calibration coefficients $N_{\dot{K}_R}$ in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (NPL Report 2019a). The reviewed uncertainty for reference air kerma rate calibration coefficient $N_{\dot{K}_R}$ is also given.

Table 9: HDR ^{192}Ir brachytherapy reference air kerma rate

Radionuclide	F_Q
^{192}Ir	1.000
Uncertainty in $N_{\dot{K}_R}$ = ± 0.8 % (k = 2)*	

*For a well-type ionisation chamber

9 ^{60}Co THERAPY LEVEL AIR KERMA

Table 10 gives the value of the multiplying factor F_Q for therapy level air kerma ^{60}Co γ-rays. F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Bass *et al.* 2019: NPL Report IR 53. Two nominally-identical cavity ionisation chambers designated PS5/1 and PS5/2 comprise the primary standard.) The reviewed uncertainty for air kerma calibration coefficient N_K is also given.

Table 10: ^{60}Co therapy level air kerma

Radionuclide	F_Q
^{60}Co	0.995
Uncertainty in N_K = ± 0.7 % (k = 2)	

10 PROTECTION LEVEL AIR KERMA (RADIONUCLIDES)

Table 11 gives values of the multiplying factor F_Q for protection level air kerma ^{241}Am, ^{137}Cs and ^{60}Co γ-rays. F_Q must be applied to pre-1st of September 2019-certificated air kerma calibration coefficients N_K in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (Bass *et al.* 2019: NPL Report IR 53 and Bass *et al.* 2019: NPL Report IR 54. A transfer standard is used as a reference for the ^{241}Am air kerma secondary calibration, traceable to the medium energy x-ray primary standard.) The reviewed uncertainty for air kerma calibration coefficients N_k in this range is also given.

Table 11: Protection level air kerma (radionuclides)

Radionuclide	F_Q
^{241}Am	0.998
^{137}Cs	0.995
^{60}Co	0.995
Uncertainty in N_K = ± 1.7 % (k = 2)	

11 THERAPY LEVEL MV X-RAY ABSORBED DOSE TO WATER

Table 12 lists values of the multiplying factor F_Q for therapy level absorbed dose ^{60}Co γ-rays and high energy x-ray beam qualities in the $TPR_{20,10}$ quality index range 0.568 – 0.800. F_Q must be applied to pre-1st of September 2019-certificated absorbed dose calibration coefficients N_D in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (NPL Report 2019b). The reviewed uncertainty for absorbed dose calibration coefficients N_D in this range is also given.

Table 12: Therapy level MV x-ray absorbed dose to water

Quality index ($TPR_{20,10}$)	Beam energy (MV)	Depth in water (g/cm^2)	F_Q
0.568	(^{60}Co)	5	1.004
0.633	4	5	1.004
0.682	6	5	1.004
0.713	8	5	1.004
0.733	10	5	1.004
0.758	15	7	1.004
0.775	18	7	1.004
0.800	25	7	1.004
Uncertainty in N_D = ± 1.3 % (k = 2)			

12 THERAPY LEVEL ELECTRON ABSORBED DOSE TO WATER

Table 13 lists values of the multiplying factor F_Q for therapy level electron beams in the $R_{50,D}$ quality index range 1.54 cm to 7.83 cm (nominal energy 4 MeV to 20 MeV). F_Q must be applied to pre-1st of September 2019-certificated therapy level absorbed dose calibration coefficients $N_{D,w}$ in Gy/C to incorporate changes to the UK primary standard effective from 1st of September 2019 (NPL Report 2019c). The reviewed uncertainty for absorbed dose calibration coefficients $N_{D,w}$ in this range is also given.

Table 13: Therapy level electron absorbed dose to water

Nominal energy (MeV)	$R_{50,D}$ (cm)	z_{ref} (cm)	F_Q
4	1.54	0.82	1.016
6	2.30	1.28	1.013
10	3.90	2.24	1.007
12	4.58	2.65	1.005
15	5.75	3.35	1.001
20	7.83	4.60	0.997
Uncertainty in $N_{D,w}$ = ± 2.0 % (k = 2)			

13 ACKNOWLEDGEMENTS

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