

Calibration Certificate

No. 201141501



PTW
CALIBRATION
LAB

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Calibration Object

NOMEX Multimeter

Description

Manufacturer

Customer

[REF] T11049 [SN] 101947

Non-invasive kV and dosimeter

PTW-Freiburg

S.C. Alarad

No. 1 Molocanilor Str.
MD-2019 Chisinau

Order No. : AU2001625

Order Date : 2020-05-29

Calibration Date

2020-06-09

Conformity

- ☒ Measured value(s) within the allowed deviation¹⁾
☐ Measured value(s) beyond the allowed deviation¹⁾

Calibration Results

RAD/FLU/DENT

Measuring Quantity

Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose Rate

Reference Calibration Factor

$N_K = 1.105 \cdot 10^5 \text{ Gy/C}$ (70 kV / 2.5 mm Al / W)

Calibration Table

Q (tube HV / TF)	Ref Dose [Gy]	Meas Dose [Gy]	Dev [%]	Result ² ($\leq \pm 3.5 \%$)
70 kV / 3.0 mm Al (RQR 5)	1.500E-03	1.501E-03	0.07	passed
90 kV / 3.0 mm Al (RQR 7)	2.439E-03	2.440E-03	0.03	passed
150 kV / 20.0 mm Al	1.650e-03	1.652e-03	0.12	passed

Measuring Quantity

Tube Voltage (PPV)

Calibration Factor

$N_{kV} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ² ($\leq \pm 1 \text{ kV}$ or $\leq \pm 1.5 \%$)
50 kV / 3.0 mm Al (RQR 3)	50.1	50.3	0.2	0.4	passed
70 kV / 3.0 mm Al (RQR 5)	70.0	70.0	0.0	0.0	passed
90 kV / 3.0 mm Al (RQR 7)	89.8	89.8	0.0	0.0	passed
100 kV / 10.0 mm Al	99.8	99.8	0.0	0.0	passed
120 kV / 3.0 mm Al (RQR 9)	119.4	119.4	0.0	0.0	passed
120 kV / 20.0 mm Al	119.6	119.1	-0.5	-0.4	passed
150 kV / 3.0 mm Al (RQR 10)	149.3	149.3	0.0	0.0	passed
150 kV / 40.0 mm Al	149.6	149.3	-0.3	-0.2	passed

1 The statement of conformity was made in accordance with DIN EN ISO 14253-1

2 For additional information on the calibration results please refer to section calibration uncertainty on page 6

Freiburg, 2020-06-10

PTW-Freiburg
Physikalisch-Technische
Werkstätten Dr. Pöchlau GmbH

(Signature)

Calibration Results cont...

RAD/FLU/DENT

Measuring Quantity

Total Filtration (TF)

Calibration Factor

 $N_{TF} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref TF [mm Al]	Meas TF [mm Al]	Dev [mm Al]	Dev [%]	Result ³ ($\leq \pm 0.5$ mmAl or $\leq \pm 10\%$)
70 kV / 3.0 mm Al	2.98	3.00	0.02	0.67	passed
150 kV / 40.0 mm Al	40.01	39.90	-0.11	-0.27	passed

Measuring Quantity

Half Value Layer (HVL)

Calibration Factor

 $N_{HVL} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HVL [mm Al]	Meas HVL [mm Al]	Dev [mm Al]	Dev [%]	Result ³ ($\leq \pm 0.25$ mm Al)
50 kV / 3.0 mm Al	1.95	1.93	-0.02	-	passed
100 kV / 10.0 mm Al	6.87	6.86	-0.01	-	passed
150 kV / 40.0 mm Al	12.87	12.84	-0.03	-	passed

Measuring Quantity

Irradiation Time

Calibration Factor

 $N_{Irad} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref Time [ms]	Meas Time [ms]	Dev [ms]	Dev [%]	Result ³ ($\leq \pm 0.5$ ms or $< \pm 1\%$)
50 kV / 3.0 mm Al	403.2	402.5	-0.7	-0.17	passed
100 kV / 10.0 mm Al	406.5	406.0	-0.5	-0.12	passed
150 kV / 40.0 mm Al	637.8	637.0	-0.8	-0.13	passed

DENT PAN

Measuring Quantity

Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose Rate

Reference Calibration Factor

 $N_K = 1.105 \cdot 10^5 \text{ Gy/C}$ (70 kV / 2.5 mm Al / W)

Measuring Quantity

Tube Voltage (PPV)

Calibration Factor

 $N_{KV} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ³ ($< \pm 1$ kV or $< \pm 1.5\%$)
70 kV / 9.0 mm Al	70.00	70.00	0.00	0.00	passed
120 kV / 35.0 mm Al	119.60	119.40	-0.20	-0.17	passed

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For additional information on the calibration results please refer to section calibration uncertainty on page 6

Calibration Results cont...

CT

Measuring Quantity Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose RateReference Calibration Factor $N_K = 1.213 \cdot 10^5 \text{ Gy/C}$ (120 kV / 12.5 mm Al / W)

Measuring Quantity Tube Voltage (PPV)

Calibration Factor $N_{KV} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ⁴ ($\leq \pm 1 \text{ kV}$ or $\leq \pm 1.5 \%$)
100 kV / 12.5 mm Al	99.80	99.90	0.10	0.10	passed
120 kV / 12.5 mm Al	119.50	119.60	0.10	0.08	passed

MAM

Measuring Quantity Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose RateReference Calibration Factor $N_K = 2.530 \cdot 10^5 \text{ Gy/C}$ (28 kV / 30 μm Mo / Mo)

Calibration Table

Q (tube HV / anode / TF)	Ref Dose [Gy]	Meas Dose [Gy]	Dev [%]	Result ⁴ ($\leq \pm 2.5 \%$)
28 kV / 30 μm Mo	4.626e-03	4.639e-03	0.28	passed
35 kV / 30 μm Mo	8.618E-03	8.579E-03	-0.46	passed

Measuring Quantity Tube Voltage (PPV)

Calibration Factor $N_{KV} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ⁴ ($\leq \pm 0.5 \text{ kV}$)
23 kV / 30 μm Mo	23.00	23.10	0.10	-	passed
25 kV / 30 μm Mo	25.10	25.10	0.00	-	passed
28 kV / 30 μm Mo	28.10	28.10	0.00	-	passed
30 kV / 30 μm Mo	30.10	30.10	0.00	-	passed
35 kV / 30 μm Mo	35.10	35.10	0.00	-	passed

Measuring Quantity Half Value Layer (HVL)

Calibration Factor $N_{HVL} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HVL [mm Al]	Meas HVL [mm Al]	Dev [mm Al]	Dev [%]	Result ⁴ ($\leq \pm 0.010 \text{ mm Al}$)
23 kV / 30 μm Mo	0.270	0.270	0.000	-	passed
35 kV / 0.7 mm Al	0.600	0.600	0.000	-	passed

Measuring Quantity Irradiation Time

Calibration Factor $N_{\text{Irad}} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref Time [ms]	Meas Time [ms]	Dev [ms]	Dev [%]	Result ⁴ ($\leq \pm 0.5 \text{ ms}$ or $\leq \pm 1 \%$)
28 kV / 30 μm Mo	242.0	242.0	0.0	0.00	passed
35 kV / 30 μm Mo	303.0	303.5	0.5	0.17	passed

4 For additional information on the calibration results please refer to section calibration uncertainty on page 6

Calibration Results cont...

MAM

Measuring Quantity Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose RateReference Calibration Factor $N_K = 1.910 \cdot 10^5 \text{ Gy/C}$ (28 kV / 50 μm Ag / W)

Calibration Table

Q (tube HV / TF)	Ref Dose [Gy]	Meas Dose [Gy]	Dev [%]	Result ⁵ ($\leq \pm 2,5 \%$)
28 kV / 50 μm Ag	2.231E-03	2.226E-03	-0.21	passed
35 kV / 50 μm Ag	3.700E-03	3.700E-03	0.00	passed

Measuring Quantity Tube Voltage (PPV)

Calibration Factor $N_{KV} = 1.0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ⁵ ($< \pm 0,5 \text{ kV}$)
28 kV / 50 μm Ag	28.10	28.20	0.10	-	passed
35 kV / 50 μm Ag	35.10	35.30	0.20	-	passed

Measuring Quantity Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose RateReference Calibration Factor $N_K = 2.345 \cdot 10^5 \text{ Gy/C}$ (28 kV / 25 μm Rh / Mo)

Calibration Table

Q (tube HV / TF)	Ref Dose [Gy]	Meas Dose [Gy]	Dev [%]	Result ⁵ ($\leq \pm 2,5 \%$)
28 kV / 25 μm Rh	3.632E-03	3.648E-03	0.44	passed
35 kV / 25 μm Rh	6.964E-03	6.994E-03	0.44	passed

Measuring Quantity Tube Voltage (PPV)

Calibration Factor $N_{KV} = 1,0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ⁵ ($< \pm 0,5 \text{ kV}$)
28 kV / 25 μm Rh	28.10	28.10	0.00	-	passed
23 kV / 25 μm Rh	35.10	35.10	0.00	-	passed

Measuring Quantity Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose RateCalibration Factor $N_K = 1.881 \cdot 10^5 \text{ Gy/C}$ (28 kV / 50 μm Rh / W)

Calibration Table

Q (tube HV / TF)	Ref Dose [Gy]	Meas Dose [Gy]	Dev [%]	Result ⁵ ($\leq \pm 2,5 \%$)
28 kV / 50 μm Rh	1.514E-03	1.524E-03	0.68	passed
35 kV / 50 μm Rh	2.436E-03	2.460E-03	0.97	passed

Measuring Quantity Tube Voltage (PPV)

Calibration Factor $N_{KV} = 1,0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ⁵ ($< \pm 0,5 \text{ kV}$)
28 kV / 50 μm Rh	28.10	28.20	0.10	-	passed
35 kV / 50 μm Rh	35.10	35.10	0.00	-	passed

5 For additional information on the calibration results please refer to section calibration uncertainty on page 6

Calibration Results cont...

MAM

Measuring Quantity Air Kerma (K_{air}) and Air Kerma Rate / Dose and Dose RateCalibration Factor $N_K = 1.999 \cdot 10^5 \text{ Gy/C}$ (28 kV / 0.7 mm Al / W)

Calibration Table

Q (tube HV / TF)	Ref Dose [Gy]	Meas Dose [Gy]	Dev [%]	Result ⁶ ($\leq \pm 2,5 \%$)
28 kV / 0.7 mm Al	3.421E-03	3.436E-03	0.44	passed
35 kV / 0.7 mm Al	6.025E-03	6.010E-03	-0.26	passed

Measuring Quantity Tube Voltage (PPV)

Calibration Factor $N_{KV} = 1,0$

Calibration Table

Q (tube HV / TF)	Ref HV [kV]	Meas HV [kV]	Dev [kV]	Dev [%]	Result ⁶ ($< \pm 0,5 \text{ kV}$)
28 kV / 0.7 mm Al	28.10	28.10	0.00	-	passed
35 kV / 0.7 mm Al	35.10	35.20	0.10	-	passed

6 For additional information on the calibration results please refer to section calibration uncertainty on page 6

Measuring Equipment

Equipment / Range	[REF] / [SN] or Type-SN	Label	Date of last Calibration / Cert. No. / Recalibration Interval [years]
Invasive HV Ref. / (40...150) kV	DYNALYZER III A / 73-05-0-1394	EMG1000411	29.08.2019 / C35081 / 2 year(s)
Invasive HV Ref. / (22...40) kV	DYNALYZER II / 61-08-0-0517	EMG1200811	11.07.2018 / 020685 (GiCi) / 2 year(s)
Electrometer (RAD)	UNIDOS 10001-11361	EMG04010I3	12.07.2019 / 1950060 / 1 year(s)
Electrometer (MAM)	UNIDOS 10001-11360	EMG04009I3	26.09.2019 / 1950083 / 1 year(s)
Temperature Reference	Lufft C100-045.0109.0202.2.1.1.25	EMG0903211	14.08.2019 / T121329 / 1 year(s)
Air Pressure Reference	Lufft C300-023.0409.0202.2.1.1.25	EMG09033G1	15.08.2019 / D33825 / 1 year(s)
Secondary Standard	TM34069-0002	-	23.08.2019 / 60064-19 (PTB) / 2 year(s)

Calibration conditions and set-up

	R/F/D (40 ... 150) kV	CT & DP (60 ... 150) kV	MAM (23 ... 35) kV
Anode	W	W	Mo / W
Anode Angle	12°	12°	20°
Waveform	HF	HF	HF
Field Size	Ø 10 cm	Ø 10 cm	Ø 10 cm
SDD	50 cm	50 cm	57 cm
Irradiation Time	520 ms ± 130 ms	520 ms ± 130 ms	260 ms ± 50 ms
Climatic Conditions	Temperature Range: (21 ± 3) °C Air Pressure Range: (1000 ± 50) hPa Relative Humidity: (40 ± 20) %		
Arrangement in radiation field	Top side of the instrument faced towards the radiation source, crosshair centred in the beam centre		
Reference Point	4.7 mm below the top side		
Dose Rate Range	(1.01 ± 0.99) Gy/min		
Calibration procedure	The calibration was performed according document: PTW-009271		

Calibration Uncertainty

Measuring quantity	Applications	Uncertainty (k = 2)
Air Kerma (K_{air}) / Dose and Dose Rate	RAD/FLU/DENT, DENT PAN, CT	2.5 %
Air Kerma (K_{air}) / Dose and Dose Rate	MAM	1.5 %
HV: Practical Peak Voltage (PPV)	RAD/FLU/DENT, DENT PAN, CT	1.2 %
HV: Practical Peak Voltage (PPV)	MAM	1.4 %
Total Filtration (TF)	RAD/FLU/DENT, DENT PAN, CT	1.7 %
Half Value Layer (HVL)	RAD/FLU/DENT, DENT PAN, CT	1.0 %
Half Value Layer (HVL)	MAM	2.8 %
Irradiation Time	all	1.0 %

Remark on results in calibration tables: The limits as denoted in the calibration tables refer to the instrument deviation with respect to the laboratory reference values. The calibration uncertainty of the laboratory reference values are denoted in the table above for the respective measuring quantity.

Remarks

- The uncertainties stated correspond to the double standard deviation ($k=2$). The uncertainty of the calibration was calculated according to ISO GUM from the partial uncertainties arising from the standards used, the calibration procedure, the environmental conditions and short time effects of the calibration object. A share for the long term instability of the object under calibration is not included.
- The calibration of the invasive HV-reference components and the air kerma secondary standard is traceable to national standards of the German National Laboratory, PTB, Braunschweig and to the National Institute of Standards and Technology, USA (NIST). This calibration certificate may not be reproduced other than in full except with the permission of the issuing laboratory. This certificate is valid only with the instrument showing the intact sticker with the certificate number. The calibration of instruments having been opened for repair are not comparable to previous calibrations. Calibration certificates without signature are not valid.
- The calibration object fully complies with the respective specifications given in the data sheet and user manual.
- The reference calibration factors as denoted throughout the calibration certificate are not to be applied on a dose measurement result. They are displayed for information purposes only.
- Used Abbreviations: R/F/D = RAD/FLU/DENT, DP = DENT PAN, SDD = Source Detector Distance, Q = radiation quality, PPV = Practical Peak Voltage (acc. IEC 61676), HVL = Half Value Layer, TF = Total Filtration, Meas = Measured (Value), Ref = Reference (Value), Dev = Deviation, W = tungsten, Mo = molybdenum, HF = High Frequency, Air Kerma = Air Kerma in Air, HV = Tube High Voltage