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Comparison of the dosimetry systems for brachytherapy in terms of calibration coefficients

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Laboratory accredited by the Polish Centre for Accreditation, accreditation No. AP 155*
* an actual scope of accreditation No. AP 155 is available on the PCA website: www.pca.gov.pl

Introduction

The use of calibrated radiotherapy electrometers with well-type ionization chambers, traceably to primary standards directly or through secondary standards, **is necessary and required by Polish law for the independent verification of brachytherapy source strength**.

In Poland, these measuring instruments are calibrated at the Secondary Standards Dosimetry Laboratory which is now the integral part of the Maria Sklodowska-Curie National Research Institute of Oncology in Warsaw.

Introduction

Calibrations are made for a dosimetry system composed of:

a) a vented well-type chamber;
b) a source holder to position the source inside the well-type chamber, so called „adapter”;
c) an electrometer;
d) an extension cable.

For these dosimetry system calibrations, the internal bias supply of the user electrometer is used to apply polarizing voltage.

These calibrations are in the scope of accreditation number AP 155 granted to our laboratory by the Polish Centre of Accreditation on May 28, 2014. This accreditation was granted for the conformity with the requirements of the PN-EN ISO/IEC 17025 standard.

Introduction

The aim of this study was comparison of 58 dosimetry systems calibrated in period of 2022-2024 in Poland.

At that time the most commonly calibrated user well-type chambers were:

- **HDR 1000 PLUS** manufactured by Standard Imaging,
- **33005** manufactured by PTW;
- **33004** manufactured by PTW.

Introduction

Characteristics of the studied well-type chambers, based on the data provided by the manufacturers:

HDR 1000 PLUS well-type chamber

adapter 70010

HDR 1000 PLUS WELL CHAMBER (REF 90008) SPECIFICATIONS

ADCL CALIBRATIONS	HDR ^{192}Ir and/or LDR radionuclides from various manufacturers as requested
ACTIVE VOLUME	245 cm^3
CONNECTOR	Two lug triax BNC (standard) TNC, Type M, or BNC + Banana (optional)
RANGE	10 U to 80 MU 0.01 mCi to 20 Ci
CABLE	3 ft, 1 m
BIAS VOLTAGE	± 300 volts, typical
LEAKAGE	Less than 50 fA
STABILITY	0.2% (Reproducibility over 2 years)
RESPONSE	± 0.5% over 25 mm at center of axis

SENSITIVITY

SOURCE	Current to Air Kerma Strength (U=1uGym^2/h)	Current to Apparent Activity
HDR Iridium:	2.1 pA/U	8.6 nA/Ci
Cesium:	2.0 pA/U	5.6 nA/Ci
LDR Iridium:	2.3 pA/U	9.1 nA/Ci
Iodine:	4.3 pA/U	5.4 nA/Ci
Palladium:	2.1 pA/U	2.4 nA/Ci

A_{wall}	0.9996, typical
ACCESSORIES	Case (REF 50004) included Wall mount accessory (REF 70007) (5) Interlocking 1" lead rings (REF 70125) Carrying case for any Comprehensive Calibration System (REF 70012)
DIMENSIONS	*Height:* 6.1 in, 15.6 cm *Insert Diameter:* 1.4 in, 3.5 cm *Diameter:* 4 in, 10.2 cm *Insert Height:* 4.8 in, 12.1 cm *Weight:* 6.1 lbs, 2.7 kg

Specifications subject to change without notice.

Introduction

Characteristics of the studied well-type chambers, based on the data provided by the manufacturers:

well-type chamber type 33005

+

adapter T33004.1.013
for catheters with diameters between 1.8 mm and 3.2 mm

or adapter T33004.1.012
for catheters with diameters between 1.0 mm and 1.8 mm

or adapter T33002.1.009
for Nucletron afterloader

Specification	
Type of product	well-type ionization chamber
Application	source strength measurement of brachytherapy sources
Measuring quantities	apparent activity air kerma strength exposure strength
Calibration	Ir-192, I-125, others upon request
Nominal response	125 fA/MBq (Ir-192) 65 fA/MBq (I-125)
Nominal volume	116 cm^3
Design	vented, guarded
Chamber voltage	400 V nominal
Reference point	87 mm below chamber top
Long-term stability	≤ ± 1 % per year
Leakage current	≤ ± 50 fA

Measures:	
Inner well diameter	32 mm
Outer dimensions	height 180 mm base diameter 127 mm outer well diameter 93 mm
Weight	1.4 kg

Useful ranges:	
Temperature	(10 ... 40) °C for sources > 100 keV photons (15 ... 35) °C for sources < 100 keV photons or < 1 MeV electrons
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Introduction

Characteristics of the studied well-type chambers, based on the data provided by the manufacturers:

well-type chamber type 33004

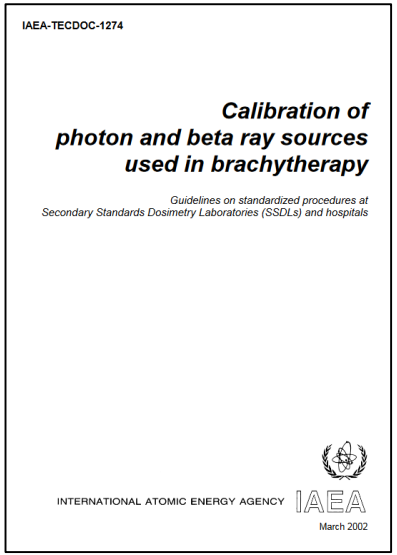
Type of product	Vented well-type chamber type 33004
Application	Calibration of afterloading sources in connection with a therapy dosemeter
Calibration	^{192}Ir, others upon request
Measuring quantities	Air kerma strength, apparent activity, exposure strength
Measuring ranges	(in connection with PTW-UNIDOS)
LOW	1.7 MBq ... 1.7 GBq
MEDIUM	85 MBq ... 85 GBq
HIGH	8.5 GBq ... 8.5 TBq[1)]
	[1)]The upper limit of the measuring range at 400 V for a saturation of 99.5 % is 4 TBq
Resolution	The resolution of the digital display is at least 0.5 % of the measuring ranges given
Measuring volume	200 cm³
Reference point	84.5 mm (3.327 in) below chamber top
Change of response with source positioning change ± 1 cm	< 1 %
Chamber voltage	max. 500 V
Leakage current	< 0.5 pA
Temperature range	(10 ... 40) °C, (50 ... 104) °F
Relative humidity range	(10 ... 80) %, max. 20 g/m³
Air pressure range	(700 ... 1060) hPa
Dimensions	
Height	190.5 mm, 7.5 in
Base diameter	178 mm, 7 in
Shaft outer diam.	93 mm, 3.66 in
Shaft inner diam.	32 mm, 1.26 in
Weight	2.4 kg, 5.29 lbs

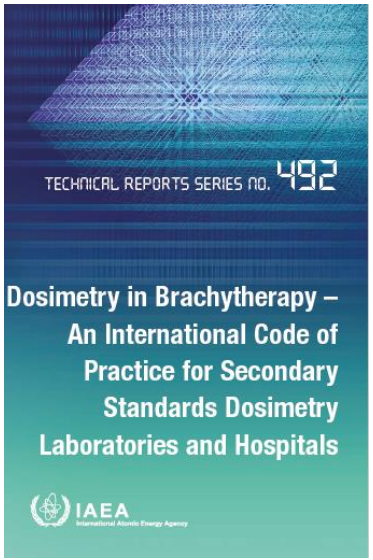
Methods

We compared calibration coefficients values for each of three groups of well-type ionization chambers mentioned earlier.

The **calibration coefficients** based on standards of the reference air kerma rate (N_{RAKR}) were established in ^{192}Ir radionuclide in reference conditions defined in:

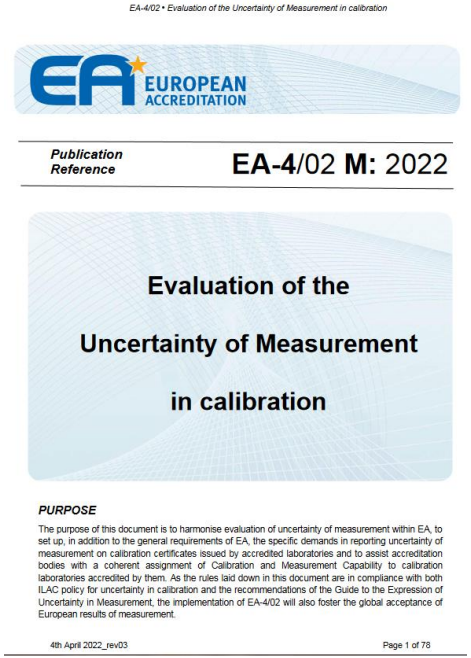
- the IAEA-TECDOC-1274;
- Technical Reports Series No. 492 issued by the International Atomic Energy Agency.





Methods

Measurement uncertainties have been determined in accordance with document EA-4/02 M:2022 Evaluation of the Uncertainty of Measurement in Calibration.


EA-4/02 • Evaluation of the Uncertainty of Measurement in calibration

EUROPEAN ACCREDITATION

Publication Reference **EA-4/02 M: 2022**

Evaluation of the Uncertainty of Measurement in calibration

PURPOSE

The purpose of this document is to harmonise evaluation of uncertainty of measurement within EA, to set up, in addition to the general requirements of EA, the specific demands in reporting uncertainty of measurement on calibration certificates issued by accredited laboratories and to assist accreditation bodies with a coherent assignment of Calibration and Measurement Capability to calibration laboratories accredited by them. As the rules laid down in this document are in compliance with both ILAC policy for uncertainty in calibration and the recommendations of the Guide to the Expression of Uncertainty in Measurement, the implementation of EA-4/02 will also foster the global acceptance of European results of measurement.

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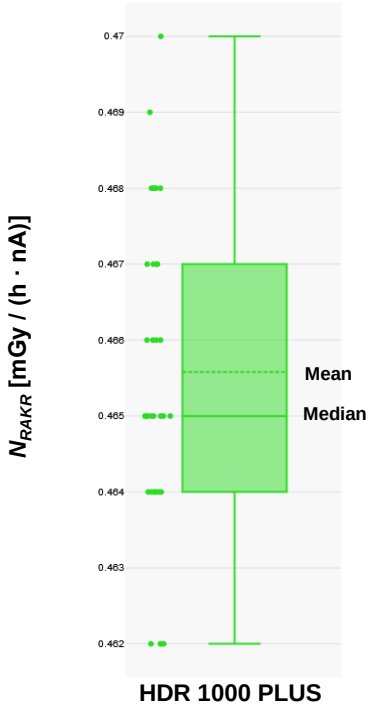
Results

Box plot

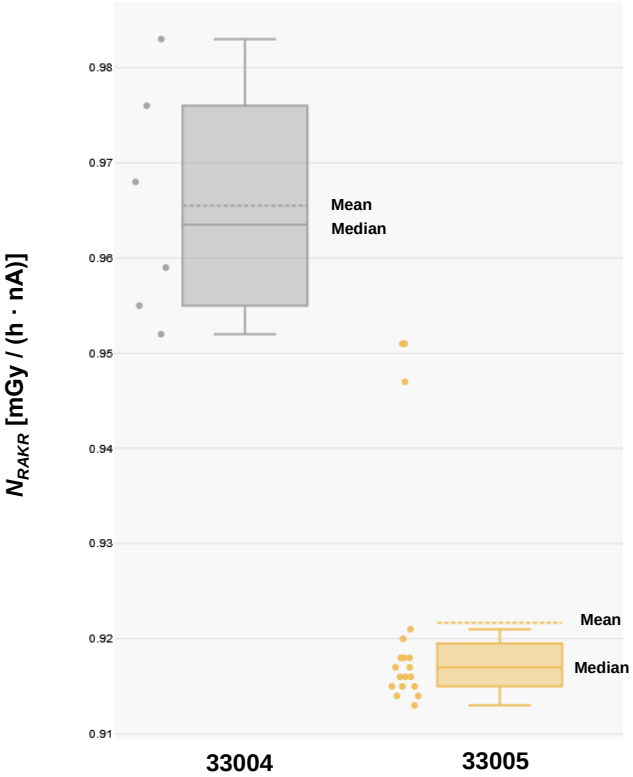


The uncertainty value of N_{RAKR} for HDR 1000 PLUS well-type chambers ranges from 3.0% to 3.2% of the value of N_{RAKR}.

It is an expanded uncertainty with a probability of expansion of about 95% and a coverage factor of $k = 2$.

Results

Box plot



The uncertainty value of N_{RAKR} for examined 33004 and 33005 well-type chambers ranges from 3.0% to 3.2% of the value of N_{RAKR}.

It is an expanded uncertainty with a probability of expansion of about 95% and a coverage factor of k = 2.

Results

Descriptive statistics

Type of chambers	HDR 1000 PLUS	33004	33005
Number of observations	31	6	19
Arithmetic mean value of N_{RAKR} [mGy / (h · nA)]	0.466	0.965	0.922
Median value of N_{RAKR} [mGy / (h · nA)]	0.465	0.964	0.917
Standard deviation value of N_{RAKR} [mGy / (h · nA)]	0.0020	0.012	0.013
Range of N_{RAKR} [mGy / (h · nA)]	0.008	0.031	0.038
Q_1 [mGy / (h · nA)]	0.464	0.955	0.915
Q_3 [mGy / (h · nA)]	0.467	0.976	0.919
$N_{RAKR\ max}$ [mGy / (h · nA)]	0.470	0.983	0.951
$N_{RAKR\ min}$ [mGy / (h · nA)]	0.462	0.952	0.913
$N_{RAKR\ max}$ / $N_{RAKR\ min}$	1.02	1.03	1.04
Outliers [mGy / (h · nA)]	none	none	0.951, 0.947, 0.951

Conclusions

The obtained results indicate that the maximum differences in the calibration coefficients of the analyzed dosimetry systems for brachytherapy do not exceed 4% in the type of the chamber.

Therefore, it should be remembered that use of each dosimetry system in clinical work must always be preceded by its calibration in a competent calibration laboratory. This will enable verification of brachytherapy source strength with the expected accuracy.

Thank you for your attention.