Physikalisch-Technische Bundesanstalt

Braunschweig und Berlin

PTB

Kalibrierschein

Calibration Certificate

Gegenstand: *Object:*	Neutron ambient dose equivalent meter
Hersteller: *Manufacturer:*	Wedholm Medical AB Blommenshovsvägen 26 SE-61129 Nyköping
Typ: *Type:*	Neutron Monitor 2222A He-3
Kennnummer: *Serial number:*	2222.0208
Auftraggeber: *Applicant:*	Wedholm Medical AB Blommenshovsvägen 26 SE-61129 Nyköping
Anzahl der Seiten: *Number of pages:*	7
Geschäftszeichen: *Reference No.:*	6.5-15/09
Kalibrierzeichen: *Calibration mark:*	6214/09
Datum der Kalibrierung: *Date of calibration:*	2009-10-27 to 2009-10-30

Im Auftrag:
By order:

Dr. A. Zimbal

Braunschweig, 2009-11-16

Siegel
Seal

Bearbeiter:
Examiner:

S. Koch

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1. Measurement conditions

The measurements were performed free in air in a low scattering room (7 m x 7 m x 6.5 m) of the PTB in a height of 3.25 m above the floor. For the calibration with neutron radiation the reference fields from a ^{241}Am-Be(α,n)-, a ^{252}Cf- and a D_2O moderated ^{252}Cf-neutron source are available /1/. A shadow object was used for the separation of the direct and the inscattered radiation /2/.

The centre of the moderator cylinder was defined as the reference point of the instrument. The radiation incidence was perpendicular to the axis of the cylinder. Relative to the irradiation direction (from the source to the instrument) the electronics was at the right side. For the measurements the instrument was adjusted with its reference point at the test point in the radiation field.

The measurements were performed with a measuring time of 100 s. The reading quantity was the integrated dose. The dose rates were calculated from the differences of the integrated doses for intervals of 100 s. All measuring values are mean values of 10 up to 17 independent readings.

During the measurements the stability of the instrument reading was tested by a ^{241}Am-Be(α,n)-check source of the PTB. The check source was reproducibly fixed close to the surface of the instrument.

The temperature in the measuring room was between 20 °C and 21 °C, the relative humidity was between 60 % and 65 %.

2. Measurement quantity

The measurement quantity is the neutron ambient dose equivalent rate $\dot{H}^*(10)$. The conventional true value of this quantity in the irradiation fields used was calculated from the flux density of the direct neutrons, which reach the point of test without further interactions, and the fluence-to-dose equivalent conversion coefficients $h^*_\Phi(10)$. The values of $h^*_\Phi(10)$ for ^{252}Cf and ^{241}Am-Be(α,n) are taken from ref. /3,4/. The value for the moderated source takes into account that the PTB-moderator differs slightly from the ISO-moderator /5/. The fluence-to-dose equivalent conversion coefficients used are listed in table 1.

Tab. 1: Fluence-to-dose equivalent conversion coefficients

source	conversion coefficient $h^*_\Phi(10)$ pSv·cm^2
^{252}Cf(D$_2$O)	110 ± 7
^{252}Cf	385 ± 8
^{241}Am-Be(α,n)	391 ± 8

The uncertainty stated is the expanded uncertainty obtained by multiplying the standard uncertainty by the coverage factor $k = 2$. It has been determined in accordance with the "Guide to the Expression of Uncertainty in Measurement" (ISO, 1995). Normally, the value of the measurand lies within the assigned range of values with a coverage probability of approximately 95 %.

3. Determination of neutron ambient dose equivalent rate

In a given radiation field, the neutron ambient dose equivalent rate $\dot{H}^*(10)$ is derived from the instrument's reading by the following relationship:

$$\dot{H}^*(10) = M \cdot N \cdot k_l \cdot k_s$$

with:

- M = reading of the instrument
- N = calibration factor
- k_l = correction factor for the linearity
- k_s = field-specific correction factor.

4. Results

4.1. Calibration factor

The calibration factor for the quantity $\dot{H}^*(10)$ was determined for the following reference conditions: neutron radiation field from the bare ^{252}Cf source with a neutron ambient dose equivalent rate of (78.1 ± 1.9) µSv/h. The result is given in table 2 and is valid for a reading of 101 µSv/h for the ^{241}Am-Be(α,n) check source of the PTB.

Tab. 2: Calibration factor

source	calibration factor N
^{252}Cf	1.88 ± 0.06

4.2. Field-specific correction factor

Because of the often undesirable energy-dependent dose-equivalent response of neutron instruments, the uncorrected reading can only be used in radiation fields with the same or similar neutron energy distribution as that of the calibration field. For use in neutron radiation fields with other energy distributions a field-specific correction factor should be applied. For two radiation fields, k_s was determined experimentally (table 3).

Tab. 3: Field-specific correction factor

neutron field	correction factor k_s
^{252}Cf	1
$^{252}Cf(D_2O)$	0.84 ± 0.08
$^{241}Am\text{-}Be(\alpha,n)$	1.02± 0.07

For other radiation fields such as work place fields, k_s can be determined by a "field calibration" (i.e. the comparison of the instrument's reading with a reference instrument which can determine the conventional true value in the work place) or by calculation. The latter method requires that the energy dependent fluence response of the instrument and the spectral neutron fluence of the radiation field is known from measurement or calculation /6,7/.

4.3. Correction factor for linearity

The linearity of the reading was tested with four ^{252}Cf-sources of known directional dependence of their neutron source strengths. The correction factors k_l were derived from the ratios of the expected and the observed readings. The correction factors for various instrument readings, normalized to a reading of 55.3 µSv/h, are listed in table 4.

Tab. 4: Correction factors for non-linearity

reading µSv/h	correction factor k_l
320	1.015 ± 0.018
55.3	1
11.0	1.003 ± 0.028
1.15	0.97 ± 0.08

4.4. Photon response of the instrument

According to IEC 61005 /8/ the response of a neutron area monitor to ^{137}Cs gamma radiation with an ambient dose equivalent rate of 10 mSv/h shall not be greater than the response to a neutron ambient dose equivalent rate of 100 µSv/h. In addition, in a field of 1 mSv/h from a neutron reference source, additional exposure to 10 mSv/h from ^{137}Cs gamma radiation shall not change this neutron indication by more than 10 %.

The instrument's response to photon radiation was tested with a ^{137}Cs-source which produced a photon ambient dose equivalent rate of about 10 mSv/h at the reference position. The reading of the integrated dose after three dose updates was

$$M_\gamma = (0)\ \mu\text{Sv}.$$

For testing, whether a reading from a neutron source is influenced by an additional photon source, a reading of

$$M_n = (530 \pm 1)\ \mu\text{Sv/h}$$

was produced with a ^{252}Cf-source. An additional exposure by the ^{137}Cs-source (photon ambient dose equivalent rate of about 10 mSv/h) resulted in a reading of

$$M_{n+\gamma} = (531 \pm 2)\ \mu\text{Sv/h}.$$

4.5. Stability check of the instrument reading

During the measurements the stability of the instrument was tested several times with a $^{241}AmBe(\alpha,n)$-check source from PTB. At a mean reading of about 101.4 µSv/h the maximum and the minimum values deviated by no more than +0.9 % and –0.8 % from this mean value.

4.6. Background reading

For a measuring time of 3600 s a integral dose of

0.000 μSv

was observed without the presence of neutron sources.

/1/: International Standard ISO 8529-1 *Reference Neutron radiations: Characteristics and methods of production* (2001)
/2/: International Standard ISO 8529-2 *Reference Neutron radiations: Calibration fundamentals of radiation protection devices related to the basic quantities characterizing the radiation field* (2000)
/3/: International Standard ISO 8529-3 *Reference Neutron radiations: Calibration of area and personal dosimeters and determination of their response as a function of neutron energy and angle of incidence* (1998)
/4/: H. Kluge *Irradiation facility with radioactive reference neutron sources: Basic principles* PTB Report, PTB-N-34, 1998
/5/: Jetzke, S. and Kluge, H. *Characteristics of the* ^{252}Cf *neutron fields in the irradiation facility of the PTB* Radiat. Prot. Dosim., 69, 247 (1997)
/6/: DIN 6802-2 *Neutronendosimetrie: Teil 2: Konversionsfaktoren zur Berechnung der Orts- und Personendosis aus der Neutronenfluenz und Korrektionsfaktoren für Strahlenschutzdosimeter* (1999)
/7/: ICRU 66 *Determination of Operational Dose Equivalent Quantities for Neutrons* (2001)
/8/: IEC 61005 *Radiation protection instrumentation – Neutron ambient dose equivalent (rate) meters* (2003)

Die Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig und Berlin ist das nationale Metrologieinstitut und die technische Oberbehörde der Bundesrepublik Deutschland für das Messwesen und Teile der Sicherheitstechnik. Die PTB gehört zum Dienstbereich des Bundesministeriums für Wirtschaft und Technologie. Sie erfüllt die Anforderungen an Kalibrier- und Prüflaboratorien auf der Grundlage der DIN EN ISO/IEC 17025.

Zentrale Aufgabe der PTB ist es, die gesetzlichen Einheiten in Übereinstimmung mit dem Internationalen Einheitensystem (SI) darzustellen, zu bewahren und – insbesondere im Rahmen des gesetzlichen und industriellen Messwesens – weiterzugeben. Die PTB steht damit an oberster Stelle der metrologischen Hierarchie in Deutschland. Kalibrierscheine der PTB dokumentieren die Rückführung des Kalibriergegenstandes auf nationale Normale.

Dieser Ergebnisbericht ist in Übereinstimmung mit den Kalibrier- und Messmöglichkeiten (CMCs), wie sie im Anhang C des gegenseitigen Abkommens (MRA) des Internationalen Komitees für Maße und Gewichte enthalten sind. Im Rahmen des MRA wird die Gültigkeit der Ergebnisberichte von allen teilnehmenden Instituten für die im Anhang C spezifizierten Messgrößen, Messbereiche und Messunsicherheiten gegenseitig anerkannt (nähere Informationen unter http://www.bipm.org).

CIPM MRA

The Physikalisch-Technische Bundesanstalt *(PTB) in Braunschweig and Berlin is the National Metrology Institute and the highest technical authority of the Federal Republic of Germany for the field of metrology and certain sectors of safety engineering. The PTB comes under the auspices of the Federal Ministry of Economics and Technology. It meets the requirements for calibration and testing laboratories as defined in the EN ISO/IEC 17025.*

It is fundamental task of the PTB to realize and maintain the legal units in compliance with the International System of Units (SI) and to disseminate them, above all within the framework of legal and industrial metrology. The PTB thus is on top of the metrological hierarchy in Germany. Calibration certificates issued by it document that the object calibrated is traceable to national standards.

This certificate is consistent with Calibration and Measurement Capabilities (CMCs) that are included in Appendix C of the Mutual Recognition Arrangement (MRA) drawn up by the International Committee for Weights and Measures (CIPM). Under the MRA, all participating institutes recognize the validity of each other's calibration and measurement certificates for the quantities, ranges and measurements uncertainties specified in Appendix C (for details see http://www.bipm.org).

Physikalisch-Technische Bundesanstalt

Bundesallee 100
38116 Braunschweig
DEUTSCHLAND

Abbestraße 2-12
10587 Berlin
DEUTSCHLAND