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Personal Dosimeter Requirements

Recommendation by the German Commission
on Radiological Protection

This Recommendation replaces the Recommendation of the same name adopted by the
Commission in 2002 (Bundesanzeiger No. 112, 21 June 2003)

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Anforderungen an Personendosimeter

Empfehlung der Strahlenschutzkommission

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1 Preface

This Recommendation sets out the minimum physical / technical requirements for personal dosimeters as the basis for development, manufacture, testing, distribution and evaluation. They meet the requirements of practical radiological protection in the case of external exposure to radiation, take account of the relevant recommendations of the ICRP (ICRP 1997), the EU (EC 2009) and the IAEA (IAEA 1999), and supplement the existing technical standards and type test requirements.

This Recommendation replaces the Recommendation of the same name adopted by the Commission in 2002 (*Bundesanzeiger* No. 112, 21 June 2003), which in turn was a revision of the Recommendation of the same name adopted by the Commission in 1993 (*Bundesanzeiger* No. 207, 3 November 1993).

2 Scope

This Recommendation pertains to personal dosimeters that are used in physical radiological protection control pursuant to the Radiological Protection Ordinance (*Strahlenschutzverordnung*) and the X-Ray Ordinance (*Röntgenverordnung*) for the measurement of personal dose equivalent.

Personal dosimeters within the meaning of this Recommendation are differentiated, according to their type of application, into official and operational dosimeters.

Official personal dosimeters are

- *official passive dosimeters*, which can be requested from, and are evaluated by, one of the monitoring services appointed by the competent authority, or
- *official electronic dosimeters*, which generate results for the user which are then collated by one of the monitoring services appointed by the competent authority and used to determine an official dose. The monitoring service must have approved the use of such a system for the purpose of official dosimetry.

Use of a personal dosimeter for official dosimetry is subject to approval by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in conjunction with the *Länder* Committee for Nuclear Energy, Specialised Committee for Radiological Protection (*Länderausschuss für Atomkernenergie, Fachausschuss Strahlenschutz*) and the *Länder* Committee for the X-Ray Ordinance (*Länderausschuss Röntgenverordnung*) (RL 2002).

Operational personal dosimeters are those,

- whose use is stipulated by the competent authority, or
- which are placed at the disposal of the persons to be monitored, at their request.

Operational personal dosimeters are distributed and evaluated by the radiological protection supervisor or a radiological protection officer at a plant or installation.

In this Recommendation, the term *personal dosimeter* is used in a broad sense. It may denote the component of the dosimetry system that is worn by the person (dosimeter probe), a display and evaluation device, or the entire dosimetry system. The specific meaning in each case is apparent from the context.

3 Type of Dosimeter, Measurand and Measuring Purpose

A personal dosimeter measures personal dose equivalent $H_p(10)$ or personal dose equivalent $H_p(0.07)$ ¹ and is worn at a site on the surface of the body which is representative in terms of exposure to radiation. It should possess the dosimeter properties specified in Sections 4 and 5. Measuring with the dosimeter is intended to determine personal dose equivalents in order to control exposure and safeguard compliance with body dose limits. Various types of dosimeters are used, depending on the type of body dose (effective dose, local skin dose, organ dose of the hands, lower arms, feet and ankles, organ dose of the eye lens), the resulting measuring purpose (determination of whole- or partial-body exposure) and the corresponding measurand (Table 1).

Table 1: Body doses, measurands and types of dosimeters

Type of body dose	Measurand	Type of dosimeter
Effective dose	$H_p(10)$	Whole-body dosimeter
Local skin dose	$H_p(0.07)$	Partial-body dosimeter
Organ dose of the eye lens ¹		
Organ dose of the hands, lower arms, feet and ankles		

Whole-body dosimeters are worn on the trunk of the body. Partial-body dosimeters are worn on the body part under surveillance.

There is no requirement for the determination of $H_p(0.07)$ with a whole-body dosimeter, for the following reasons:

- the contribution of skin dose (averaged over the whole body) to effective dose is very low, and
- local skin dose must be measured at the representative site, which is very rarely the trunk of the body.

The choice of a suitable dosimeter is also determined by the following criteria:

- the type of radiation to be measured (photon, neutron and electron/beta radiation) (termed “stipulated type of radiation” below),
- the objective of monitoring (official evidence of compliance with body dose limits, or operational monitoring of radiation exposure with short-term availability of the dose values measured, also for specific activities) and
- duration of the surveillance period: short-term monitoring (≤ 1 working day) and long-term monitoring (1 to 3 months; up to 6 months in exceptional cases).

For the purpose of operational monitoring, dosimeters are often used which allow the personal dose equivalent to be determined at any time (e.g. electronic dosimeters). Besides measuring personal dose equivalent, they often have other functions as well; for example, they may measure dose rate and/or offer additional alarm functions. They constitute a specific type of device which must fulfil a number of specific requirements beyond the properties described in Sections 4 and 5. These requirements are set out in (IEC 2010) and fall outside the scope of this Recommendation. If electronic dosimeters are used for official monitoring, other additional requirements must be complied with during the transmission of the measurement

¹ The introduction of $H_p(3)$ may be necessary in the future to measure eye lens doses (SSK 2011).

data to the monitoring service appointed by the competent authority (e.g. data integrity and data protection).

4 General Properties and Comments

The primary task of a personal dosimeter is to measure the personal dose equivalent $H_p(10)$ or the personal dose equivalent $H_p(0.07)$. The provision of additional data about exposure conditions (e.g. radiation energy / direction) is useful but falls outside the scope of the specific requirements stipulated in this Recommendation.

Personal dosimeters should fulfil the following requirements, irrespective of the specific purpose of monitoring and the type of device:

a) Assignment of dosimeter probe

The dosimeter must be marked clearly, unambiguously and permanently, with the marking being identifiable by the user, so that it can be clearly identified as being allocated to the person under surveillance and, if necessary, to the evaluation device, throughout the monitoring period.

b) Protection against operating errors and manipulation

Appropriate precautions must be taken to prevent, impede and detect operating errors and manipulation with the dosimeter as far as is possible and reasonable. This includes marking with the correct method of wearing.

c) Operational reliability

In the event of operational faults occurring in the dosimeter or evaluation device, leading to measurement values being erroneous or lost, the measuring / evaluation process must be automatically interrupted and an alarm triggered. If the dosimeter is not of a type which allows this, operational faults should be detectable during readout and evaluation.

d) Measurement time

A time period (maximum measurement time) must be specified between the issuing or regeneration of a personal dosimeter and its evaluation or readout, during which period the permissible measurement deviations (DIN 1995) in the nominal range of use for the measurands and influence quantities (Tables 2 to 4) may not be exceeded. For official personal dosimeters, this period may not be less than three months.

e) Evaluation period

Provision must be made for the evaluation of official dosimeters within one working day of their arrival at the monitoring service and for the evaluation of operational dosimeters within a period that is appropriate for their measuring purpose, if no direct readout of the personal dose equivalent is possible.

f) Ambient conditions

The requirements pertaining to the measurement deviation of personal dosimeters stipulated in Section 6 must be fulfilled under all environmental conditions for which usage is approved: possible mechanical stress (shock, vibration), climatic conditions and the action of electromagnetic fields. Dosimeters worn on the hands (finger ring dosimeters) to determine partial-body dose should have adequate mechanical stability. They should also be water-proof and sterilisable or easy to disinfect.

It is also pointed out that in the event of contamination of the dosimeter being established, the possible effects on the measured value must be taken into account.

5 Dosimetric Properties

A personal dosimeter must be suitable for measuring the radiation fields existing in the workplace in accordance with the measuring purpose as stated in Table 1, and must be in line with the current state of technology. Use of a personal dosimeter may be restricted to one or several types of radiation (photon, beta / neutron radiation) (intended type of radiation). A dosimeter may not be approved for measuring certain types of radiation to which it is not sufficiently sensitive, in which case it must be ensured that the device is not used in these types of radiation fields.

Prior to the use of a dosimeter in pulsed radiation fields, its suitability must be verified in accordance with type test requirements (PTB 2007).

For types of radiation for whose measurement a dosimeter has been type-approved, the ranges of the measurands and influence quantities stated in Tables 2 to 4 apply as minimum requirements, based on the exposure conditions commonly occurring in radiological protection (known as *minimum measuring ranges / minimum nominal ranges of use* below). In these ranges, the requirements relating to the *measurement deviation* for personal dose equivalent (Section 6) must be fulfilled. In the type approval procedure, these ranges must be verified as the minimum; the manufacturer may, however, also apply for other ranges for testing. The maximum testing ranges are stated in the German Verification Ordinance (*Eichordnung*). If a dosimeter is used outside the approved nominal ranges of use, the radiological protection supervisor is obliged to collect data on the response and assess the suitability of the dosimeter. Here, the manufacturer should provide information that is as comprehensive as possible, particularly with a view to enabling the response outside the nominal range of use of the radiation energy to be evaluated.

Tab. 2: *Minimum nominal ranges of use for influence quantities, applicable to all types of dosimeters*

Influence quantity	Minimum nominal range of use
Dose rate	100 nSv/h to 1 Sv/h
Ambient temperature	– 10 °C to + 40 °C
Relative humidity of air	40 % to 90 %

Tab. 3: *Minimum measuring ranges / minimum nominal ranges of use of the measurands and influence quantities for whole-body dosimeters*

Measurand / influence quantity	Photon radiation	Neutron radiation
	Minimum measuring range / minimum nominal range of use	Minimum measuring range / minimum nominal range of use
Dose	0.1 mSv to 1 Sv	0.1 mSv to 1 Sv
Radiation energy	20 keV to 150 keV or 80 keV to 1.25 MeV	1 keV to 1.5 MeV or 1.5 MeV to 15 MeV
Radiation incidence angle	0° up to ± 60°	0° up to ± 60°

Tab. 4: *Minimum measuring ranges / minimum nominal ranges of use of the measurands and influence quantities for partial-body dosimeters*

Measurand / influence quantity	Photon radiation	Beta radiation
	Minimum measuring range / nominal range of use	Minimum measuring range / nominal range of use
Dose	1 mSv to 10 Sv	1 mSv to 10 Sv
Radiation energy	30 keV to 250 keV	0.2 MeV to 0.8 MeV ^{*)}
Radiation incidence angle	0° up to ± 60°	0° up to ± 60°

^{*)} Mean energy of beta radiation

If the dosimeter type is subject to approval under the German Verification Ordinance (*Eichordnung*), the type test requirements established by the Physikalisch-Technische Bundesanstalt (PTB) (National Metrology Institute) also apply. If DIN standards exist for other types, these standards define the current state of technology.

6 Permissible Measurement Deviation for Personal Dose Equivalent

The influence quantities stated in Sections 4 and 5 contribute to the total measurement uncertainty (TMU) in the determination of personal dose equivalent. A further contribution is made by the uncertainties associated with dosimeter calibration.

The maximum permissible measurement deviation of a personal dosimeter, depending on dose, was specified taking account of the recommendations made in ICRP Publication 75 (ICRP 1997) and the relevant standards (IEC 2010) and (DIN 2008).

For whole-body dosimeters for the measurement of $H_p(10)$, for example, with a monitoring period of one month and a dose exceeding approximately 4 mSv, the measurement value H_{pm} of the personal dose equivalent may not be greater than 1.67 times, and may not be smaller than 0.71 times, the conventional true value H_{pw} of the personal dose equivalent (see Figure 1). Similarly, the measurement value H_{pm} totalled over a period of 12 months (annual dose) may not be greater than 1.67 times, and may not be smaller than 0.71 times, the conventional true value H_{pw} if this total exceeds 4 mSv. These factors are derived from the introduction of symmetric limits for the inverse response equal to $\pm 40\%$. For partial-body dosimeters for the measurement of $H_p(0.07)$, the same applies above approximately 30 mSv (see Figure 2), if the organ dose for the eye lens is to be determined¹, and above approx. 100 mSv, if the local skin dose and the organ dose for the hands, lower arms, feet or ankles are to be determined.

Please note:

Dosimeters by means of which the personal dose equivalent accumulated over a period of one month is measured are particularly significant in the monitoring of personal dose equivalent. However, natural ambient radiation produces mean measurement values for personal dose equivalent of 2 μ Sv per day, equivalent to 0.06 mSv per month, with possible local variations of similar magnitudes. Taking into account the extra time required for transport from and to the monitoring service, a value of 0.1 mSv is appropriate as the lower measuring range limit of a whole-body dosimeter for the measurement of $H_p(10)$. For partial-body dosimeters for the measurement of $H_p(0.07)$, as regards the lower measuring range limit, it is not meaningful to make a distinction between personal dosimeters for the measurement of organ dose for the eye lens and those used for the measurement of local skin dose and organ doses for the hands, lower arms, feet or ankles. In view of the limit values for these organs, which are more than 10 times higher, 1 mSv is appropriate as a lower measuring range limit for partial-body dosimeters for the measurement of $H_p(0.07)$.

For measurements over periods of less than one month (e.g. daily dose evaluation), it is essential to ensure that when deriving a total for the month, the lower measuring range limits of 0.1 mSv for whole-body dosimeters and 1 mSv for partial-body dosimeters are met.

These lower measuring range limits are therefore interpreted in the following as the smallest stated values H_{p0} . With these values, a relative deviation of the measured value H_{pm} from the conventional true value H_{pw} of $\pm 100\%$ is allowed. With increasing measurement values of the personal dose equivalent, the maximum permissible relative measurement deviation decreases according to equation (1), so that with high values (i.e. for $H_{pw} \gg H_{p0}$), the quotient H_{pm}/H_{pw} may only lie in the interval from 0.71 to 1.67:

$$\frac{1}{1.4} \left(1 - \frac{2H_{p0}}{H_{p0} + H_{pw}} \right) \leq \frac{H_{pm}}{H_{pw}} \leq \frac{1}{0.6} \left(1 + \frac{H_{p0}}{4H_{p0} + H_{pw}} \right) \quad (1)$$

with

H_{pm} measured value of personal dose equivalent,

¹ The introduction of $H_p(3)$ may be necessary in future to measure eye lens dose (SSK 2011).

- H_{pw} conventional true value of the personal dose equivalent,
 H_{p0} lower measuring range limit, with
 $H_{p0} = 0.1$ mSv for whole-body dosimeters for the measurement of $H_p(10)$ and
 $H_{p0} = 1$ mSv for partial-body dosimeters for the measurement of $H_p(0.07)$.

The maximum permissible measurement deviations are shown in Figure 1 for whole-body dosimeters for the measurement of $H_p(10)$ and in Figure 2 for partial-body dosimeters for the measurement of $H_p(0.07)$.

For photon radiation with mean energy below 10 keV, beta radiation with mean energy below 0.2 MeV and neutron radiation, in nominal ranges of use in which equation (1) cannot be fulfilled with the current state of metrology, the following equation (2) may be applied instead:

$$\frac{1}{2} \left(1 - \frac{2H_{p0}}{H_{p0} + H_{pw}} \right) \leq \frac{H_{pm}}{H_{pw}} \leq 2, \quad (2)$$

H_{p0} , H_{pw} and H_{pm} as in equation (1).

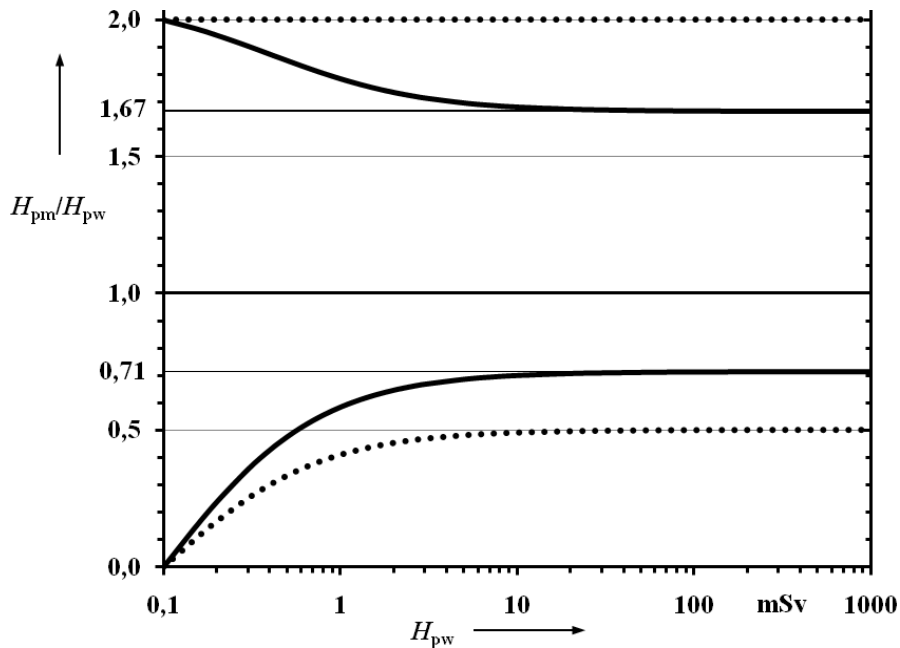


Figure 1: Maximum permissible relative measurement deviations, shown as variation limits of the quotient H_{pm}/H_{pw} as function of the conventional true value of the measurand H_{pw} for whole-body dosimeters for the measurement of $H_p(10)$ with $H_{p0} = 0.1$ mSv according to equation (1), solid curve, and according to equation (2), dotted curve.

In mixed radiation fields, in which the above-mentioned harder-to-measure components contribute more than 20 % of the total dose, equation (2) also applies to total dose. Equation (1) applies for a contribution below 20 %.

Metrological verification of compliance with (1) and (2) should take place under defined testing conditions based on the exposure conditions applicable to the practical use of dosimeters and for which a precise H_{pw} value is known. In this context, by way of deviation from the requirement specified in ICRP 75 (ICRP 1997), statistical certainty of 90 % must be

maintained. The measurement values falling outside this range should be due to random, not systematic, factors.

The measurement deviations stated here must not be confused with measurement uncertainties in the measuring of personal dose equivalent. Guidance on the calculation of these measurement uncertainties is provided, for example, in DIN / ISO standards (DIN 1995, ISO 2008) and in (Ambrosi 1999).

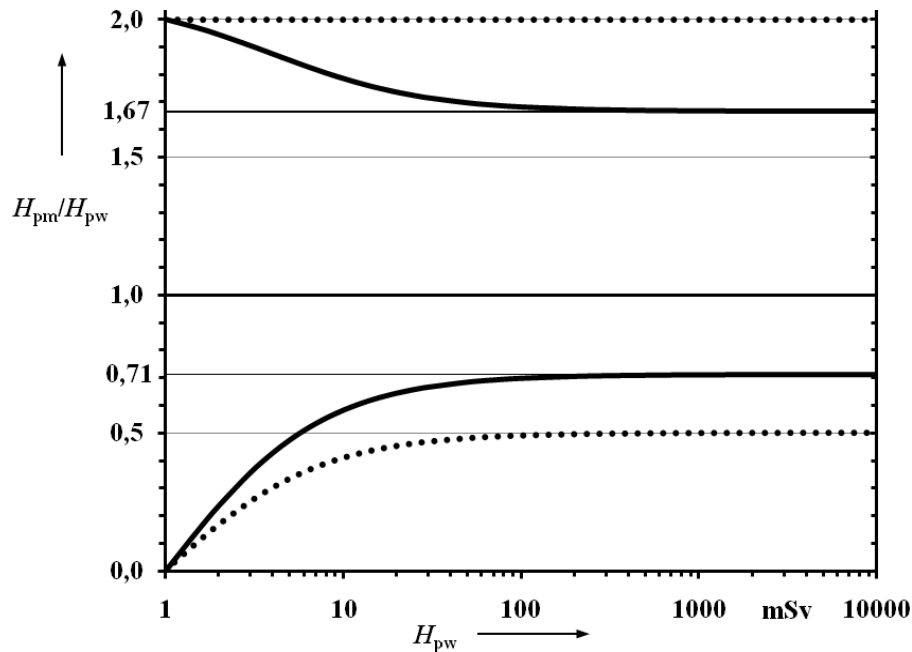


Figure 2: Maximum permissible relative measurement deviations, shown as variation limits of the quotient H_{pm}/H_{pw} as function of the conventional true value of the measurand H_{pw} for partial-body dosimeters for the measurement of $H_p(0.07)$ with $H_{p0} = 1$ mSv according to equation (1), solid curve, and according to equation (2), dotted curve.

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