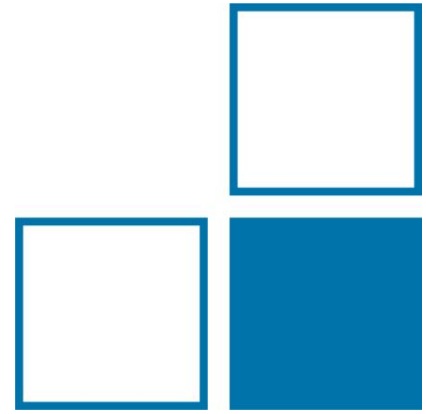
Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

Basic requirements on area dosemeters

Design and type test requirements

Dr. Hayo Zutz



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  - IEC and PTB-requirements
- **Requirements on area dosemeters**
  - fundamental
  - dosimetric
- **Existing problems**
  - pulsed radiation

IEC and PTB requirements

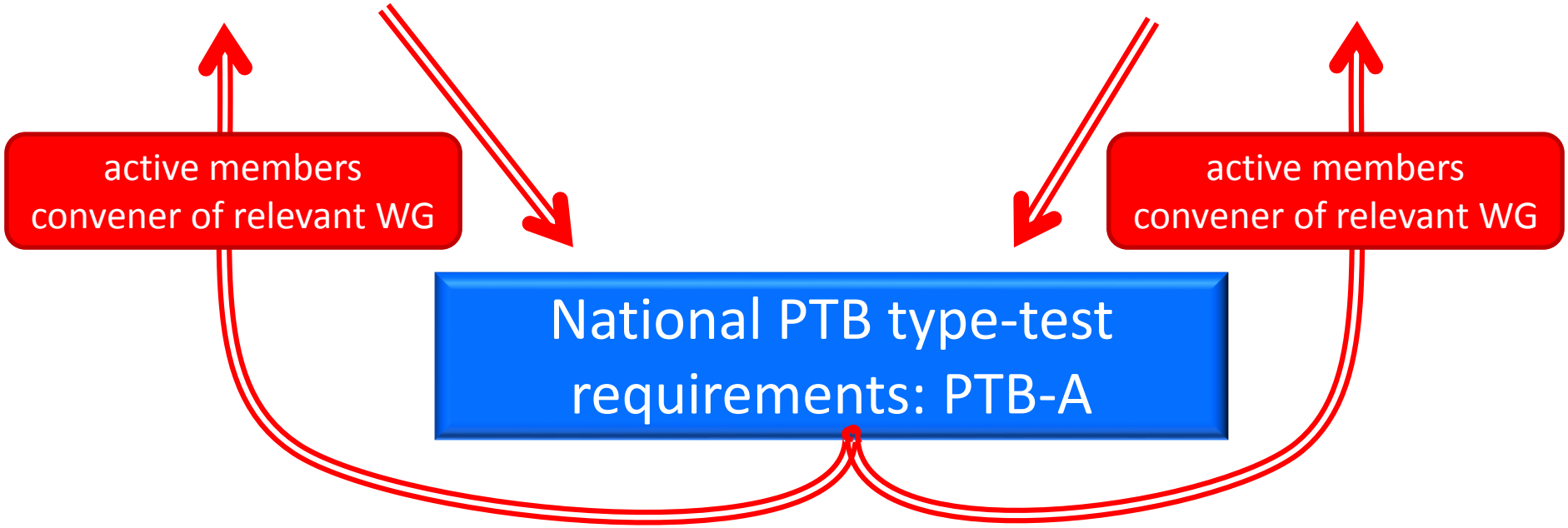
- On the international level the requirements on area dosemeters are given by standards of the International Electrotechnical Commission

- IEC 60846-1:2009
  Radiation protection instrumentation –
  Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation –
  Part 1: Portable workplace and environmental meters and monitors

IEC and PTB requirements

requirements on dosemeters

reference radiation fields



Situation in Germany

- Regulated by the German act concerning the placement and provision of measuring instruments on the market, their use and verification, and also on prepackages (Weights and Measures Act)

- Dosemeters which should by used for legally relevant measurements must have a conformity assessment

  1. type-testing by PTB
  2. examination of each single dosemeter

General

- IEC 60846-1:2009 covers dosemeter in the following range:

Measuring quantity	Energy range for Photon radiation	Energy range for Beta-particle radiation
$H^*(10)$	12 keV to 10 MeV	—
$H'(0,07)$	8 keV to 250 keV	0,07 MeV[a] to 1,2 MeV almost equivalent to E_{max} from 225 keV to 3,54 MeV

[a] For beta-particle radiation, an energy of 0,07 MeV is required to penetrate the dead layer of skin of 0,07 mm (almost equivalent to 0,07 mm of ICRU tissue) nominal depth.

- The German PTB-A 23.3 are limited to photon radiation and the maximum energy range is 5 keV to 7 MeV as stated by the Measures and Verification Ordinance (MessEV)

General requirements

- Indication
  - In units of dose equivalent (rate), e.g. mSv or mSv/h
  - Changing of measurement range and read-out scale simultaneous
  - Scales readable under normal lighting conditions
  - Test for failure of display
- Alarm and alarm levels
- Overload indication
- Instruction manual
- Designation and inscriptions
  - Type designation, Serial number
  - measurand and measuring range

Software requirements

The software of the dosemeter (firmware and/or PC) have to fulfill the WELMEC software guide 7.2 (risk class C).

The requirements depend e.g. on:

- Type of system e.g. build only for this purpose or can be used for other purposes (PC,…)
- Storage of measurement data
- Transmission of measurement data

Example of requirements:

- Software & calibration parameters secured against any changes (intended or unintended)

Metrological requirements

All tests are type-tests:

- individual calibration of each dosemeter not considered
- only limits for the relative response:

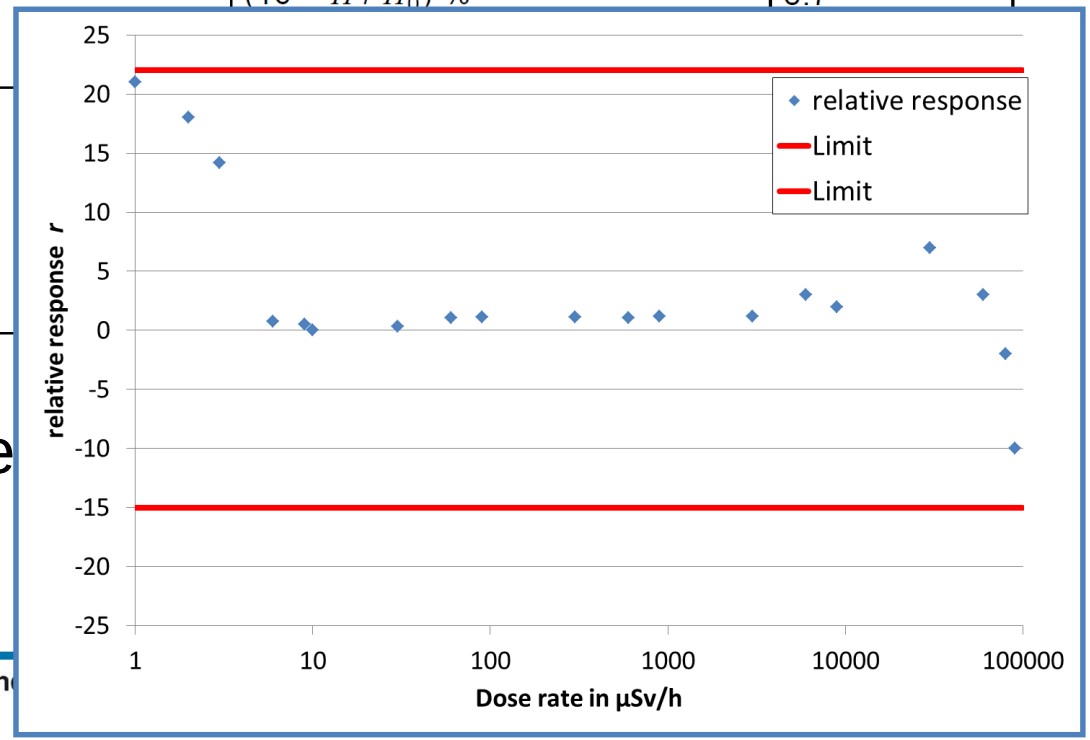
1. Calculate the response: $R = \frac{G}{H} = \frac{\text{Indication}}{\text{Conventional quantity value}}$
2. Normalizing to response at reference condition: $R_0 = \frac{G_{r,0}}{H_{r,0}}$
3. Compare relative response $r = \frac{R}{R_0}$ with limits

Metrological requirements

- Linearity & coefficient of variation

Characteristic under test or influence quantity	(Minimum) rated range of influence quantity	Limits of variation of the relative response	Subclause
Linearity	Three orders of magnitude including 10 µSv h^{-1} and 100 µSv	– 15 % to + 22 %	5.5 and 8.7
Statistical fluctuation: dose equivalent	$H = H_0$ [a] $H_0 < H < 11\ H_0$ $H \geq 11\ H_0$	15 % $(16 - H / H_0)$ %	8.7
Statistical fluctuation: dose equivalent rate	$\dot{H} < \dot{H}_0$ [a] $\dot{H}_0 \leq \dot{H} < 11\ \dot{H}_0$ $\dot{H} \geq 11\ \dot{H}_0$		

- PTB-A also allows for three orders of magnitude including 1 mSv and 100 mSv/h



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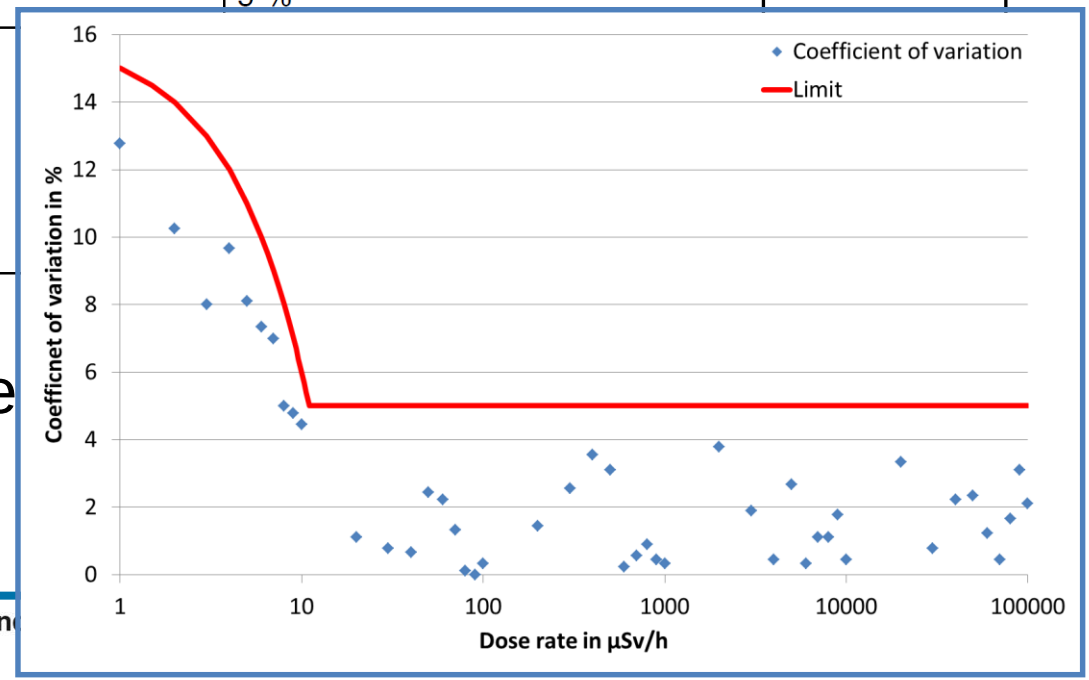


Metrological requirements

- Energy and angle dependence

Characteristic under test or influence quantity	(Minimum) rated range of influence quantity	Limits of variation of the relative response	Subclause
X and gamma radiation energy and angle of incidence	80 keV to 1,5 MeV or 20 keV to 150 keV and 0° to ± 45° from reference direction	– 29 % to + 67 %	8.4.2
Angle of incidence – X and gamma radiation	0° to 90° from reference direction	To be stated by the manufacturer	8.4.2

- PTB-A
  - 80 keV to **1,25 MeV** or 20 keV to 150 keV

Metrological requirements

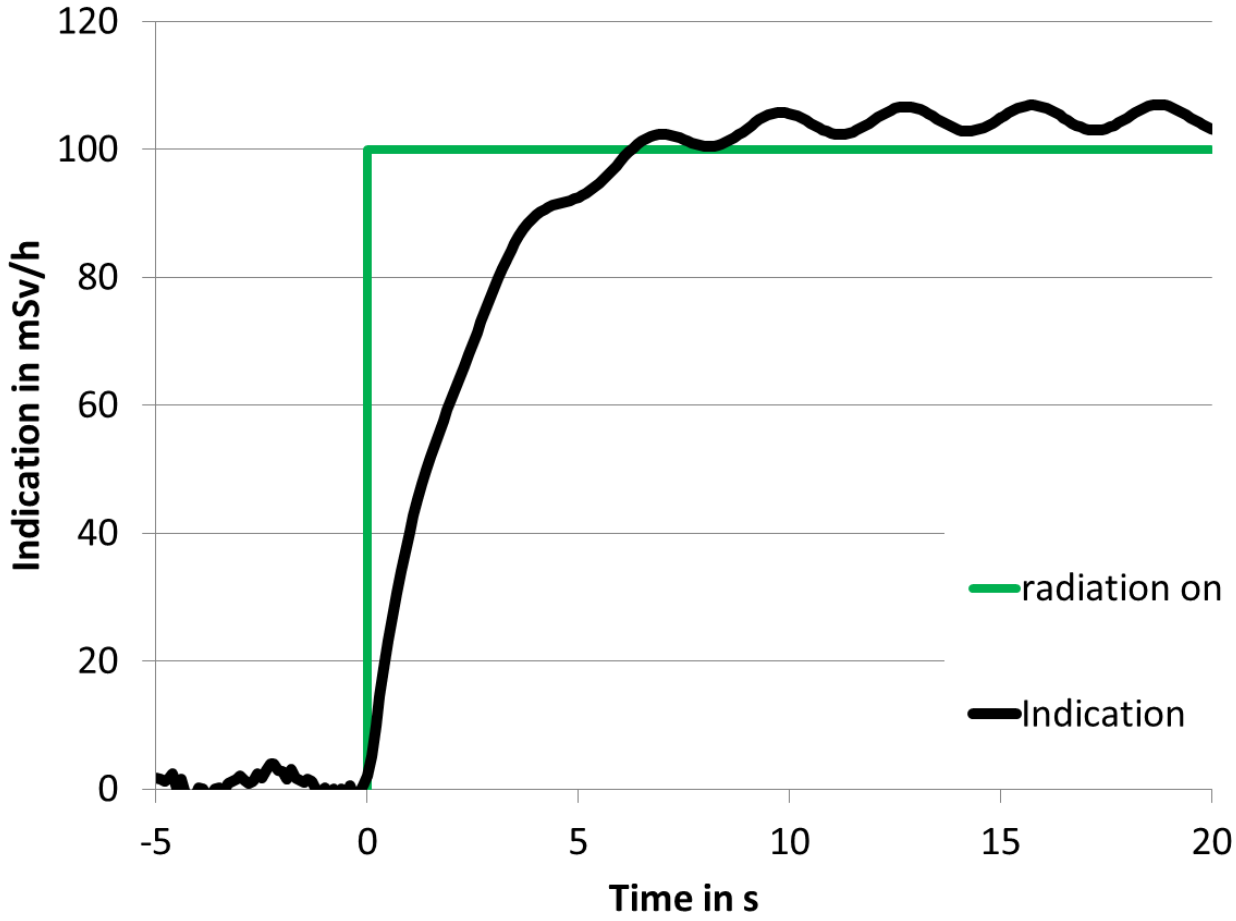
- Dose rate during dose measurement and overload

Characteristic under test or influence quantity	(Minimum) rated range of influence quantity	Limits of variation of the relative response	Subclause
Dose rate for dose measurements	5 μSv h^{-1} to 1 Sv h^{-1} [b]	–13 % to +18 %	8.11
Overload	100 times the range maximum for range maxima up to and including 0,1 Sv h^{-1} 10 times the range maximum, or 10 Sv h^{-1}, whichever is the greater, for range maxima more than 0,1 Sv h^{-1}	Indication to be off-scale on the high side or dose equivalent (rate) meter to indicate overload (for 5 min)	8.8

- PTB-A:
  - Dose rate: Overload up to 50 times the range maximum or 10 Sv/h
  - Dose: at least 1 Sv, else 50 times the range maximum or 10 Sv

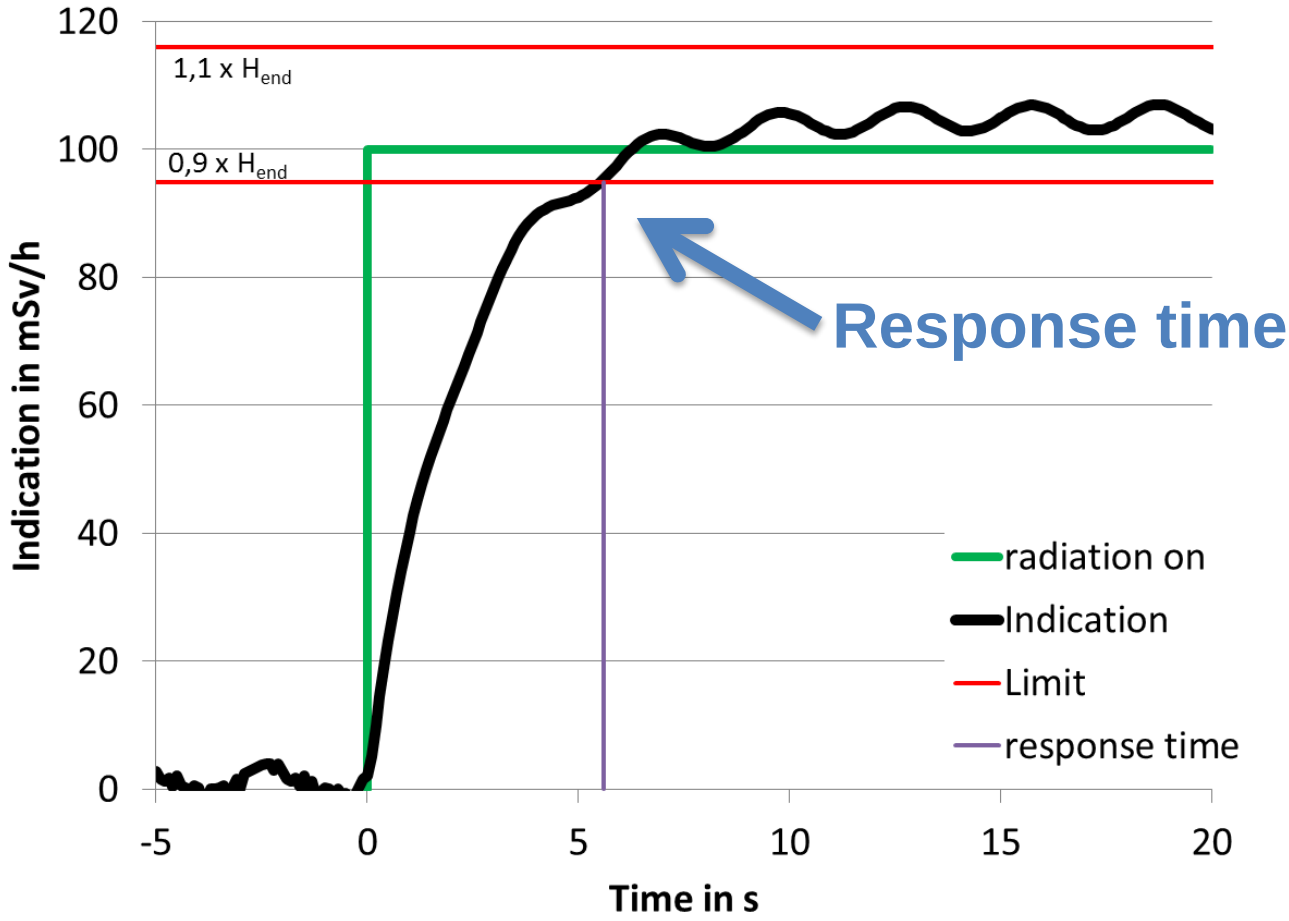
Metrological requirements

Response time τ



Metrological requirements

Response time τ



Metrological requirements

Response time τ

IEC 60846-1:2009

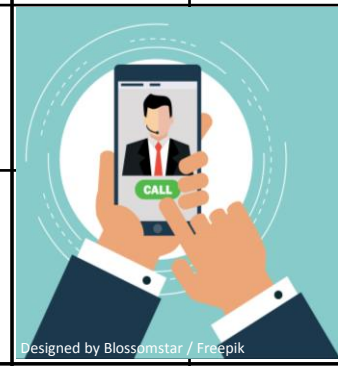
τ <10 s	$\dot{H}_{\mathrm{END}}$ < 10 mSv/h
τ = 2 s	$\dot{H}_{\mathrm{END}}$ > 10 mSv/h

PTB-A:

60 s	for $\dot{H}_{\mathrm{END}}$ < 60 µSv/h
$60\ s\ -\ \frac{\dot{H}_{\mathrm{END}} - 60\ \frac{\mu\mathrm{Sv}}{\mathrm{h}}}{940\ \frac{\mu\mathrm{Sv}}{\mathrm{h}}} \cdot 50\ \mathrm{s}$	for 60 µSv/h ≤ $\dot{H}_{\mathrm{END}}$< 1 mSv/h
10 s	for $\dot{H}_{\mathrm{END}}$ ≤ 1 mSv/h

EMC requirements

Requirements on electromagnetic compatibility

Influence quantity or instrument parameter	Minimum rated range of influence quantity	Test according to	Frequency	Maximum value of deviation [a]	Criterion [b]
Electrostatic discharge, charging voltage	0 kV to ± 8 kV air discharge 0 kV to ± 4 kV contact discharge	IEC 61000-4-2	10 disturbances per hour	± 0,7 H_0 or ± 0,7 $\dot{H}_0$	B
General radiated electromagnetic fields, field strength and modulation	80 MHz to 800 MHz and 960 MHz to 1,4 GHz 0 V m^{-1} to 10 V m^{-1} (r.m.s., unmodulated) 80 % AM (1 kHz)	IEC 61000-4-3			A
Radiated electromagnetic fields of mobile phones and wireless LAN, field strength and modulation	800 MHz to 960 MHz and 1,4 GHz to 2,7 GHz 0 V m^{-1} to 30 V m^{-1} (r.m.s., unmodulated) 80 % AM (1 kHz)	IEC 61000-4-3			A
Conducted disturbances induced by radio-frequencies, frequency and voltage	150 kHz to 80 MHz 0 to 10 V (r.m.s., unmodulated) 80 % AM (1 kHz)	IEC 61000-4-6	10 % of time	± 0,7 H_0 or ± 0,7 $\dot{H}_0$	A
50 Hz/60 Hz magnetic field, field strength	0 A m^{-1} to 30 A m^{-1}	IEC 61000-4-8	10 % of time	± 0,7 H_0 or ± 0,7 $\dot{H}_0$	A

[a] H_0 is the lower limit of the effective range of measurement.

[b] See IEC 61000-6-2.

PTB-A

80 MHz to 2 GHz
0 to 30 V/m

EMC requirements

Additional requirements in PTB-A on electromagnetic compatibility

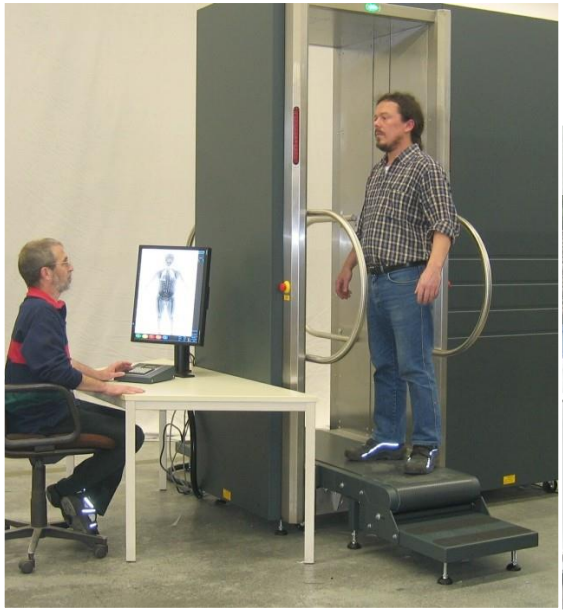
	Influence quantity	Test in accordance with standard	Minimum rated range of use	In the case of dosemeters acc. to Section 2, subsection 3	Crite-rion*
4.	Fast transients unsymmetrical, peak voltage	IEC EN 61000-4-4	0 to ± 2 kV (current conductors) 0 to ± 1 kV (signal conductors)	yes	B
5.	Surges, peak voltage	IEC EN 61000-4-5	0 to ± 2 kV unsym. 0 to ± 1 kV sym.	yes	B
6.	AC mains voltage dips, duration	IEC EN 61000-4-11	20 ms (100 % reduction) 200 ms (60 % reduction) 500 ms (30 % reduction) 5000 ms (>95 % reduction)	yes	B C C C

*The criteria indicate the permitted behaviour during and after the disturbance in accordance with IEC EN 61000-6: A: unrestricted functionality; B: temporary device failure (followed by automatic resetting) is permitted, but no loss of data or instrument settings is permitted; C: device failure is permitted, but no loss of stored data is permitted.

Pulsed radiation

- Application of pulsed fields increased remarkably
- … can be produced as a pulsed field or can appear pulsed for the dosemeter
- “Pulsed”: duration less 10 s

X-ray diagnostics

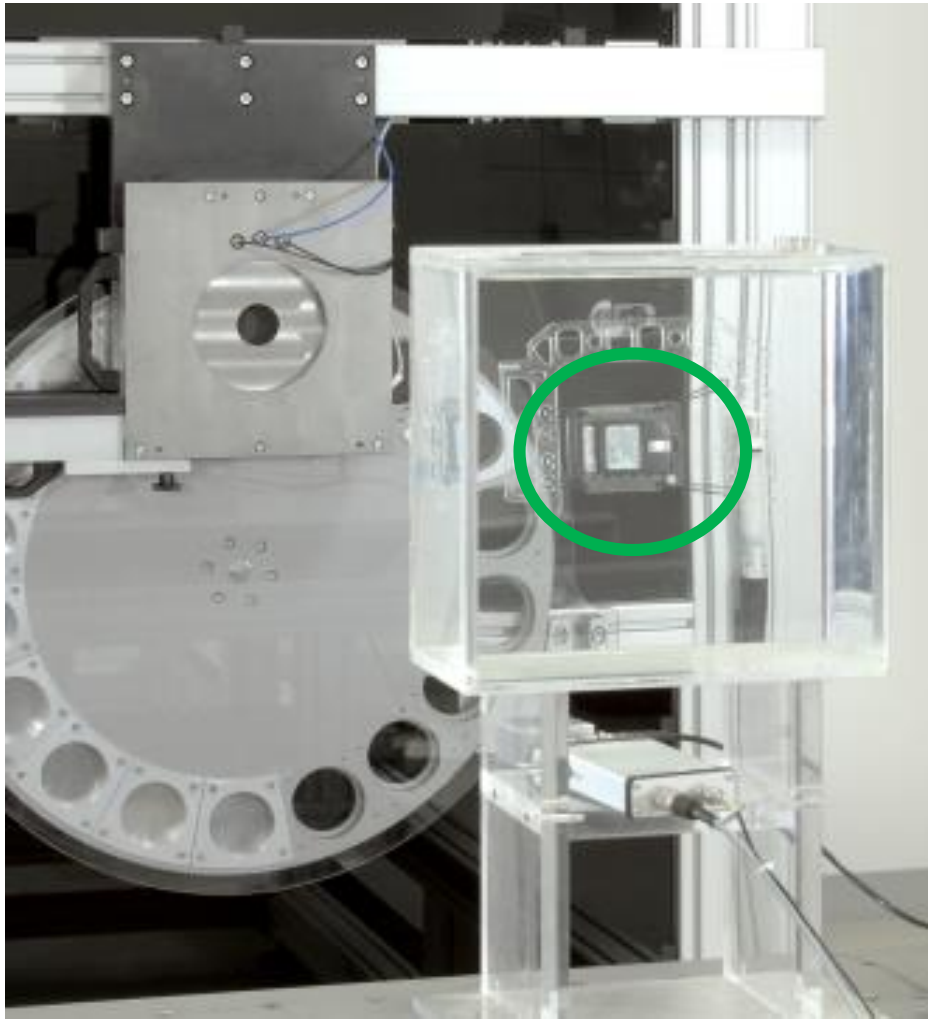


X-ray scanner

Science and material testing

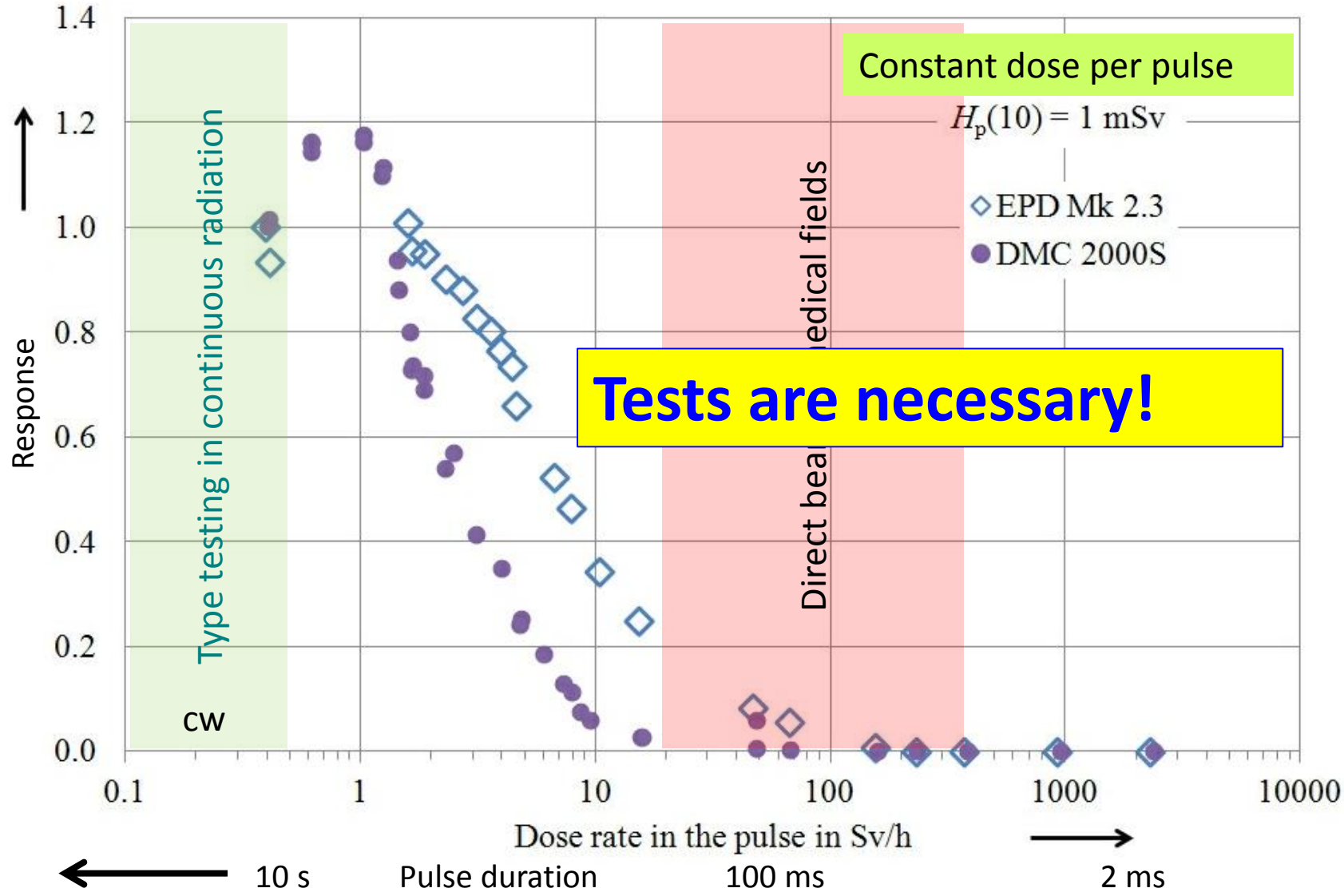
Electronic dosemeters in pulsed fields

Pulsed X-ray fields at PTB



Typical electronic personal dosemeters
(results also valid for area dosemeters!)

Electronic dosemeters in pulsed fields



Pulsed radiation

- Application of pulsed fields increased remarkably
- … can be produced as a pulsed field or can appear pulsed for the dosemeter
- "Pulsed": duration less 10 s
- **Dosemeters are only tested in continuous fields**
- **Characteristics of dosemeters determined in cont. fields can't be transferred to those in pulsed fields**
- **Electronic dosemeters could measure considerably wrong, or even fail completely in pulsed fields**

Pulsed radiation

The **reference fields** for testing the dosemeter are described by:

ISO/TS 18090-1:2015:
"Radiological Protection – Characteristics of reference pulsed radiation – Part I Photon radiation"

The **testing procedure** for dosemeters and the requirements are given in:

IEC/TS 62743:2012:
"Radiation Protection Instrumentation – Electronic counting dosemeters for pulsed fields of ionizing radiation"
for counting dosemeter

and

IEC/TS 63050:
"Radiation Protection Instrumentation – Electronic dosemeters for pulsed fields of ionizing"
as a more generalized version (in preparation)

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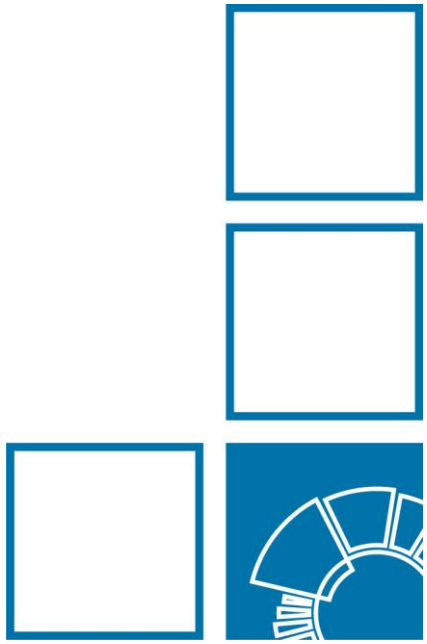
The concept is similar to that used for other influence quantities.
A 20 % influence of the pulsation is allowed with respect to continuous radiation and the parameter range is determined.
No general "approved for pulsed radiation"

Summary

- IEC 60846-1 and PTB-A 23.3 include requirements on area dosemeters
  - Indication
  - Software
  - Linearity and coefficient of variation
  - Photon energy and angle dependence
  - EMC

- Pulsed radiation is a problem for current dosemeters

➢ Can this be overcome by MEDIPIX/TIMEPIX?



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