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Radiation protection instrumentation — Electronic counting dosemeters for pulsed fields of ionizing radiation

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A list of organizations represented on this committee can be obtained on request to its secretary.

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIATION PROTECTION INSTRUMENTATION – ELECTRONIC COUNTING DOSEMETERS FOR PULSED FIELDS OF IONIZING RADIATION

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC 62743, which is a technical specification, has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
45B/706/DTS	45B/726A/RVC

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

The specification and determination of the special characteristics required for dosemeters to be used in pulsed fields of ionizing radiation have been excluded from all standards for direct reading personal and environmental dosemeters issued before 2012 for radiation protection purposes. These standards only specify characteristics for continuous radiation. This Technical Specification provides the necessary information for the measurement of one single radiation pulse, which is the most difficult situation to be measured. The characteristics of a dosemeter for repeated pulses is expected to be better than for one single radiation pulse with the same parameters but worse than for continuous radiation, i.e., in between of the characteristics for these two extreme conditions. This Technical Specification applies for such direct reading dosemeters that use pulse counting for the determination of the measured dose value. Dosemeters that use delayed pulses, e.g., due to activation by neutrons, are excluded.

The concept is similar to the concept used for other influence quantities, e.g., radiation energy. The workplace is characterized by the parameter range occurring at that workplace, i.e., in the case of energy the expected possible values of radiation energy. It can then be determined if the dosemeter under consideration can be used. The required parameters for a workplace where pulsed radiation occurs are

– the minimum value of the radiation pulse duration, $t_{\text{pulse, min}}$, occurring at the workplace,
– the maximum value of the dose rate during the radiation pulse, $\dot{H}_{\text{pulse,max}}$, occurring at the workplace,
– the maximum value of the dose per radiation pulse, $H_{\text{pulse, max}}$, occurring at the workplace.

The parameters to be determined by the type test of the counting dosemeter are

– the maximum value of the measurable dose rate in the pulse, $\dot{H}_{\text{count,max}}$,
– the dead time of the detector, t_{dead},
– the dose indication per each counting event which is registered by the dosemeter electronics, G_{count},
– the type of the dead time, i.e., extendable or non-extendable dead time, and finally
– the measurement cycle time of the dosemeter, T_{cycle}.

In principle, the parameters resulting from the type test could be determined using continuous radiation fields if the detector is connected to a simple, linear and straight forward counting electronics. But nearly any counting dosemeter exhibits one or more of the following properties. It

– uses internal range switching,
– uses software to correct for known deficiencies, e.g., the dead time or the radiation energy,
– uses special, proprietary algorithms,
– adjusts the measurement cycle time, T_{cycle}, to the dose rate, $\dot{G}_{\text{dose}}$, measured by the dosemeter,
– mitigates the effect of EMC-pulses and mechanical drops.

All these properties could affect the results when determining the characteristics for pulsed radiation fields by using continuous radiation fields. The conclusion is that measurements using pulsed radiation fields are required for testing of dosemeters.

As a help to the user to judge whether or not the dosemeter under consideration can be used, Table A.1 in the informative Annex A gives some parameter values for typical workplaces where pulsed radiation occurs. They are based on the knowledge available in 2012 and may change with the next generation of pulsed radiation generating equipment.

This Technical Specification contains much information for which worldwide experience is not available at the date of its development. Therefore, it was decided to publish it as a Technical Specification. It is expected that within the next years this experience will be gained and then maintenance of this publication could lead to an International Standard.

RADIATION PROTECTION INSTRUMENTATION – ELECTRONIC COUNTING DOSEMETERS FOR PULSED FIELDS OF IONIZING RADIATION

1 Scope

This Technical Specification applies to all types of counting dosemeters, irrespective of the measuring quantity and the type of radiation intended to be measured. It ensures that a single radiation pulse can be correctly measured even if the dosemeter is in the internal state relevant for measuring background or environmental radiation. The characteristics of the dosemeter for repeated pulses is expected to be better than for one single radiation pulse with the same parameters but worse than for continuous radiation, i.e., in between of the characteristics for these two extreme conditions. This Technical Specification does not specify the characteristics of the dosemeter for repeated pulses. The Technical Specification does not apply for those types of counting dosemeters that either

– do not have an indication or software read-out of the dose rate and the number of pulses counted,
– convert the non-pulsed detector signal to counts by a converter, or
– use nuclear reactions to generate long and nearly continuous secondary radiation fields which then are measured by the dosemeter using counting techniques instead of measuring the direct radiation pulse.

The pulsed radiation source is characterized by the parameters

– radiation pulse duration, t_{pulse},
– pulse peak dose rate, $\dot{H}_{\text{pulse,peak}}$,
– dose per radiation pulse, H_{pulse}.

This Technical Specification considers the pulsation of the radiation field as an additional influence quantity like particle energy and direction of radiation incidence. Therefore, the tests described are additional to all the tests in the respective standards.

This technical specification describes methods to determine the characteristic parameters of the counting dosemeter. A prerequisite of the method is that the model function of the dosemeter can sufficiently be approximated by

$$G_{\text{dose}} = G_{\text{count}} \times n_{\text{count}} \times k_{\text{dead}} \qquad (1)$$

where
G_{dose} is the dose indication of the dosemeter,
G_{count} is the dose indication per counting event,
n_{count} is the number of counting events counted by the dosemeter, and
k_{dead} is the correction for dead time losses.

This simplified model function should not fully describe the dosemeter but it should be valid only – maybe with effective values – for the tests in the case of a single pulse occurring when the dosemeter is in the internal state relevant for measuring background or environmental radiation, i.e., the dosemeter has not performed any specific parameter adjustment for high dose rate. In this sense this simplified model function uses effective parameters specific for pulsed radiation.

This technical specification is applicable to all types of radiation for which a suitable pulsed reference field is available and all other requirements are fulfilled.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

ISO 4037-3:1999, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence*

The International System of Units, 8th edition, International Bureau of Weights and Measures, 2006.

3 Terms and definitions, abbreviations and symbols, quantities and units

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-395[1] and the following apply.

3.1.1
continuous radiation
<area and individual dosimetry> ionizing radiation with a constant dose rate at a given point in space for time intervals longer than 10 s, if the power-on and -off processes are neglected

Note 1 to entry: The time span of 10 s is taken from type test requirements of IEC 61526:2010 and IEC 60846-1:2009 that the dosemeter shall be capable of detecting changes in the dose rate within 10 s.

3.1.2
counting event
ionizing interaction by which one count is produced by the dosemeter electronics

Note 1 to entry: Adapted from IEC 60050-531:1974, 531-13-01.

3.1.3
dead time correction
correction to be applied to the observed number of counting events in order to take into account the number of counting events lost due to the dead time

Note 1 to entry: Adapted from IEC 60050-394:2007, 394-39-22.

3.1.4
dead time
t_{dead}
time interval after the initiation of a counting event caused by an ionizing event, during which a dosemeter operating in pulse mode cannot respond to a further ionizing event

Note 1 to entry: Adapted from IEC 60050-394:2007, 394-38-50.

1 To be published. IEC 60050-395 will replace and cancel IEC 60050-393 and IEC 60050-394.

3.1.5
dose of a radiation pulse
H_{pulse}
dose value attributed to one radiation pulse

3.1.6
dose indication
G_{dose}
indication of the counting dosemeter in terms of dose

3.1.7
dose indication per counting event
G_{count}
indication increment of the counting dosemeter for one counting event

3.1.8
dose rate indication
$\dot{G}_{\text{dose}}$
indication of the counting dosemeter in terms of dose rate

3.1.9
extendable dead time
paralyzable dead time
dead time that is extended if further ionizing events occur during the dead time interval

3.1.10
internal state
soft and hardware parameters set internally (by the dosemeter)

EXAMPLE When the dosemeter is for a long time span not exposed to any artificial radiation then the sensitivity and the cycle time are set to the maximum values to indicate the dose value with the highest resolution possible and to reduce the coefficient of variation of the indication.

3.1.11
ionizing event
any interaction by which one or more ions are produced

[SOURCE: IEC 60050-531:1974, 531-13-01]

3.1.12
maximum measurable dose rate in the pulse
$\dot{H}_{\text{count, max}}$
maximum value of the radiation pulse peak dose rate which can be measured by the counting dosemeter without exceeding stated maximum errors

3.1.13
maximum pulse dose
$H_{\text{pulse,max}}$
maximum value of the dose of a radiation pulse occurring at a given workplace

3.1.14
maximum pulse peak dose rate
$\dot{H}_{\text{pulse, max}}$
maximum value of the pulse peak dose rate occurring at a given workplace

3.1.15
measurement cycle time
T_{cycle}
time interval required by the counting dosemeter for one sequence of the repeated operations to determine the actual value of the indication

3.1.16
non-extendable dead time
non-paralyzable dead time
dead time that is not extended if further ionizing events occur during the dead time interval

3.1.17
pulsed radiation
<area and individual dosimetry> ionizing radiation which never has a constant dose rate at a given point in space for time intervals longer than 10 s

3.1.18
radiation pulse
abrupt variation of short duration of the radiation dose rate from zero followed by a rapid return to zero

[SOURCE: IEC 60050-702:1992, 702-03-01, modified – The term "pulse" given in IEC 60050-702 has been replaced by "radiation pulse" and the words "a physical quantity" and "the initial value" given in IEC 60050-702 have been replaced by "the radiation dose rate from zero" and "zero".]

3.1.19
radiation pulse duration
radiation pulse width
t_{pulse}
interval of time between the first and last instants at which the instantaneous value of a pulse reaches a specified fraction of its pulse magnitude or a specified threshold

[SOURCE: IEC 60050-702:1992, 702-03-04, modified – The terms "pulse duration" and "pulse width" given in IEC 60050-702 have been replaced by "radiation pulse duration" and "radiation pulse width" and a symbol has been added.]

3.1.20
radiation pulse peak time
pulse peak time
interval of time between the first and last instants at which the instantaneous dose rate value of a pulse reaches 80 % of its radiation pulse peak dose rate

3.1.21
radiation pulse peak dose rate
pulse peak dose rate
$\dot{H}_{pulse,peak}$
mean value of the dose rate during the radiation pulse peak time

3.2 List of symbols and abbreviations

Table 1 gives a list of the symbols and abbreviated terms used.

Table 1 – Symbols and abbreviated terms

Symbol	Meaning	Unit
G_{count}	Dose indication per counting event detected by the dosemeter	Sv
G_{dose}	Dose indication of the counting dosemeter	Sv
$G_{\text{dose},\,i}$	Dose indication of the counting dosemeter for the pulse condition no. i	Sv
$\dot{G}_{\text{dose}}$	Dose rate indication of the counting dosemeter	Sv h^{-1}
$\overline{\dot{G}_{\text{dose},i}}$	Mean dose rate indication of the counting dosemeter of all the indications no. i	Sv h^{-1}
H_0	Lower limit of the measuring range of the counting dosemeter	Sv
H_{pulse}	Dose value of one radiation pulse	Sv
$H_{\text{pulse},\,i}$	Dose value of one radiation pulse for the pulse condition no. i	Sv
$H_{\text{pulse, max}}$	Maximum value of the dose of one radiation pulse occurring at a given workplace	Sv
$\dot{H}_{\text{count, max}}$	Maximal value of the pulse peak dose rate in the radiation pulse	Sv h^{-1}
$\dot{H}_{\text{pulse, max}}$	Maximum value of the dose rate of the radiation pulse occurring at a given workplace	Sv h^{-1}
$\dot{H}_{\text{pulse, peak}}$	Pulse peak dose rate	Sv h^{-1}
$\dot{H}_{\text{pulse, peak},\,i}$	Pulse peak dose rate for the pulse condition no. i	Sv h^{-1}
K	Product of all correction factors internally applied to the indication of the dosemeter with the exception of that for the dead time	—
$k_{\text{dead, ex}}$	Correction factor for dead time externally applied to the indication of the dosemeter	—
$k_{\text{dead, int}}$	Correction factor for dead time internally applied to the indication of the dosemeter	—
n_{count}	Number of counting events counted by the dosemeter	—
n_i	Number of counting events counted by the dosemeter for the measurement no. i	—
n_{final}	Final number of counting events counted by the dosemeter for the measurement of G_{dose}	—
$v_{\text{count, rel}}$	Relative coefficient of variation of a single measurement	—
t	Time span used for the test of the indication of dose rate	s
T_{cycle}	Measurement cycle time of the dosemeter	s
t_{dead}	Dead time of the counting dosemeter	s
t_{pulse}	Duration of the radiation pulse	s
$t_{\text{pulse, min}}$	Minimum value of the radiation pulse duration	s

3.3 Quantities and units

In the present Technical Specification, units of the International System (SI) are used. The definitions of radiation quantities are given in IEC 60050-395.

Multiples and submultiples of SI units will be used, when practicable, according to the SI system.

4 General test procedure

4.1 Nature of test

All tests are considered as type tests. They treat the pulsation of the radiation field as an additional influence parameter like particle energy and direction of radiation incidence. These tests are additional to all the tests in the respective standards.

4.2 Reference conditions and standard test conditions

The general reference conditions and standard test conditions are the same as stated in the respective standard for the type of counting dosemeter under investigation. The special reference conditions for testing concerning pulsed radiation are given in Table 2.

5 General requirements

5.1 Summary of requirements

The response of the counting dosemeter shall not change by more than ± 20 % due to the pulsation of the field as long as the dosemeter is considered to be suitable for the measurement in pulsed radiation fields. In addition, an overload up to a factor of 100, or 1 000 Sv h^{-1} if this is smaller, shall not reduce the dose indication below the value obtained for the pulse with the maximum dose rate for which the dosemeter is considered to be suitable.

The requirements are summarized in Table 3.

NOTE The factor 100 can, e.g., be found in the overload requirements of IEC 60846-1:2009.

5.2 Parameters required to be known of the pulsed radiation field

The following parameters of the pulsed radiation field at the workplace at which the counting dosemeter is intended to be used shall be known:

– the minimum value of the radiation pulse duration, $t_{\text{pulse, min}}$, occurring at the workplace
– the maximum value of the pulse peak dose rate, $\dot{H}_{\text{pulse, max}}$, occurring at the workplace
– the maximum value of the dose per radiation pulse, $H_{\text{pulse, max}}$, occurring at the workplace.

5.3 Parameters required to be determined of the counting dosemeter

The determination of the following parameters of the counting dosemeter is described in Clause 6:

– Dose indication of the dosemeter per counting event, G_{count},
– dead time of the dosemeter, t_{dead},
– type of the dead time, i.e., extendable or non-extendable dead time,
– measurement cycle time, T_{cycle}, and
– maximum measurable dose rate in a radiation pulse, $\dot{H}_{\text{count, max}}$.

5.4 Criteria for suitability of a dosemeter in pulsed radiation fields

5.4.1 General

The criteria given below apply only to a dosemeter with a detector producing pulses which are counted to determine the dose (rate). The criteria are valid for any type of pulsed radiation field and are derived from the requirement given in 5.1. The criteria depend on the pulse duration of one single radiation pulse, t_{pulse}, relative to the dead time of the counting dosemeter, t_{dead}. This dependence of the criteria on the value of an instrument parameter is different from all other influence quantities. The characteristics of the dosemeter for repeated pulses is expected to be better than for one single radiation pulse with the same parameters but worse than for continuous radiation, i.e., in between of the characteristics for these two extreme conditions. This Technical Specification does not specify the criteria for suitability of a dosemeter for repeated radiation pulses.

5.4.2 Radiation pulse duration larger than or equal to the dead time: $t_{pulse} \geq t_{dead}$

5.4.2.1 Requirements

The maximum value occurring at the workplace of the pulse peak dose rate, $\dot{H}_{\text{pulse, max}}$, should not exceed the maximum measurable dose rate value, $\dot{H}_{\text{count, max}}$, determined for the counting dosemeter.

5.4.2.2 Test method and interpretation of the results

Check if $\dot{H}_{\text{pulse, max}} \leq \dot{H}_{\text{count, max}}$ is fulfilled, see 6.6.2 for $\dot{H}_{\text{count, max}}$. Then the dosemeter is suitable. Otherwise the dosemeter is not suitable for the workplace considered and shall not be used.

5.4.3 Radiation pulse duration shorter than the dead time: $t_{pulse} < t_{dead}$

5.4.3.1 Requirements

The maximum value occurring at the workplace of the dose per one radiation pulse, $H_{\text{pulse,max}}$, shall not exceed 0,2 times the dose indication per counting event, G_{count}, determined for the counting dosemeter.

NOTE This is based on theoretical considerations [Knoll, 2010].

5.4.3.2 Test method and interpretation of the results

Check if $H_{\text{pulse}} \leq 0{,}2 \times G_{\text{count}}$ is fulfilled. Then the dosemeter is suitable. Otherwise the dosemeter is not suitable for the workplace considered and shall not be used.

5.5 Type of radiation

This Technical Specification is applicable to all types of radiation for which a suitable pulsed reference field is available and all other requirements are fulfilled.

5.6 Mechanical characteristics

Not applicable.

5.7 Requirements to software, data and interfaces

The manufacturer shall state for the type test whether the value of T_{cycle} depends on parameters measured by the dosemeter. If the measurement cycle time is not constant, the manufacturer shall state any dependencies. In addition, the manufacturer shall state the method to access for the type test the number of counting events counted by the dosemeter and the time that the dosemeter requires to come back to its internal state relevant for measuring background or environmental radiation after any additional external radiation field is switched off.

6 Radiation detection requirements

6.1 General

The characteristic parameters of the counting dosemeter shall be determined using pulsed radiation. A prerequisite of the method is that the model function of the dosemeter is sufficiently approximated by

$$G_{\mathrm{dose}} = K \times G_{\mathrm{count}} \times n_{\mathrm{count}} \times k_{\mathrm{dead,\,int}} \tag{2}$$

where
- G_{dose} is the dose indication of the dosemeter,
- K is the product of all correction factors internal to the dosemeter with the exception of $k_{\mathrm{dead,\,int}}$,
- G_{count} is the dose indication per counting event of the dosemeter,
- n_{count} is the number of counting events counted by the dosemeter,
- $k_{\mathrm{dead,\,int}}$ is the correction factor for dead time internal to the dosemeter.

The model function (2) may not fully describe the dosemeter but should be valid at least for the case of a single pulse occurring when the dosemeter is in the internal state relevant for measuring background or environmental radiation. The dead time correction internal to the dosemeter, which is considered by $k_{\mathrm{dead,\,int}}$, can be disregarded if:

– the radiation pulse duration, t_{pulse}, is much shorter than the measuring time of the dosemeter, T_{cycle} and

– the quotient of these two values is not similar or smaller than that between the maximum dose rate during the pulse the dosemeter can measure, $\dot{H}_{\mathrm{count,max}}$, and the dose rate to be measured.

This is because any dead time correction assumes a constant count rate during the measuring cycle and for short radiation pulses this assumption will lead to the disregarding of any dead time correction. Any other corrections can be assumed to be included in G_{count}. In this sense the value of K in equation (2) can be set to unity and the parameters being effective parameters specific for pulsed radiation.

All the measurements described in 6.2 to 6.6 assume these simplifications. It shall also be assured that all measurements were performed in such a way that each radiation pulse is completely contained within one measuring cycle and the dose indication shall be reset to zero prior to any measurement. In addition, a non-extendable dead time is assumed.

6.2 Indication of the dose rate and the number of counts

6.2.1 Requirements

The dosemeter shall have an indication of the dose rate and the number of counts or an equivalent software read-out and these indications shall be linked to the indication of the dose.

6.2.2 Method of test

Check the manual and the display of the dosemeter if an indication of the dose, the dose rate and the number of counts exists or is at least available for the type test by use of software provided by the manufacturer.

Irradiate the dosemeter with a constant dose rate of about 10 mSv h^{-1} for a fixed and well known time span, t, of about 600 s and note the indications of the dose, $G_{\mathrm{dose},i}$, the dose rate, $\dot{G}_{\mathrm{dose},i}$, and the respective total number of counts, n_i, every 30 s and the final indication of the dose, G_{dose} and the final number of counts, n_{final}. Determine the mean value of the dose rate indications, $\overline{\dot{G}_{dose,i}}$ and all the quotients $\left(G_{dose,i} - G_{dose,i-1}\right)/\left(n_i - n_{i-1}\right)$.

It shall be assured that during the time span, t, no range switching occurs; otherwise the measurements before the range switching shall be omitted.

6.2.3 Interpretation of the results

Check if the relations

$$0{,}95 \le \frac{G_{dose}}{\overline{\dot{G}_{dose,\,i}} \times t} \le 1{,}05 \text{ for any } i \text{ and}$$

$$0{,}95 \le \frac{G_{dose,\,i} - G_{dose,\,i-1}}{n_i - n_{i-1}} \times \frac{n_{final} \times t}{G_{dose}} \le 1{,}05 \text{ for any } i \ge 2$$

are valid, then the requirements of 6.2.1 are fulfilled.

6.3 Measurement cycle time, T_{cycle}

6.3.1 Requirements

The measurement cycle time, T_{cycle}, shall not exceed 30 s.

6.3.2 Method of test

Expose the dosemeter with one single radiation pulse with a pulse duration, t_{pulse}, and a pulse peak dose rate, $\dot{H}_{pulse,\,peak}$, that are well known. $\dot{H}_{pulse,\,peak}$ shall be less than 0,05 times the maximum dose rate the dosemeter can measure determined in the type test using continuous radiation. The duration of the radiation pulse shall be as long as possible, e.g., 50 ms, but short enough to ensure that the dead time correction internal to the dosemeter can be neglected, e.g., shorter than 100 ms.

The measurement cycle time is given by

$$T_{cycle} = \frac{G_{dose}}{\dot{G}_{dose}} \tag{3}$$

where T_{cycle} is the measurement cycle time,
G_{dose} is the dose indication of the dosemeter, and
$\dot{G}_{dose}$ is the dose rate indication of the dosemeter.

Assure that the resulting measurement cycle time is at least 10 times the radiation pulse duration. Otherwise, the radiation pulse duration shall be reduced accordingly.

With the properly chosen parameters, at least 10 measurements shall be performed, thereby assuring that the dosemeter returns to its internal state relevant for measuring background or environmental radiation before the next measurement is performed.

The relative coefficient of variation of a single measurement shall be less than 10 %. Otherwise enlarge the radiation pulse duration if this does not conflict with the requirement of a radiation pulse duration less than 0,1 times the measurement cycle time. For the required waiting time see 5.7.

6.3.3 Interpretation of the results

If the measurement cycle time does not exceed 30 s then the requirement of 6.3.1 is fulfilled.

6.4 Indication per counting event, G_{count}

6.4.1 Requirements

The indication increment per counting event, G_{count}, shall not exceed 10 nSv or 0,1 H_0, whichever is the greatest. H_0 is the lower limit of the measuring range of the dose.

6.4.2 Method of test

Expose the dosemeter with one single radiation pulse with a pulse duration, t_{pulse}, and a pulse peak dose rate, $\dot{H}_{pulse,peak}$, that are well known. $\dot{H}_{pulse,peak}$ shall be less than 0,05 times the maximum dose rate the dosemeter can measure determined in the type test using continuous radiation. The duration of the radiation pulse shall be as long as possible, e.g., 50 ms, but short enough to ensure that the dead time correction internal to the dosemeter can be neglected, e.g., shorter than 100 ms.

The indication per counting event is given by

$$G_{count} = \frac{G_{dose}}{n_{count}} \tag{4}$$

where G_{count} is the dose indication per counting event,
G_{dose} is the dose indication of the dosemeter, and
n_{count} is the number of counting events counted by the dosemeter.

With the properly chosen parameters, at least 10 measurements shall be performed, thereby assuring that the dosemeter returns to its internal state relevant for measuring background or environmental radiation before the next measurement is performed. For the required waiting time see 5.7.

The relative coefficient of variation of a single measurement shall be less than 10 %. Otherwise, enlarge the radiation pulse duration as long as this does not conflict with the requirement of a radiation pulse duration of less than 0,1 times the measurement cycle time.

6.4.3 Interpretation of the results

If the indication per counting event, G_{count}, determined from at least 10 measurements, does not exceed 10 nSv or 0,1 H_0, whichever is the greatest, then the requirement of 6.4.1 is fulfilled.

6.5 Dead time, t_{dead}

6.5.1 Requirements

The dead time, t_{dead}, shall not exceed 10 µs.

6.5.2 Method of test

Expose the dosemeter with two different single radiation pulses (pulse conditions 1 and 2), with well known pulse duration, t_{pulse}, dose per radiation pulse, H_{pulse}, and pulse peak dose rate, $\dot{H}_{pulse,peak}$. The pulse conditions shall differ by the pulse peak dose rate, $\dot{H}_{pulse,peak}$, but shall both have the same pulse duration, t_{pulse}. This duration shall be shorter than 0,01 times the measurement cycle time. For the first pulse condition the pulse peak dose rate,

$\dot{H}_{\text{pulse, peak,1}}$, shall be less than 0,05 times the maximum dose rate the dosemeter can measure, determined in the type test using continuous radiation. For the second pulse condition the pulse peak dose rate, $\dot{H}_{\text{pulse, peak,2}}$, shall be of the order of 3 times the maximum dose rate the dosemeter can measure, determined in the type test using continuous radiation. With the properly chosen parameters, at least 10 measurements for each pulse condition shall be performed, thereby assuring that the dosemeter returns to its internal state relevant for measuring background or environmental radiation before the next measurement is performed. For the required waiting time see 5.7.

Determine the mean indications $G_{\text{dose,1}}$ and $G_{\text{dose,2}}$ for the two pulse conditions.

The dead time is given by

$$t_{\text{dead}} = \frac{G_{\text{count}} \cdot t_{\text{pulse}}}{G_{\text{dose, 2}}} \left(1 - \frac{1}{k_{\text{dead, ex}}} \right) \tag{5}$$

where t_{dead} is the non-extendable dead time of the dosemeter,
G_{count} is the dose indication per counting event, see 6.4,
t_{pulse} is the pulse duration of the radiation pulse,
$G_{\text{dose, 2}}$ is the dose indication of the dosemeter for the second pulse, determined from at least 10 measurements, and
$k_{\text{dead, ex}}$ is the dead time correction external to the dosemeter for the measurement of the second pulse, determined from at least 10 measurements.

The dead time correction external to the dosemeter for the measurement of the second pulse is given by

$$k_{\text{dead, ex}} = \frac{H_{\text{pulse, 2}}}{G_{\text{dose, 2}}} \times \frac{G_{\text{dose, 1}}}{H_{\text{pulse, 1}}} \tag{6}$$

where $k_{\text{dead, ex}}$ is the dead time correction external to the dosemeter for the measurement of the second pulse,
$H_{\text{pulse, 1}}$ is the dose for the first radiation pulse,
$H_{\text{pulse, 2}}$ is the dose for the second radiation pulse,
$G_{\text{dose, 1}}$ is the dose indication of the dosemeter for the first pulse, determined from at least 10 measurements,
$G_{\text{dose, 2}}$ is the dose indication of the dosemeter for the second pulse, determined from at least 10 measurements.

The dead time correction external to the dosemeter for the measurement of the second pulse should be between 1,4 and 1,7. Otherwise adjust the dose per pulse for the second radiation pulse, $H_{\text{pulse, 2}}$, accordingly.

6.5.3 Interpretation of the results

If the dead time, t_{dead}, does not exceed 10 µs, then the requirement of 6.5.1 is fulfilled.

6.6 Maximum measurable dose rate value, $\dot{H}_{\text{count, max}}$

6.6.1 Requirements

The maximum measurable dose rate value of the counting dosemeter, $\dot{H}_{\text{count, max}}$, shall at least be 1 Sv h^{-1}.

6.6.2 Method of test

The maximum measurable dose rate can be calculated from the parameters determined in 6.3 and 6.4 and the requirement given in 5.1 (i.e., the response of the counting dosemeter shall not change by more than ±20 % due to the pulsation of the field). The maximum measurable dose rate is given by

$$\dot{H}_{\text{count, max}} = \frac{0{,}25 \times G_{\text{count}}}{t_{\text{dead}}} \tag{7}$$

where $\dot{H}_{\text{count, max}}$ is the maximum measurable dose rate in the radiation pulse,
G_{count} is the dose indication per counting event, and
t_{dead} is the non-extendable dead time of the dosemeter.

6.6.3 Interpretation of the results

If the maximum measurable dose rate value of the counting dosemeter, $\dot{H}_{\text{count, max}}$, is at least 1 Sv h^{-1}, then the requirement of 6.6.1 is fulfilled.

6.7 Pulse dose rate overload alarm

6.7.1 General

This test shall only be performed if the dosemeter is provided with a pulse dose rate overload alarm and this alarm is adjustable to $\dot{H}_{\text{count, max}}$.

6.7.2 Requirements

The alarm, when adjusted to $\dot{H}_{\text{count, max}}$, shall be actuated in not more than 5 % of the pulses, if the pulse peak dose rate, $\dot{H}_{\text{pulse, peak}}$, is set to 0,7 × $\dot{H}_{\text{count, max}}$ (pulse condition 1) and shall be actuated in at least 95 % of the pulses, if the pulse peak dose rate, $\dot{H}_{\text{pulse, peak}}$, is set to 1,3 × $\dot{H}_{\text{count, max}}$ (pulse condition 2). The alarm shall not be deactivated automatically.

6.7.3 Method of test

Adjust the pulse dose rate overload alarm to $\dot{H}_{\text{count, max}}$. Then the dosemeter shall be exposed with 20 pulses each of

a) t_{pulse} = 1 000 × t_{dead} and $\dot{H}_{\text{pulse, peak, 1}}$ = 0,7 × $\dot{H}_{\text{count, max}}$ (pulse condition 1) and
b) t_{pulse} = 1 000 × t_{dead} and $\dot{H}_{\text{pulse, peak, 2}}$ = 1,3 × $\dot{H}_{\text{count, max}}$ (pulse condition 2).

It shall be assured that the dosemeter returns to its internal state relevant for measuring background or environmental radiation before the next measurement is performed. For the required waiting time see 5.7. The number of pulse dose rate overload alarms shall be counted for both conditions.

6.7.4 Interpretation of the results

If for the 20 pulses with the pulse condition 1 two or less pulse dose rate overload alarms occur and if for the 20 pulses with the pulse condition 2, 18 or more pulse dose rate overload alarms occur and if the pulse dose rate overload alarm is not deactivated automatically, then the requirements of 6.7.2 are fulfilled.

NOTE The uncertainty of the measured dose rate for the pulses is considered by allowing one more false alarm for pulse condition 1 and one less alarm for pulse condition 2.

6.8 Proof of model function and pulse overload alarm

6.8.1 General

The measurement of the parameters requires that the assumption of the model function of the dosemeter as given in 6.1 is valid and that the dead time can be assumed to be non-extendable up to $\dot{H}_{\text{count, max}}$.

Therefore, a verification of these assumptions is necessary.

6.8.2 Requirements

a) Up to a dose rate in the radiation pulse of $\dot{H}_{\text{count, max}}$ the dose response of the dosemeter shall not be affected by more than ± 20 %.

b) Up to a dose rate in the radiation pulse of 100 times $\dot{H}_{\text{count, max}}$, or 1 000 Sv h^{-1} if this is smaller, the dose indication for a single pulse shall not be below the value obtained for the pulse with the dose rate $\dot{H}_{\text{count, max}}$ and the pulse overload alarm, if provided, shall be activated.

6.8.3 Method of test

Expose the dosemeter with four different single radiation pulses (pulse conditions 1 to 4) of which the pulse duration, t_{pulse}, the dose per radiation pulse, H_{pulse}, and the pulse peak dose rate, $\dot{H}_{\text{pulse, peak}}$, are well known. The pulses shall differ by the pulse peak dose rate, $\dot{H}_{\text{pulse, peak}}$ but shall all have the same pulse duration, t_{pulse}. This duration shall be shorter than 0,1 times the measurement cycle time. For the first pulse the pulse peak dose rate, $\dot{H}_{\text{pulse, peak, 1}}$, shall be less than 0,05 times the maximum dose rate the dosemeter can measure, $\dot{H}_{\text{count, max}}$. For the second pulse the pulse peak dose rate, $\dot{H}_{\text{pulse, peak, 2}}$, shall be equal to $\dot{H}_{\text{count, max}}$. For the third pulse the pulse peak dose rate, $\dot{H}_{\text{pulse, peak, 3}}$, shall be equal to 10 times $\dot{H}_{\text{count, max}}$ and for the fourth pulse the pulse peak dose rate, $\dot{H}_{\text{pulse, peak, 4}}$, shall be equal to 100 times $\dot{H}_{\text{count, max}}$, or 1 000 Sv h^{-1}, whichever is smaller. With the properly chosen parameters, at least 10 measurements for each pulse condition shall be performed, thereby assuring that the dosemeter returns to its internal state relevant for measuring background or environmental radiation before the next measurement is performed. For the required waiting time see 5.7.

Determine the mean indications $G_{\text{dose, 1}}$ to $G_{\text{dose, 4}}$ for the four radiation pulses and note if the pulse overload alarm is activated for all the pulses with the conditions 3 and 4.

6.8.4 Interpretation of the results

If the relation

$$0,8 \times \frac{G_{\text{dose,1}}}{H_{\text{pulse,1}}} \leq \frac{G_{\text{dose,2}}}{H_{\text{pulse,2}}} \leq 1,2 \times \frac{G_{\text{dose,1}}}{H_{\text{pulse,1}}}$$

is valid then the requirement of 6.8.2 a) is fulfilled.

If the relations

$G_{\text{dose, 3}} \geq G_{\text{dose, 2}}$ and

$G_{\text{dose, 4}} \geq G_{\text{dose, 2}}$

are fulfilled and the pulse overload alarm, if provided, is activated for all pulses with the conditions 3 and 4, then the requirements of 6.8.2 b) are fulfilled.

7 Environmental requirements

No additional requirements for pulsed radiation.

8 Mechanical requirements

The manufacturer shall state if the dosemeter is provided with a capability for detecting mechanical shocks and if this results in discarding the pulses due to mechanical shocks.

No additional requirements for pulsed radiation.

9 Electromagnetic requirements

The manufacturer shall state if the dosemeter is provided with a capability for detecting or distinguishing electromagnetic disturbances and if this results in discarding the pulses due to electromagnetic disturbances.

No additional requirements for pulsed radiation.

10 Documentation

10.1 Operation and maintenance manual

Each instrument shall be supplied with operating instructions, maintenance and technical documentation as specified in the respective standard. In addition, the following measurement results shall be given:

- dose indication per counting event, G_{count},
- dead time of the dosemeter, t_{dead},
- statement that the dead time is non-extendable,
- measurement cycle time, T_{cycle},
- maximal value of the pulse peak dose rate in the radiation pulse measurable by the dosemeter, $\dot{H}_{\text{count, max}}$,
- time that the dosemeter requires to come back to its internal state relevant for measuring background or environmental radiation after any additional external radiation field is switched off.

NOTE The maximum value of the dose rate in continuous radiation fields measurable by the dosemeter is stated in the documentation required by the respective standard.

10.2 Type test report

At request the manufacturer shall provide a report covering the type tests performed in accordance with the requirements of this Technical Specification.

Table 2 – Reference conditions and standard test conditions for tests using pulsed radiation

Influence quantity	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Photon radiation energy	H-100 (ISO 4037-3)	H-100 (ISO 4037-3)
Angle of incidence of radiation	Reference direction given by the manufacturer	Direction given ± 5°
Pulse duration	Continuous	≥ 100 s
Dose rate	100 mSv h^{-1}	50 mSv h^{-1} to 200 mSv h^{-1} [a]
Time interval between measurements	As stated by the manufacturer, see 5.7	Longer than that stated by the manufacturer, see 5.7
[a] The actual value of the dose (rate) at the time of test shall be stated.		

Table 3 – Characteristics of counting dosemeters used in pulsed fields of ionizing radiation

Line	Characteristic under test or influence quantity	Requirement or minimum rated range of influence quantity	Limit of variation of instrument parameter or relative response for whole rated range	Sub-clause
1	Model function, dose rate in the pulse	$G_{\text{dose}} = G_{\text{count}} \times n_{\text{count}} \times k_{\text{dead, int}}$	Response obtained for $\dot{H}_{\text{count, max}}$ ± 20 %	6.1 6.8
2	Type of dead time	Non-extendable	Up to $\dot{H}_{\text{count, max}}$ the dead time shall be non-extendable	6.1 6.8
3	T_{cycle}	$T_{\text{cycle}} \leq 30$ s	–	6.3
4	G_{count}	$G_{\text{count}} \leq 10$ nSv or $G_{\text{count}} \leq 0{,}1\ H_0$, whichever is greater	–	6.4
5	t_{dead}	$t_{\text{dead}} \leq 10$ µs	–	6.5
6	$\dot{H}_{\text{count, max}}$	$\dot{H}_{\text{count, max}} \geq 1$ Sv h^{-1}	± 20 %	6.6 6.8
7	Pulse overload alarm, if provided	Adjustable to $\dot{H}_{\text{count, max}}$	$\dot{H}_{\text{pulse, peak, 1}} = 0{,}7 \times \dot{H}_{\text{count, max}}$: Alarm activated ≤ 5 % of pulses $\dot{H}_{\text{pulse, peak, 2}} = 1{,}3 \times \dot{H}_{\text{count, max}}$: Alarm activated ≥ 95 % of pulses	6.7
8	Dose rate overload for dose measurement	$\dot{H}_{\text{pulse, peak}} \leq 100 \times \dot{H}_{\text{count, max}}$ or 1 000 Sv h^{-1} if this is smaller	Dose indication greater than that obtained for $\dot{H}_{\text{count, max}}$	6.8

Annex A
(informative)

Parameter values for typical workplaces where pulsed radiation occurs

Table A.1 – Parameter values for workplaces where pulsed radiation occurs, as of 2012

Line	Facility or workplace	Minimal value of the radiation pulse duration, $t_{\text{pulse, min}}$	Maximum pulse peak dose rate, $\dot{H}_{\text{pulse, max}}$	Maximum pulse dose, $H_{\text{pulse, max}}$
1	Angiography	2 ms	10 Sv h^{-1}	0,1 mSv
2	C-bow X-ray facility	5 ms	10 Sv h^{-1}	1 mSv
3	Non-Intrusive Inspection (NII) system using linear accelerator (LINAC)	3,5 µs	500 Sv h^{-1} (at 1 m distance)	0,5 µSv (at 1 m distance)
4	Linear accelerator (LINAC) for cancer therapy	3 µs	250 000 Sv h^{-1} (at 1 m distance)	20 mSv (at 1 m distance)

Annex B
(informative)

Parameters characterizing the pulsed radiation field

See draft for ISO/NP TS 18090-1, *Radiological protection – Characteristics of reference pulsed radiation – Part 1: Photon radiation*[2].

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2 Under development.

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