INTERNATIONAL STANDARD

# ISO 11934

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# X and gamma radiation — Indirect- or direct-reading capacitor-type pocket dosemeters



*Rayonnements X et gamma — Dosimètres individuels à condensateur pour lecture directe ou indirecte*



Reference number
ISO 11934:1997(E)

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 11934 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.



This first edition cancels and replaces ISO 1758:1976, ISO 1759:1976 and ISO 4071:1978 which have been technically revised.



Annex A of this International Standard is for information only.



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# X and gamma radiation — Indirect- or direct-reading capacitor-type pocket dosemeters

## 1 Scope

This International Standard specifies the requirements for direct- and indirect-reading capacitor-type pocket dosemeters and the accessory electrometers used for personal dosimetry of X and gamma radiation.

The tests described in this International Standard are designed to be carried out on the dosemeter equipment associated with the operating accessories specified by the manufacturer.

NOTE — Electrical and mechanical characteristics of accessories are considered to belong to the scope of the International Electrotechnical Commission (Technical Committee 45).



This International Standard is not applicable without qualification to pocket dosemeters used to determine doses due to sources of pulsed radiation or to mixed fields of photons and neutrons. Furthermore, the dosemeters should not be used in radiation fields where the dose rate is likely to exceed their maximum dose rate capability as specified by the manufacturer.



## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6980:1996, *Reference beta radiations for calibrating dosemeters and dose-rate meters and determining their response as a function of beta-radiation energy.*

ISO 8529-3:–[1], *Neutron reference radiation — Part 3: Calibration of area and personal dosemeters and determination of response as a function of energy and angle of incidence.*

ISO 9227:1990, *Corrosion tests in artificial atmospheres — Salt spray tests.*

VIM:1993, *International Vocabulary of Basic and General Terms in Metrology*, ISO, OIM

[1] To be published. (Revision, in part, of ISO 8529:1989)

# 3 Definitions

For the purposes of this International Standard, the definitions given in the VIM (see clause 2) and the following definitions apply.

### 3.1 direct-reading capacitor-type pocket dosemeter

Device, used for individual monitoring, that permits direct reading of the radiation dose quantity.

NOTE — Such a device consists essentially of an ionization chamber connected to a capacitor. This capacitor is charged by a charging device which may or may not be built into the dosemeter, thus giving the charge indicator a deflection which can be read against a calibrated scale by means of an optical system. If the dosemeter is exposed to ionizing radiation, ionization in the chamber results in a decrease of the capacitor charge.

### 3.2 indirect-reading capacitor-type pocket dosemeter

Capacitor-type pocket ionization chamber from which the radiation dose quantity can be read indirectly by means of a separate electrometer.

### 3.3 type test

Test of one or more devices made to a certain design to show that the design meets certain specifications.



### 3.4 influence quantity

Quantity which may have a bearing on the results of a measurement without being the objective of the measurement. [ISO 4037-3]

### 3.5 reference conditions

Set of influence quantities for which the calibration factor is valid without any correction. [ISO 4037-3]

### 3.6 standard test conditions

Range of values of a set of influence quantities under which a calibration or a determination of response is carried out. [ISO 4037-3]

### 3.7 conventionally true value of a quantity

Best estimate of a quantity determined by a primary or secondary standard or by a reference instrument that has been calibrated against a primary or secondary standard.

### 3.8 response

<of a detector> Ratio of the quantity evaluated from the detector reading to the conventionally true value of this quantity. [ISO 4037-2]

### 3.9 error of indication

Difference between the indicated value of a quantity and the conventionally true value of that quantity, at the point of interest.

### 3.10 relative intrinsic error

Quotient of the error of indication of a quantity by the conventionally true value of that quantity measured for a reference radiation under specified reference conditions.

It is expressed as a percentage.

### 3.11 calibration quantity

Physical quantity used to establish the characteristics of a dosemeter.

### 3.12 calibration factor

Conventionally true value of a quantity the dosemeter is intended to measure, divided by its indication.

### 3.13 kerma, $K$



Quotient of $dE_{tr}$ by $dm$, where $dE_{tr}$ is the sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged ionizing particles in a material of mass $dm$.



The SI unit of kerma is the joule per kilogram. The special name for the unit of kerma is gray (Gy).

NOTE 1 Air kerma free in air, $K_a$, is generally used in place of the quantity exposure, $X$. The SI unit of exposure is coulomb per kilogram, while the former unit is the röntgen, 1 R=2,58 x $10^{-4}$ C/kg.

NOTE 2 Up to photon energies of 3 MeV, it can be assumed that the quantities "air kerma free in air" and "exposure" are approximately equivalent and that a value of $K_a$ = 1 Gy corresponds to an exposure $X$= 29,45 mC/kg. Above 3 MeV and up to 9 MeV, the quantity "air kerma" can still be obtained using small ionization chambers with build-up caps. However, for this higher energy range, absorbed dose in tissue should be used as the calibration quantity. [ICRP 51; ISO 4037-2]

### 3.14 absorbed dose, $D$

Quotient of $d\varepsilon$ by $dm$, where $d\varepsilon$ is the mean energy imparted by ionizing radiation to matter of mass $dm$.

The SI unit of absorbed dose is the joule per kilogram. The special name for the unit of absorbed dose is gray (Gy).

NOTE — In quoting values of absorbed dose it is necessary to specify the material, e.g. tissue.

### 3.15 dose equivalent, $H$

Product of $Q$ and $D$ at a point in tissue, where $D$ is the absorbed dose and $Q$ is the quality factor at that point.

The SI unit of dose equivalent is joule per kilogram. The special name for the unit of dose equivalent is sievert (Sv).

NOTE — The quality factor for X, gamma and beta radiation is one.

### 3.16 personal dose equivalent, $H_p(d)$

Dose equivalent in soft tissue, at an appropriate depth, $d$, below a specified point on the body.

The SI unit of personal dose equivalent is joule per kilogram. The special name for the unit of dose equivalent is sievert (Sv).

### 3.17 ambient dose equivalent, $H^*(d)$

Dose equivalent, at a point in a radiation field, that would be produced by the corresponding expanded and aligned field, in the ICRU sphere at a depth, $d$, on the radius opposing the direction of the aligned field.



The SI unit of ambient dose equivalent is joule per kilogram. The special name for the unit of dose equivalent is sievert (Sv).



NOTE — For strongly penetrating radiation, a depth of 10 mm is currently recommended. The ambient dose equivalent for this depth is then denoted by $H^*(10)$. [ICRU 51]

## 4 Standard conditions for dosemeter tests

### 4.1 Reference conditions

The reference conditions for indirect or direct reading capacitor-type pocket dosemeters, in accordance with ISO 4037-3, are:

- temperature $T$ = 20 °C ;
- relative humidity R.H. = 65 % ;
- atmospheric pressure $p$ = 101,3 kPa ;
- radiation background: ambient dose equivalent rate $\dot{H}^*(10) \leq$ 0,1 μSv/h.

### 4.2 Standard test conditions

Except for temperature and humidity tests, the standard test conditions should be in accordance with ISO 4037-2:

- temperature $T$ between 18 °C and 22 °C ;
- relative humidity R.H. between 50 % and 75 % ;

- atmospheric pressure $p$ between 86 kPa and 106 kPa ;
- radiation background : ambient dose equivalent rate $\dot{H}^*(10) < 0{,}25\ \mu Sv/h$.

The actual conditions should be indicated in the test report. They should not undergo large or rapid changes during a series of measurements.

When a dosemeter ionization chamber is not airtight, the reading of this dosemeter shall be corrected to reference temperature and atmospheric pressure conditions by multiplying it by $(p_{ref}/p) \cdot (T_K/T_{K,ref})$ where $p_{ref}$ and $T_{K,ref}$ are the reference pressure and temperature, $p$ and $T_K$ are the actual measured ones. Here the temperatures are expressed as absolute temperatures (K).

### 4.3 Irradiation conditions

The reference radiations to be used shall be selected from table 1 (see 6.2.9). The calibration quantity shall be measured with a reference instrument which has itself been calibrated in a reference beam traceable to national standards.

Except in the case of special tests, the irradiation should impinge perpendicularly to the principal axis of the dosemeter.

The distance "source to dosemeter" is defined as the distance from the equivalent point source to the geometric centre of the sensitive volume of the dosemeter. When the dosemeter is calibrated on a phantom, it should be positioned with its back face in contact with the phantom.



If a radioactive source is used, the duration of the irradiation must be at least 100 times longer than the time to advance and retract the source. If this condition cannot be met, the amount of interfering irradiation resulting from the movement of the source must be determined.

The irradiation room and calibration devices should meet the following specifications :

a) table and supports should be made of a low atomic number material and should have minimum mass;

b) if several dosemeters are irradiated together, the distance between them should be such that the mutual influence on their reading is small. The difference in the readings of a dosemeter irradiated together with other dosemeters and a dosemeter irradiated alone in the same position should be less than 3 %.

c) in order to subject several dosemeters to the same value of the calibration quantity, their supports should be placed on the same dose rate contour. If sufficient homogeneity cannot be achieved, the support may be made to rotate around the source.

## 5 Quantities

For most of the tests, the calibration quantities shall be air kerma or absorbed dose in tissue, whichever is appropriate for the particular type of radiation.

However, for the tests on the dependence of the dosemeter response on radiation energy and angle of incidence, results shall be reported in terms of personal dose equivalent.

# 6 Requirements concerning performance characteristics and test procedures

## 6.1 General

The following requirements apply to all tests.

a) The tests shall always be performed on a number of dosemeters randomly selected from a batch.

b) In order to avoid uncertainties due to geotropism, the readout procedure, including the position of the dosemeter, shall be specified by the manufacturer.

c) For direct-reading dosemeters, the length of the scale and the number of divisions shall permit a reading that corresponds to 2% of the full-scale value.

d) For indirect-reading dosemeters, the analog or digital readout shall permit a reading that corresponds to 2% of full range.



e) The dosemeters shall be capable of being set to zero within a value that corresponds to 2 % of the full-scale value within three attempts by an experienced operator.



f) For all the tests, a reference radiation from table 1 (see 6.2.9) shall be selected.

## 6.2 Tests with X or gamma radiation

### 6.2.1 Zero-point stability

#### 6.2.1.1 Requirements

The leakage of charge shall not give rise to a change in the zero point exceeding 2% of the full-scale value for a dosemeter stored in standard test conditions for 8 h.

Direct-reading dosemeters: The change in reading shall not exceed 2 % of the full-scale value when the dosemeter is disconnected from the charging source.

Indirect-reading dosemeters: The change in reading shall not exceed 2 % of the full-scale value when the fully charged dosemeter is reconnected to the reader.

#### 6.2.1.2 Test procedures

Set a series of 10 dosemeters to zero, store them under standard test conditions and read them ($r_i$) after 8 h. If the full-scale value of the dosemeter reading, $r_{max}$ , is less or equal to 1 mSv, the readings, $r_i$, shall be corrected for natural background dose.

Direct-reading dosemeters: Set a series of 10 dosemeters to zero, disconnect them and read them immediately ($r_i$).

Indirect-reading dosemeters: Charge a series of 10 dosemeters, disconnect them from the charger, immediately reconnect and read them, $r_i$.

Calculate the deviations, $d_i$, due to leakage or disconnection, in percent:

$d_i = 100\ (r_i / r_{max})$, where $r_i$ are the readings and $r_{max}$ is the full-scale value.

### 6.2.2 Stability of reading

#### 6.2.2.1 Requirement

The reading of the dosemeter shall not vary by more than 2 % of the full-scale value after a time of up to 8 h between the irradiation and a reading.

#### 6.2.2.2 Test procedures

Irradiate 10 dosemeters to a reading between 50 % and 85 % of the full-scale value. Read them immediately ($r_0$) and read them again ($r_i$) every hour following irradiation, up to 8 h.



For each dosemeter, calculate the relative deviation, $d_i$, in percent:



$d_i = 100\ (r_i - r_0)/r_{max}$ for each of the 8 readings, $r_i$, where $r_0$ is the initial reading and $r_{max}$ is the full-scale value.

### 6.2.3 Repeatability

#### 6.2.3.1 Requirements

The repeatability of the measurements shall be determined using the same dosemeter subjected to the identical irradiation conditions, including laboratory and operator.

The results of the repeatability test for each dosemeter shall be such that $2s/\bar{r} < 0{,}05$ where $\bar{r}$ is the mean reading of the sampled dosemeter and $s$ is the standard deviation.

#### 6.2.3.2 Test procedure

Set 3 dosemeters to zero. Irradiate them to a reading between 50 % and 85 % of the full-scale value. Read them, $r_i$, and reset to zero. Repeat the test 10 times.

Calculate the mean, $\bar{r}$, of the 10 readings of each dosemeter, and the standard deviation, $s$:

$$\bar{r} = \frac{1}{10}\sum_{i=1}^{10} r_i$$

$$s = \sqrt{\sum_{i=1}^{10} (r_i - \bar{r})^2 \Big/ 9} \, .$$

### 6.2.4 Batch homogeneity

#### 6.2.4.1 Requirements

Batch homogeneity shall be determined by observing the variability among the readings of dosemeters subjected to the same value of the radiation quantity under identical conditions, including laboratory and operator.

The results of the batch homogeneity test shall be such that $2s/\bar{r} < 0{,}1$ where $\bar{r}$ is the mean reading of the dosemeters and $s$ is the standard deviation.

#### 6.2.4.2 Test procedure



Irradiate 10 dosemeters to the same value of the radiation quantity between 50 % and 85 % of the full-scale value and read them ($r_i$).



Calculate the mean of the readings, $\bar{r}$, and the standard deviation, $s$ :

$$\bar{r} = \frac{1}{10}\sum_{i=1}^{10} r_i$$

$$s = \sqrt{\sum_{i=1}^{10} (r_i - \bar{r})^2 \Big/ 9} \, .$$

### 6.2.5 Lower limit of detection

#### 6.2.5.1 Requirements

For capacitor-type pocket dosemeters, the lower limit of detection is given by the lowest scale reading that can be distinguished from the fluctuations of background for a given time interval including leakage. The lower limit of detection, $r_{min}$, is determined by taking twice the standard deviation, $2s$, of the mean value of the difference in the readings for a series of dosemeters at the beginning and at the end of an 8 h storage in standard test conditions, rounding up $2s$ to the next scale division.

After a series of irradiations with values of the radiation quantity corresponding to a significant fraction of the full-scale value of the dosemeter the lower limit of detection shall not vary from the originally determined limit.

#### 6.2.5.2 Test procedure

Set 10 dosemeters as close as possible to zero and read them, $r_{0,i}$. Store for 8 h in standard test conditions and read again, $r_i$.

Calculate the absolute difference between the two readings, $\Delta r_i = | r_i - r_{0,i} |$, the mean value, $\overline{\Delta r}$, and the standard deviation, $s$ :

$$\overline{\Delta r} = \frac{1}{10}\sum_{i=1}^{10} \Delta r_i$$

$$s = \sqrt{\sum_{i=1}^{10} \left(\Delta r_i - \overline{\Delta r}\right)^2 \Big/ 9}$$

The lower limit of detection, $r_{\min}$, is then 2 $s$ rounded up to the next scale division.

To test the stability of the lower limit of detection take the 10 dosemeters that have been tested for their lower limit. Irradiate them successively 10 times to at least 80 % of the full-scale value and reset to zero. At the end of the irradiation, determine the lower limit of detection $r'_{\min}$ as described. Compare with the original value $r_{\min}$.



### 6.2.6 Relative intrinsic error

#### 6.2.6.1 Requirement



The relative intrinsic errors, $I$, shall not exceed 10%.

#### 6.2.6.2 Test procedure

Set 10 dosemeters to zero. Irradiate each to at least 3 different values of the radiation quantity, equally spaced between 20 % and 100 % of the full-scale value. Read, $r_i$, and reset the dosemeters to zero after each irradiation.

Calculate the relative intrinsic errors, $I_i$, in percent:

$$I_i = 100\,(r_i - r_0)/r_0$$

where $r_0$ is the conventionally true value of the radiation quantity used in the irradiation, and $r_i$ are the readings of the dosemeters .

### 6.2.7 Linearity

#### 6.2.7.1 Requirements

For the test of linearity the coefficient of variation, $s_I/\bar{I}$, for the series of relative intrinsic error measurements made in 6.2.6 shall be less than 0,1 , where $\bar{I}$ is the mean value of the intrinsic error and $s_I$ is the standard deviation.