

# INTERNATIONAL STANDARD

**ISO**  
**1757**

Second edition  
1996-12-15

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## Personal photographic dosimeters

*Dosimètres photographiques individuels*

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Reference number  
ISO 1757:1996(E)



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## 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 1757 was prepared by Technical Committee ISO/TC 85, *Nuclear energy*, Subcommittee SC 2, *Radiation protection*.

This second edition cancels and replaces the first edition (ISO 1757:1980), which has been technically revised.

Annex A forms an integral part of this International Standard. Annexes B and C are for information only.

## Introduction

Historically, personal doses of radiation were and in many cases still are, expressed in units of the quantity used for dosimeter calibration: in the case of photons, exposure, air kerma or absorbed dose in tissue (ICRU 33, ICRU 51) and, in the case of beta radiation, absorbed dose to tissue (ISO 6980).

In the light of internationally proposed new quantities in radiation protection, designed to provide a measure of risk irrespective of the type or energy of radiation or where it has come from, personal doses ideally should be expressed in terms of effective dose (ICRP 60). More practical, and therefore operationally more suitable, quantities are specified in ICRU 47.

It is possible to classify and test many aspects of personal photographic dosimeters with respect to the calibration quantity, air kerma, that should be used whenever possible for the testing so that results are directly traceable to primary standards. However, it is recognized that the determination of angular and energy response characteristics requires other calibration quantities, such as personal dose equivalent,  $H_p(d)$ , defined in ICRU 47, which has now become widely used for operational personal dosimetry, and which has also been recommended for use by the IEC.

# Personal photographic dosimeters

## 1 Scope

This International Standard specifies physical characteristics of personal photographic dosimeters and corresponding methods for testing their physical response. The test results obtained are as far as possible, expressed in terms of air kerma and, only when necessary, as in the case of energy and angular response, in terms of the operational quantity personal dose equivalent defined in ICRU 47.

The use of personal photographic dosimeters involves two steps: firstly, data acquisition including their evaluation with respect to the calibration quantity and secondly, interpretation of the data in terms of a personal dose quantity such as personal dose equivalent (ICRU 47) or effective dose (ICRP 60). This International Standard is intended to test the physical characteristics of photographic dosimeters and does not provide information on the calculation of the doses to individuals.

This International Standard applies to personal photographic dosimeters having a minimum measuring range from 200  $\mu\text{Sv}$  to 1 Sv and which, in accordance with national regulations and ICRP recommendations, are used:

- to determine personal doses due to X or gamma radiation;
- to determine personal doses due to beta radiation, whether or not this radiation is accompanied by photons.

This International Standard is particularly applicable to dosimeters intended to be carried on the body.

It does not cover dosimeters equipped with fluorescent intensifying screens.

Furthermore, this International Standard is not applicable without qualification:

- to photographic emulsions incorporated in dosimeters that may be used to detect neutrons or other particles;
- to photographic dosimeters used to determine the personal doses due to sources of pulsed radiation (e.g. accelerators)<sup>1)</sup>;
- to photographic dosimeters used in mixed fields of photons and neutrons;
- to nuclear track emulsions.

This International Standard is intended for the manufacturer or supplier of the film or dosimeter system, who is responsible for supplying material that complies with ISO specifications, as well as for the user who desires to test such compliance.

NOTE 1 As specified in clause 7, some performance characteristics are the responsibility of the manufacturer of the film and others the responsibility of the supplier of the holders or of the complete dosimeters.

1) The independence of response to dose rate should be tested when the air kerma rate is in excess of  $10^6$  Gy/s (see reference [3]).

The tests described below cover both dosimeters supplied to users who will process and evaluate them within their own establishment and those which are processed and interpreted by an external service.

NOTE 2 Tests i) to k) of table 1 and the relevant procedures in clause 8 concern dosimeter characteristics that can only be verified through the application of methods for the calculation of dosimetric quantities. These methods as well as calibration procedures are dealt with in annex B.

## 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 5-1:1984, *Photography — Density measurements — Part 1: Terms, symbols and notations.*

ISO 5-2:1991, *Photography — Density measurements — Part 2: Geometric conditions for transmission density.*

ISO 5-3:1995, *Photography — Density measurements — Part 3: Spectral conditions.*

ISO 5-4:1995, *Photography — Density measurements — Part 4: Geometric conditions for reflection density.*

ISO 921:—<sup>2)</sup>, *Nuclear energy — Vocabulary.*

ISO 4037-1:—<sup>3)</sup>, *X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods.*

ISO 4037-2:—<sup>3)</sup>, *X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy — Part 2: Dosimetry of X and gamma reference radiation for radiation protection over the energy range from 8 keV to 1,3 MeV and from 4 MeV to 9 MeV.*

ISO 6980:—<sup>4)</sup>, *Reference beta radiation for calibrating dosimeters and dose ratemeters and for determining their response as a function of beta radiation energy.*

IEC 846:1989, *Beta, X and gamma radiation dose equivalent and dose equivalent rate meters for use in radiation protection.*

## 3 Definitions

For the purposes of this International Standard, the following definitions apply:

**3.1 personal photographic dosimeter:** Dosimeter, comprising one or more photographic films positioned in a holder which incorporates one or more filters, with which it is possible to evaluate a radiation dose quantity from a measurement of optical densities of the film emulsion(s) beneath the various filters.

NOTE — For simplicity, the term “dosimeter” is used in the text of this International Standard to mean “personal photographic dosimeter”.

2) To be published. (Revision of ISO 921:1972)

3) To be published. (Revision of ISO 4037:1979)

4) To be published. (Revision of ISO 6980:1984)

**3.2 filter:** Part of the dosimeter that modifies the intensity of radiation on the emulsion.

**3.3 optical transmission density:** Logarithm to the base 10 of the ratio of aperture flux (ISO 5-1) to the flux transmitted by the sample under the same beam geometric conditions.

**3.4 optical reflection density:** Logarithm to the base 10 of the ratio of absolute reference reflected flux (ISO 5-1) to the flux reflected by the sample under the same beam geometric conditions.

**3.5 characteristic curve:** Curve representing, for a given radiation of a certain energy, the value of the optical density of the emulsion processed under given conditions as a function of the calibration quantity under a specified filter.

**3.6 latent image:** Invisible change occurring within the photographic emulsion when it is exposed to actinic radiation, i.e. visible light, ultraviolet or radiation that is directly or indirectly ionizing and that will be converted upon processing into a visible image.

**3.7 stability of latent image:** Degree to which an emulsion is capable of producing a developed image of given optical characteristics, irrespective of the time elapsed between the formation of the image and the development of the emulsion and irrespective of the ambient conditions that have prevailed during this time (temperature or humidity).

**3.8 fading:** Loss of latent image (i.e. of potential information) as a function of time between the formation of the latent image and the development of the emulsion.

NOTE — Fading is strongly influenced by ambient conditions such as temperature and humidity.

**3.9 solarization:** Reversal phenomenon, which normally occurs at high irradiation levels, causing the optical density to diminish with increasing irradiation.

**3.10 conventional true value,  $Q$ :** Best estimate of a quantity at the point of interest.

**3.11 response,  $R$ :** Ratio of the quantity evaluated from the detector reading,  $M$ , and the conventional true value of this quantity,  $Q$ .

**3.12 sensitivity of a photographic emulsion,  $S$ :** Ratio of the change in the optical density,  $\Delta OD$ , by the corresponding change in the conventional true value of the calibration quantity,  $\Delta Q$ .

**3.13 lower limit** (of the nominal range): Value of the calibration quantity corresponding to an optical density which is the mean of the optical densities for a batch of unexposed films plus twice the value of the experimental standard deviation of that mean.

**3.14 upper limit** (of the nominal range): Value of the calibration quantity  $Q$  (taking into account saturation and solarization) for which the sensitivity of the emulsion(s)  $S = \Delta OD / \Delta Q$  is positive and has at least a value of 0,4 Gy<sup>-1</sup> for optical transmission and 0,2 Gy<sup>-1</sup> for reflection density.

**3.15 coefficient of variation,  $V$ :** For a set of  $n$  measurements  $x_i$ , value given by the following formula:

$$V = \frac{1}{\bar{x}} \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

where  $\bar{x}$  is the arithmetic mean value of  $n$  measurements.

**3.16 coefficient of performance,  $P$ :** For a set of  $n$  measurements  $x_i$ , value given by the following formula:

$$P = \frac{1}{x'} \frac{\sum_{i=1}^n (x_i - x')}{n}$$

where  $x'$  is the conventional true value of the reference quantity.

NOTE — The coefficient of performance describes the bias of a series of measurements with respect to the conventional true value.

**3.17 control specimens:** Reference film packets, film holders or dosimeters of the same type and batch as those used in the test procedures.

**3.18 calibration quantity:** Physical quantity used to establish the characteristics of the emulsion(s) of the photographic film irradiated either alone or in a particular holder.

**3.19 conversion coefficient:** Factor used to convert one physical quantity into another.

**3.20 kerma,  $K$ :** Quotient of  $dE_{tr}$  by  $dm$ , where  $dE_{tr}$  is the sum of the initial kinetic energies of all the charged ionising particles liberated by uncharged ionising particles in a suitably small volume element of a specific material of mass  $dm$ . The SI unit of kerma is the joule per kilogram (J/kg). The special name for the unit of kerma is the gray (Gy) (see ICRU 33).

#### NOTES

1 Air kerma (kerma in free air) is generally used in place of the quantity exposure. The SI unit of exposure is coulomb per kilogram; the unit formerly used is the röntgen, R (1 R =  $2,58 \times 10^{-4}$  C/kg).

2 Up to photon energies of 3 MeV, it can be taken that the quantities of air kerma,  $K_a$ , and exposure,  $X$ , are approximately equivalent and that  $K_a = 1$  Gy corresponds to  $X = 29,45$  mC/kg. Above 3 MeV and up to 9 MeV, the quantity air kerma can still be achieved using small ionization chambers with build-up caps (DOS 18). However, for this higher energy range, absorbed dose in tissue should be used as the calibration quantity (see ISO 4037-2 and ICRP 51).

**3.21 absorbed dose,  $D$ :** Quotient of  $d\bar{E}$  by  $dm$ , where  $d\bar{E}$  is the mean energy imparted to matter in a suitable small volume element of a specific material of mass  $dm$ . The SI unit of absorbed dose is the joule per kilogram (J/kg). The special name for the unit of absorbed dose is the gray (Gy) (see ICRU 33).

NOTE — In quoting values of absorbed dose, it is necessary to specify the material, e.g. absorbed dose in air,  $D_a$ , or absorbed dose in tissue,  $D_T$ .

**3.22 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 the joule per kilogram (J/kg). The special name for the unit of dose equivalent is the sievert (Sv) (see ICRU 51).

NOTE — The quality factor for X, gamma and beta radiation is equal to 1.

**3.23 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 dose equivalent is the joule per kilogram (J/kg). The special name for the unit of dose equivalent is the sievert (Sv) (see ICRU 51).

#### NOTES

1 For weakly penetrating radiation, a depth of 0,07 mm for the skin is employed and denoted by  $H_p(0,07)$  while for strongly penetrating radiation, a depth of 10 mm is employed and denoted by  $H_p(10)$ .

2 For calibrations, ICRU has extended the definition of  $H_p(d)$  to phantoms having the composition of ICRU tissue, i.e. a mass composition of 76,2 % oxygen, 11,1 % carbon, 10,1 % hydrogen and 2,6 % nitrogen and a density of one, including a slab phantom of dimensions 30 cm × 30 cm and 15 cm to represent the human torso.

3 For practical calibrations or determining the response of an individual dosimeter for photon or beta radiation a slab phantom of 30 cm × 30 cm × 15 cm made of polymethylmethacrylate (PMMA)<sup>5)</sup> is recommended. For irradiation, the personal dosimeter should be fixed on the front face of the phantom. It is understood that there are no corrections to be applied to the reading of an individual dosimeter fixed on the surface of this phantom due to differences in backscatter between the PMMA and the ICRU tissue slab phantom (see note 2).

## 4 Description and design requirements

Personal photographic dosimeters are made up of two parts:

- a) the film packet(s), consisting of:
  - the photosensitive part enclosed in a protective wrapping from which it shall not be removed before processing. It may consist of one or more emulsions coated on one or more thin bases,
  - the protective wrapping which protects the photosensitive emulsion against the effect of light and if required also against outside chemical and mechanical agents;
- b) the holder containing one more filters, with the aid of which observations about the radiation field and the irradiation conditions can be made, and which permit, in many cases, an assessment of the radiation energy; the area(s) of the filter(s) should be sufficiently large in order to avoid edge effects.

Each dosimeter shall have some means of identification (see clause 9).

## 5 Classification and designation

### 5.1 Classification

Personal photographic dosimeters having a minimum measuring range from 200 μSv to 1 Sv are classified as follows.

#### 5.1.1 Classification of dosimeters according to radiation energy range

Dosimeters are assigned to one of the following five classes on the basis of the radiation energy range over which the dosimeter response meets the specifications in table 1 k):

- a) class 1: dosimeters designed for the range of X- and gamma-ray energies from about 250 keV to 9 MeV;
- b) class 2: dosimeters designed for all or part of the range of X- and gamma-ray energies from about 20 keV to about 250 keV;
- c) class 3: dosimeters designed to be used over the entire range of X- and gamma-ray energies from about 20 keV to 9 MeV;
- d) class 4: dosimeters designed for the measurement of beta radiation with maximum energies from 0,5 MeV to 4 MeV;
- e) class 5: dosimeters designed for the measurement of beta radiation with maximum energies from 1,5 MeV to 4 MeV.

5) Lucite, Perspex and Plexiglas are examples of suitable products available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by ISO of these products.

NOTE — Since the highest photon energies currently used which may require monitoring extend up to 50 MeV, dosimeters of classes 1 and 3 should be able to give an adequate response up to 50 MeV.

### 5.1.2 Classification of dosimeters according to resistance to water vapour

One of the two following categories shall apply to all dosimeters, depending upon their resistance to water vapour:

- a) category W: dosimeters complying with the specifications of table 1 g) (resistance to water vapour and/or actinic chemicals);
- b) category Y: dosimeters which do not comply with the specifications of table 1 g).

## 5.2 Designation

Photographic dosimeters shall be designated by a reference to this International Standard, followed by their energy range, their resistance to water vapour, and by the number of emulsions.

### EXAMPLE

**Personal photographic dosimeter ISO 1757-1-W-3**

## 6 Quantities

Calibration quantities for obtaining and reporting results of tests in accordance with table 1 a) to h) shall be air kerma or absorbed dose in tissue, whichever is appropriate for the particular type of radiation. Since these are essentially comparative tests, all irradiation, if not stated otherwise, may be carried out in free air or on a phantom.

The results of tests on the dependence of response of personal photographic dosimeters on radiation energy and on angle of radiation incidence [i.e. tests given in table 1 i) and j)] should be reported in terms of the personal dose equivalent (see annex A).

## 7 Requirements concerning performance characteristics

The specifications concerning the characteristics of photographic dosimeters are given in table 1.

As far as the characteristics of the photographic emulsion are concerned, these are the responsibility of the film manufacturer who is required to carry out the tests specified in table 1 a) to g) in order to provide information on the results of these tests. Similarly, the physical characteristics of the film holder are the responsibility of the manufacturer of the holder who should carry out the tests specified in table 1 k). Tests specified in table 1 i) to k) should be carried out by the organization who takes responsibility for the choice of combination of film and holder to provide the complete dosimeter. These tests in many cases are performed by a designated testing laboratory.