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Personal photographic dosemeters

Dosimètres photographiques individuels

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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 dosemeter 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 dosemeters 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 dosemeters

1 Scope

This International Standard specifies physical characteristics of personal photographic dosemeters 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 dosemeters 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 dosemeters and does not provide information on the calculation of the doses to individuals.

This International Standard applies to personal photographic dosemeters having a minimum measuring range from 200 µSv 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 dosemeters intended to be carried on the body.

It does not cover dosemeters equipped with fluorescent intensifying screens.

Furthermore, this International Standard is not applicable without qualification:

— to photographic emulsions incorporated in dosemeters that may be used to detect neutrons or other particles;

— to photographic dosemeters used to determine the personal doses due to sources of pulsed radiation (e.g. accelerators) [1)];

— to photographic dosemeters 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 dosemeter 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 dosemeters.

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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 dosemeters 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 dosemeter 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:—[2], *Nuclear energy — Vocabulary.*

ISO 4037-1:—[3], *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods.*

ISO 4037-2:—[3], *X and gamma reference radiation for calibrating dosemeters and doserate 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:—[4], *Reference beta radiation for calibrating dosemeters 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 dosemeter: Dosemeter, 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 "dosemeter" is used in the text of this International Standard to mean "personal photographic dosemeter".

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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 dosemeter 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, ΔOD, by the corresponding change in the conventional true value of the calibration quantity, ΔQ.

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) $S = \Delta\mathrm{OD}/\Delta Q$ is positive and has at least a value of 0,4 Gy^{-1} for optical transmission and 0,2 Gy^{-1} 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 dosemeters 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 × 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 $d\bar{\varepsilon}$ by dm, where $d\bar{\varepsilon}$ 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 dosemeter for photon or beta radiation a slab phantom of 30 cm × 30 cm × 15 cm made of polymethylmethacrylate (PMMA)[5] is recommended. For irradiation, the personal dosemeter 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 dosemeter 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 dosemeters 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 dosemeter shall have some means of identification (see clause 9).

5 Classification and designation

5.1 Classification

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

5.1.1 Classification of dosemeters according to radiation energy range

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

a) class 1: dosemeters designed for the range of X- and gamma-ray energies from about 250 keV to 9 MeV;

b) class 2: dosemeters 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: dosemeters designed to be used over the entire range of X- and gamma-ray energies from about 20 keV to 9 MeV;

d) class 4: dosemeters designed for the measurement of beta radiation with maximum energies from 0,5 MeV to 4 MeV;

e) class 5: dosemeters designed for the measurement of beta radiation with maximum energies from 1,5 MeV to 4 MeV.

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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, dosemeters of classes 1 and 3 should be able to give an adequate response up to 50 MeV.

5.1.2 Classification of dosemeters according to resistance to water vapour

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

a) category W: dosemeters complying with the specifications of table 1 g) (resistance to water vapour and/or actinic chemicals);

b) category Y: dosemeters which do not comply with the specifications of table 1 g).

5.2 Designation

Photographic dosemeters 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 dosemeter 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 dosemeters 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 dosemeters 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 dosemeter. These tests in many cases are performed by a designated testing laboratory.

Table 1 — Performance requirements of personal photographic dosemeters

Characteristic to be tested	Requirements	Test procedure
a) **Uniformity of the optical density of the emulsion(s)** *(pertaining to emulsions)* This test is carried out to ensure uniformity of the film emulsion.	Classes 1 to 5: 1) The difference between the maximum and minimum values of the optical density measured over the surface of each sample of the emulsion shall be less than 0,05 for optical transmission and for optical reflection density. 2) The standard deviation of the mean densities of the samples shall be less than 0,02 for optical transmission density and 0,05 for optical reflection density.	8.2.1
b) **Stability of the latent image** *(pertaining of emulsions)* This test is meant to check the fading behaviour of the latent image under normal test conditions and should assure that the stored dosimetric information is retained during a normal dosemeter-wearing period.	Deviations found on comparison of test samples with control specimens shall not be greater than 10 % of the calibration quantity received.	8.2.2
c) **Resistance to aging** *(pertaining to emulsions)* This test checks the ability of film emulsions to withstand abnormal pre-use storage conditions.	1) Artificial aging: Deviations found on comparison of test samples with control specimens shall not be greater than 20 % of the calibration quantity received. Variations in mean optical density of the base fog level in relation to control samples shall not exceed 0,10. 2) Natural aging: See requirements in a) and b).	8.2.3
d) **Effect of photon energy** *(pertaining to emulsions)* This test is meant to check the variations from batch to batch of the effect of different photon energies on the optical density of the emulsion.	Between different batches, the ratio of the calibration quantities resulting in the same optical density shall not vary by more than 10 % over the nominal range of the emulsion.	8.2.4
e) **Nominal range** *(pertaining to emulsions)* The test of the nominal range of the dosemeter is to verify that the minimum requirements for the measuring range of the dosemeter are met.	Lower limit: The calibration quantity at the lower limit shall give rise to an optical density that is at least two standard deviations (of the base fog level) higher than the mean optical density of the base fog level. Upper limit: The upper limit (taking into account saturation and solarization) of the nominal range is determined as the maximum value of the calibration quantity Q 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^{-1} for optical transmission and 0,2 Gy^{-1} for reflection density.	8.2.5

Table 1 — Performance requirements of personal photographic dosemeters *(continued)*

Characteristic to be tested	Requirements	Test procedure
f) **Opacity to light** *(pertaining to film packets)*	No streaks or inhomogeneities shall be observed on the processed test film. The mean optical density over the useful area of the film shall not differ by more than three standard deviations by comparison with the mean optical density of the control specimen.	8.2.6
g) **Resistance of wrapping to water vapour** *(pertaining to film packets)* This test is applicable only to dosemeters of category W.	1) Latent image fading: The average of the deviations found by comparison with the control specimens shall not exceed 10 % of the value of the calibration quantity received. 2) Variation in response: The average of the deviations found by comparison with the control specimens shall not exceed 10 % of the value of the calibration quantity received. 3) Variation in optical density of the base fog level: The average of the deviations in the base fog level found by comparison with the control specimens shall not exceed 0,05.	8.2.7
h) **Quality control of the filter(s) and plastic holder** *(pertaining to film packet holders)*	1) Uniformity of material thickness: The difference between the maximum and the minimum of the optical density of an emulsion behind any filter due to variations in material thickness shall be less than 5 % of the mean optical density value for a sample of filter or holder. The standard deviation of the mean optical density shall not exceed 2 % for the same sample of filter or holder. 2) Influence of (natural) radioactive nuclides possibly contained in the filter(s): The difference of the mean optical density values between the filter film samples and the reference films shall not exceed 0,05.	8.2.8
i) **Angular dependence of response** *(pertaining to dosemeters)* This test is made as a relative assessment of the angular response of the dosemeter to its response to radiation with normal (0°) incidence.	If $H'_p(E,\alpha)$ is the conventional true value of the personal dose equivalent (penetrating or superficial) at an average energy E and an angle α at the measurement position inside the phantom used for these tests and if $H_p(E,\alpha)$ is the value of the personal dose equivalent (penetrating or superficial) as determined from the dosemeter under test, then the angular response $R(E,\alpha) = H_p(E,\alpha)/H'_p(E,\alpha)$ can be evaluated. This allows the ratios $R(E,\alpha)/R(E,0)$ to be calculated. These ratios shall not differ from 1,0 by more than: ± 20 % for classes 1 and 2; ± 30 % for class 3; ± 50 % for class 4.	8.2.9

Table 1 — Performance requirements of personal photographic dosemeters *(concluded)*

Characteristic to be tested	Requirements	Test procedure
j) **Influence of irradiation through the back of the dosemeter** *(pertaining to dosemeters)* Comparison of dosemeter response for normal radiation incidence and irradiation from the back, i.e. reversed position.	All classes: For dosemeters tested, the ratio of the response for irradiation from the back to that obtained for an exposure from the front shall be determined and stated.	8.2.10
k) **Energy dependence of response** *(pertaining to dosemeters)* This test is meant to determine the energy response of the dosemeter. It is performed as a type test essentially once and is only repeated when major changes (filters, algorithm) are made to the system.	Classes 1 to 4: If $H'_p(E,0)$ is the conventionally true value of the personal dose equivalent (penetrating or superficial) at an average energy E and under perpendicular radiation incidence (0°) at the point of measurement in the phantom used for these tests and $H_{p,i}(E,0)$ the value of the personal dose equivalent (penetrating or superficial) determined for the ith of n dosemeters, then the absolute value of the coefficient of performance, $\lvert P \rvert$, given by: $$\lvert P \rvert = \frac{1}{H'_p(E,0)} \frac{\sum_{i=1}^{n} [H_{p,i}(E,0) - H'_p(E,0)]}{n}$$ shall be: $\leq$ 0,10 for class 1; $\leq$ 0,20 for class 2; $\leq$ 0,35 for classes 3 and 4. In addition, all individual deviations should fulfil the following condition: $\lvert H_{p,i}(E,0) - H'_p(E,0) \rvert / H'_p(E,0)$; $\leq$ 0,30 for classes 1 and 2; $\leq$ 0,45 for classes 3 and 4. In addition, the coefficient of variation V is given by: $$V = \frac{1}{\overline{H}_p(E,0)} \sqrt{\frac{\sum_{i=1}^{n} [H_{p,i}(E,0) - \overline{H}_p(E,0)]^2}{n-1}}$$ where $\overline{H}_p(E,0)$ is the mean value of $H_{p,i}(E,0)$. V shall be $\leq$ 0,35 for all classes. Class 4: The test is only performed for the quantity of superficial personal dose equivalent $H_p(0,07)$. Class 5: No test required. NOTE — If an elaborate algorithm involving optical densities under different filter areas is used to meet the performance requirement over the range of radiation energies of interest, this algorithm should be made available to all users of the particular dosemeter.	8.2.11

8 Test procedure

8.1 General test conditions

The tests given in this International Standard are in some cases tests for the evaluation of the performance of complete dosemeters comprised of film packets placed in film holders, in other cases of the film packets contained in these holders, of the holders or of the photographic emulsions in these film packets.

8.1.1 Specifications for samples (emulsion, film packets or dosemeters) undergoing test and for control specimens

The test samples and control specimens (see 3.17) shall be provided with means of identification in accordance with the method specified by the manufacturer.

The control specimens shall be taken from the same manufacturing batch as the test samples. In particular they shall be identical with regard to the number and nature of the filters.

Depending on the type of tests, irradiation shall be carried out either on the complete dosemeters or on the bare film packets.

NOTE — The tests may be carried out with or without a phantom, unless otherwise stated.

8.1.2 Pre-test conditioning

Before any test, dosemeters due to undergo a test or to be used as control specimens shall be placed for at least 4 h but not more than 20 h in an ambient atmosphere having a temperature of (20 ± 2) °C and a relative humidity between 45 % and 75 %. The radiation background shall not exceed an air kerma rate of 0,25 µGy/h.

8.1.3 Normal test conditions

Unless otherwise stated, tests shall be performed with normal (perpendicular) radiation incidence at a temperature of (20 ± 2) °C and a relative humidity between 45 % and 75 %. The radiation background shall not exceed an air kerma rate of 0,25 µGy/h.

8.1.4 Reference radiation

8.1.4.1 Dosemeters of classes 1 to 3

For tests with X- and gamma-radiation, the radiation qualities shall be chosen from those listed in tables 2 to 4 so as to cover the nominal energy range of the dosemeter tested. The characteristics of these radiations, the methods for producing them and the geometrical conditions are described in ISO 4037-1.

According to the energy and dose rate required a high-energy gamma reference beam (photon radiation energies between 4 MeV and 9 MeV) can be selected among those defined in ISO 4037-1:

a) 4,44 MeV obtained from the $^{12}C(p,p'\gamma)^{12}C$ reaction on bombarding a carbon target with 5 MeV protons;

b) 6,13 MeV obtained from the $^{19}F(p,\alpha\gamma)^{16}O$ reaction on bombarding a fluorine target with protons;

c) 6 MeV and 9 MeV from thermal neutron capture in titanium and nickel.

During irradiation, there shall be electronic equilibrium in the air surrounding the samples. If, for environmental reasons, this requirement cannot be met, appropriate build-up materials shall be placed in front of the sample to ensure electronic equilibrium (or transient electronic equilibrium in the case of high-energy radiation).

Table 2 — Narrow spectrum "A" series

High voltage kV	Mean energy keV	Additional filtration 1) mm Lead	Tin	Copper
40	33	—	—	0,21
60	48	—	—	0,6
80	65	—	—	2,0
100	83	—	—	5,0
120	100	—	1,0	5,0
150	118	—	2,5	—
200	163	1,0	3,0	2,0
250	205	3,0	2,0	—
300	248	5,0	3,0	—

NOTE — The narrow-spectrum series shall be used specifically to test the energy dependence of dosemeter response.

1) The total filtration includes a fixed filtration adjusted to 4 mm of aluminium.

Table 3 — Wide spectrum "B" series

High voltage kV	Mean energy keV	Additional filtration 1) mm Tin	Copper
60	45	—	0,3
80	58	—	0,5
110	79	—	2,0
150	104	1,2	—
200	134	2,0	—
250	169	4,0	—
300	202	6,5	—

NOTE — The wide-spectrum series shall be used when sufficient radiation intensity cannot be achieved otherwise.

1) The total filtration includes a fixed filtration adjusted to 4 mm of aluminium.

Table 4 — Radionuclide sources

Radionuclide	Energy of gamma radiation keV	Half-life years
^{241}Americium	59,54	433
^{137}Caesium	661,6	30,1
^{60}Cobalt	1 173,3 and 1 332,5	5,272

8.1.4.2 Dosemeters of classes 4 and 5

The radiation to which the dosemeters are exposed during the tests described below has energies which are included within the range to be covered by these dosemeters. The beta radiation employed for the tests shall be chosen from among those described in ISO 6980 so as to cover the useful energy range of the dosemeters tested.

8.1.5 Intensity of the radiation field

The intensity of the radiation field for calibration shall be sufficient to permit irradiation times for which latent-image changes are negligible.

8.2 Procedures

8.2.1 Checking uniformity of optical density of emulsion [see table 1 a)]

The tests shall be performed for an optical density of 1,0 for each emulsion of the film packet and be carried out choosing an appropriate reference radiation from among the following:

a) class 1: gamma radiation from ^{137}Cs or ^{60}Co;

b) class 2: any selected radiation from 8.1.4 in the energy range lower than 250 keV;

c) class 3: any selected reference radiation from 8.1.4;

d) classes 4 and 5: preferably beta radiation from a $^{90}Sr/^{90}Y$ source (see ISO 6980).

For each production batch of an emulsion, expose ten film packets, randomly selected from different boxes, to a value of the calibration quantity corresponding to an optical density of 1,0. Measure, for each emulsion, the optical density at ten different places evenly distributed over its surface. Determine the difference between the maximum and the minimum values of the optical density of each sample and calculate the standard deviation of the mean.

Perform the density measurement on the same side of the film surface as used in normal routine operation.

This test is influenced by possible variations in both the exposure conditions and the development procedure. Hence it is essential that the influence of both factors is kept to a minimum to ensure that the results of the test are not invalidated.

8.2.2 Test of stability of latent image [see table 1 b)]

This test of the resistance to fading shall be performed on each emulsion in the film packet.

For each emulsion, prepare two lots of five film packets and identify the lots by the letters A and B, the latter being considered as control specimens.

Expose lot A to one of the reference radiations (see 8.1.4), such that the optical density is in the quasilinear part of the characteristic curve of the emulsion being tested.

Store lots A and B for 30 days under normal test conditions. At the end of the storage period, expose the unexposed lot B to the same value of the calibration quantity as lot A. Wait 24 h. Process all film samples together.

8.2.3 Testing film for resistance to aging [see table 1 c)]

8.2.3.1 Artificial aging

This test shall be carried out on each emulsion in the film packet.

For each emulsion prepare eight lots of three film packets and mark each lot with a letter A to H. Place lots A to D for seven days in a dry oven open to the atmosphere (with no source of humidity of desiccant) set at a temperature of (50 ± 1) °C and keep lots E to H under normal test conditions (see 8.1.3).

Between 4 h and 20 h after the heat treatment is finished, expose lots A to C and lots E to G (control specimens) to one of the reference radiations under the following conditions:

a) film packets A and E shall receive a value of the calibration quantity corresponding to one-quarter of the measuring range of the emulsion;

b) film packets B and F shall receive a value of the calibration quantity corresponding to one-half of this range;

c) film packets C and G shall receive a value of the calibration quantity corresponding to four-fifths of this range.

Place film packets D which have undergone the heat treatment together with control specimens H. These two lots shall not be irradiated.

Proceed with the simultaneous development of all the films mentioned above. Determine the calibration quantities for the lots of films which were irradiated. Calculate separately the mean of the calibration quantities read from the films undergoing test and the mean of the calibration quantities read from the control specimens. Compare these means. Determine and compare the mean optical density of the base fog of the two lots which were not irradiated.

8.2.3.2 Natural aging

Store, until one month before the expiry date and under the conditions specified by the manufacturer, a number of film packets sufficient for the tests specified in table 1 a) and b).

Perform these tests according to the procedures given in 8.2.1 and 8.2.2.

The test results should fall within the limits of the requirements specified in table 1 a) and b).

8.2.4 Test of the effect of photon energy on emulsion [see table 1 d)]

This test shall be performed for each emulsion in the film packet.

For each emulsion, prepare two lots of five film packets and mark these lots with the letter A or B. Lot A is irradiated with a reference radiation and lot B with an energy for which the energy response of the emulsion is maximum.

a) Classes 1 and 3: lot A is irradiated with a reference gamma radiation (^{60}Co or ^{137}Cs) and lot B with an energy E from 8.1.4 close to 60 keV (e.g. ^{241}Am gamma radiation or 65 keV mean energy "A" radiation).

b) Class 2: the same procedure as above is adopted except that the reference radiation chosen from 8.1.4 shall be within the energy range from 100 keV to 250 keV.

c) Classes 4 and 5: the same procedure as above is adopted except that irradiation is performed with two different beta radiation sources chosen from ISO 6980.

The value of the calibration quantities shall be chosen such that the resulting optical densities are about 1. Calculate the ratio $[Q(\mathrm{A})/Q(\mathrm{B})] \times [\mathrm{OD}(E)/\mathrm{OD}(E_{\mathrm{ref}})]$ where Q(A) and Q(B) are the values of the respective calibration quantities.

8.2.5 Test of the nominal range [see table 1 e)]

8.2.5.1 Test at lower limit

If several emulsions of different sensitivities are included in the film packet to cover the measuring range, the most sensitive emulsion shall be examined.

Irradiate three film packets with the following reference radiations to a calibration quantity at the lower limit.

a) Classes 1 and 3: ^{137}Cs or ^{60}Co gamma radiation;

b) Class 2: 248 keV mean energy of the "A" series;

c) Classes 4 and 5: ^{90}Sr/^{90}Y beta radiation.

Process the exposed films simultaneously with ten unexposed films from the same batch of emulsion under the general test conditions.

Measure the optical densities of the unexposed films and determine the mean value and the standard deviation of these measurements. Measure the optical density of the irradiated films and calculate the mean value.

Add two standard deviations in density to the density of the control specimens and compare with the optical density of the exposed films. This latter value should be greater than the former.

8.2.5.2 Test at the upper limit, taking into account saturation and reversal

If several emulsions of different sensitivities are included in the film packet to cover the measuring range, the least sensitive emulsion shall be examined.

Prepare two lots of three film packets designated by the markings A and B. Irradiate lot A to a value of the calibration quantity at the upper limit Q_{ul} and lot B to the same value plus 0,1 Gy, i.e. $Q_{ul + 0,1}$. From the mean optical densities OD of the two lots, calculate the sensitivity, S, at the upper limit as follows:

$$S = [\mathrm{OD}(Q_{ul + 0,1}) - \mathrm{OD}(Q_{ul})]/0,1$$

8.2.6 Checking opacity of package to light [see table 1 f)]

This test shall be performed on a number of film packets randomly selected.

Expose the film packets to an illumination from a xenon lamp of 1 000 cd/cm^2 for one hour at a sufficiently large distance from the light source to avoid the film packets exceeding a temperature of 30 °C. Set the face of the film packets perpendicular to the luminous radiation. Then expose the other face of the film packets under the same conditions for one hour. The expose each edge of the film packets under the same conditions for one hour. Process film packets simultaneously with control specimens and compare their optical densities with respect to streaks or lack of homogeneity of the optical density. Measure the optical density at ten different places on each film. Calculate the mean optical density and the standard deviation for each film and compare the values.

8.2.7 Checking resistance of wrapping to water vapour for film packets of category W [see table 1 g)]

This test shall be performed on film packets of category W only.

Prepare six lots of five film packets for each emulsion of the film packet on which this check is made and identify these lots by the letters A to F.

Carry out the following procedures on the lots indicated:

a) lot A: irradiate and then expose to damp treatment;

b) lot B: irradiate (without damp treatment) and then store;

c) lot C: expose to damp treatment and then irradiate;

d) lot D: store (without damp treatment) and then irradiate;

e) lot E: expose to damp treatment;

f) lot F: no special treatment.

NOTE — The film packets of lots B, D and F are the control specimens for the lots A, C and E, respectively.

Expose the film packets (lots A and B, then C and D) with a value of the calibration quantity corresponding approximately to the middle of the measuring range of the emulsion tested. For damp treatment, keep the dosemeters of lots A, C and E in a ventilated enclosure having a temperature of (38 ± 0,5) °C and a relative humidity of (90 ± 2) % for 7 days. Store the control specimens of lots B, D and F which are not subjected to damp treatment under normal test conditions.

The two operations to which lots A and C are subjected shall be performed in immediate succession.

The six lots of dosemeters shall be developed simultaneously, the calibration quantity for lots A, B, C and D being determined and the optical density for lots E and F being measured.

The average of the results for each of the six lots shall be calculated and the differences then established between:

— lots A and B, to determine the latent image fading;

— lots C and D, to determine the variation in sensitivity;

— lots E and F, to determine the variation in the optical density of the base fog level.

8.2.8 Quality control of filter(s) [see table 1 h)]

This test shall be performed either on the filter material or on the manufactured film-holders.

8.2.8.1 Test of homogeneity of filter material

Clamp a set of ten samples, cut out from non-adjoining areas of the plates used for the production of filters of the same size as the filters, to ten film packets. Irradiate these filter-film combinations in free air with a reference radiation from 8.1.4, having energies between 33 keV and gamma radiation from $^{137}Cs/^{60}Co$, adapted to the filter material to be tested.

The chosen value of the calibration quantity shall be such that the resulting optical density is 1,0 ± 0,5.

On each emulsion, measure the optical density in ten different places evenly distributed over the surface. Calculate the mean optical density per filter area for each film. This test shall be repeated for each type of filter whenever a new set of filters or holders is manufactured.

NOTE — A variation of this test can also be performed with the manufactured film-holders. Since for a filter field it is generally practical to make only one optical density measurement per holder, the test should be performed on at least 50 holders randomly selected from, e.g., a new delivery in order to achieve a meaningful result.

8.2.8.2 Check of radioactivity

In cases where filters may contain radioactive material (e.g. tin or lead filters), check that radiation from these radionuclides does not induce a measurable optical density.

Prepare two lots of five film packages designated A and B. Place the film packages of lot A in holders or clamp to the filter plates and leave both lots A and B (the control specimen) under test conditions (see 8.1.3) for their normal wearing period. Process the films simultaneously. Measure the optical density for each film under the considered filter. Calculate the mean values and compare test and control film results.

8.2.9 Checking angular dependence of response of dosemeter [see table 1 i)]

For each emulsion, the test shall be performed with the dosemeters irradiated on a phantom. Angles of radiation incidence shall be in two planes perpendicular to each other — one through the axis of symmetry of the dosemeter that is parallel to the short dosemeter side and the other through the axis of symmetry parallel to the long dosemeter side. In each case, the fixed angles of incidence used for the irradiations shall be 0°, 30°, 45° and 60°, with the dosemeters irradiated on a phantom at a constant distance large enough to assure an expanded field over the surface of the phantom.

Prepare seven lots of three dosemeters designated by the letters A to G. All dosemeters shall be irradiated identically at a value of personal dose equivalent producing optical densities in the quasilinear range of the characteristic curves of an emulsion. Lot A is irradiated at 0° (normal incidence), lot B and C at 30° turning around the long and short side of the dosemeters respectively. Lots D and E are exposed likewise at an angle of 45° and F and G at an angle of 60°. The following reference radiations (see 8.1.4) shall be used:

a) class 1: mean energy 248 keV of the "A" series and ^{137}Cs or ^{60}Co gamma radiation;

b) class 2: mean energy 65 keV of the "A" series or ^{241}Am and 248 keV of the "A" series;

c) class 3: mean energy 65 keV of the "A" series or ^{241}Am and ^{137}Cs or ^{60}Co gamma radiation;

d) class 4: ^{204}Tl and $^{90}Sr/^{90}Y$ beta radiation (see ISO 6980);

e) class 5: no test is required.

For a given radiation energy, E, the ratio of the dosemeter response at an angle α, $R(E,\alpha)$, to the response at normal incidence, $R(E,0)$, is calculated. The conventional true values used to calculate the responses are obtained from the angular correction factors $f(d,E,\alpha)$ given in table A.2. The depth d is either 0,07 mm or 10 mm.

NOTE — In order to avoid the introduction of absolute errors in the determination of dose equivalent, the results of these tests are expressed as dimensionless ratios.

8.2.10 Checking influence of back-irradiation [see table 1 j)]

This test shall be carried out on a phantom. The following reference radiations (see clause 8.1.4) shall be used:

a) classes 1 and 3: ^{137}Cs or ^{60}Co gamma radiation;

b) class 2: X-radiation of mean energy between 100 keV and 248 keV;

c) classes 4 and 5: ^{90}Sr/^{90}Y beta radiation (see ISO 6980).

Provide two lots of three film packets designated by the letters A and B. Place lot A in holders and irradiate them on the phantom at a fixed distance from the source to a value of personal dose equivalent corresponding to the quasilinear range of the characteristic curve. Repeat this procedure with the same holders, replacing the film packets by those of lot B and irradiate them after having rotated the holders through 180° (irradiation from the back).

Calculate separately the means of the responses for the dosemeters irradiated on the front and for those irradiated from the back. Compare these means.

8.2.11 Checking energy dependence of response of dosemeter [see table 1 k)]

For each emulsion and each radiation type and energy, the test shall be performed with the dosemeters irradiated on a phantom, at normal radiation incidence.

Five randomly selected dosemeters shall be irradiated identically to a value of personal dose equivalent using the following reference radiations (see 8.1.4):

a) class 1: mean energy 248 keV of the "A" series and ^{137}Cs or ^{60}Co gamma radiation;

b) class 2: mean energy 33 keV of the "A" series:

- mean energy 58 keV of the "B" series or ^{241}Am gamma radiation,
- mean energy 79 keV of the "B" series,
- mean energy 134 keV of the "B" series,
- mean energy 248 keV of the "A" series;

c) class 3: as for class 2 but in addition ^{137}Cs or ^{60}Co gamma radiation;

d) class 4: ^{204}Tl and ^{90}Sr/^{90}Y beta radiation (see ISO 6980);

e) class 5: no test is required.

For each reference radiation, the conventionally true value of the personal dose equivalent (penetrating or superficial) inside the phantom used for these tests, $H'_p(d,E,0)$, shall be obtained from the value $Q(E,0)$ of the calibration quantity air kerma or absorbed dose in tissue by the following equation:

$$H'_p(d,E,0) = Q(E,0)\, c(d,E,0)$$

where $c(d,E,0)$ is the weighted average conversion coefficient to convert from the relevant calibration quantity $Q(E,0)$ to personal dose equivalent for the energy spectrum of the particular reference radiation under normal radiation incidence (0°).

Values of $c(d,E,0)$ for depths d = 0,07 mm and d = 10 mm in the ICRU tissue slab phantom as a function of radiation type (photons, beta radiation) and energy, E, are given in annex A.

9 Identification

The dosemeter shall have simple, unique and secure means of identification. The marking procedure shall not impair the useful portion of the emulsion, either directly or indirectly, nor shall it change its optical density in any manner.

10 Marking and accompanying documents

10.1 Marking

10.1.1 Individual marking

The film packet shall carry any necessary markings for determining its origin, its expiry date and the response characteristics of the dosemeter for which it is intended.

10.1.2 Collective marking

On each box (or other collective packing) of film packets or, failing this, on an accompanying note, shall be the following information:

a) name or trademark of manufacturer;

b) complete designation (class, division, category);

c) series number or manufacturer's batch number;

d) expiry date.

10.2 Accompanying documentation

The note attached to each box or other packing container shall carry at least the following information, if it is not provided on the container:

a) complete designation (see 5.2);

b) name and trademark of manufacturer;

c) measuring ranges for which the film packets are designed;

d) method of processing.

Annex A
(normative)

Conversion coefficients and angular correction factors

In this International Standard, air kerma, K_a, for photons and absorbed dose in air, D_a, are considered as the calibration quantities for most of the tests. For testing the angular and the energy dependences of response of the dosemeter, however, the operational quantity personal dose equivalent, $H_p(d)$, both penetrating and superficial, as proposed by ICRU are used (see ICRU 47).

In the following coefficients $c(d,E,\alpha)$ that convert K_a for photons and D_a for beta radiation into personal dose equivalent are given for depths d = 0,07 mm and 10 mm in the ICRU tissue slab phantom. This phantom has the dimensions of 30 cm × 30 cm × 15 cm, a mass composition of 76,2 % oxygen, 11,1 % carbon, 10,1 % hydrogen and 2,6 % nitrogen and a density of 1. The coefficients $c(d,E,\alpha)$ depend on the radiation type (photons and beta radiation), energy, E, and angle of radiation incidence (α = 0° to 60°). As a first approximation, these conversion coefficients can be split into:

$$c(d,E,\alpha) = c(d,E,0) \times f(d,E,\alpha)$$

where

$c(d,E,0)$ is the conversion coefficient for normal radiation incidence;

$f(d,E,\alpha)$ is the correction factor for a given thickness d, energy E, and angle α.

The values for the conversion coefficients $c(d,E,0)$ for photons in table A.1 are taken from ISO 4037-2 and those for beta sources are taken from ISO 6980.

The dependence of angular response $f(d,E,\alpha)$ is given in table A.2. Values for photons were calculated using data published in reference [2]. The values for the beta sources are taken from ISO 6980. It should be noted that they depend strongly on the distance to the source.

For practical calibrations or for determining the response of an individual dosemeter for photon or beta radiation, a PMMA phantom of dimensions 30 cm × 30 cm × 15 cm is used. For irradiation, the personal dosemeter 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 dosemeter fixed on the surface of this phantom due to differences in backscatter between this and an ICRU tissue slab phantom of the same size.

Table A.1 — Conversion coefficients $c(d,E,0)$ relating personal dose equivalent to air kerma for filtered X-radiation and for gamma reference radiations as specified in ISO 4037-1 for normal radiation incidence

Type of radiation	Mean energy keV	$c(0{,}07,E,0)$	$c(10,E,0)$
Narrow spectrum:			
A40	33	1,29	1,22
A60	48	1,57	1,68
A80	65	1,72	1,89
A100	83	1,71	1,87
A120	100	1,67	1,80
A150	118	1,61	1,72
A200	163	1,49	1,57
A250	205	1.42	1,48
A300	248	1,37	1,42
Wide spectrum:			
B60	45	1,52	1,60
B80	58	1,65	1,80
B110	79	1,71	1,87
B150	104	1,65	1,78
B200	134	1,56	1,66
B250	169	1,48	1,56
B300	202	1,43	1,49
Radionuclides:			
^{241}Am	59,54	1,72	1,88
^{137}Cs	661,6	1,21	1,22
^{60}Co	1 173,3 and 1 332,5	1,18	1,18
Beta radiation:			
^{204}Tl	240	1,12	
^{90}Sr/^{90}Y	570	1,19	

NOTE — In this case of beta radiation, the quantity air kerma is replaced by absorbed dose in air (IEC 846).

Table A.2 — Angular correction factors $f(d,E,\alpha)$ to be applied to conversion coefficients of table A.1

Radiation	α = 0°	α = 30° d = 0,07 mm	α = 30° d = 10 mm	α = 45° d = 0,07 mm	α = 45° d = 10 mm	α = 60° d = 0,07 mm	α = 60° d = 10 mm	Classes concerned
^{241}Am/A65	1,00	0,98	0,97	0,95	0,90	0,89	0,77	2 and 3
A248	1,00	1,00	0,98	1,00	0,94	0,99	0,86	1 and 2
^{137}Cs	1,00	1,01	1,00	1,01	0,98	1,02	0,95	1 and 3
^{60}Co	1,00	1,00	0,99	1,00	0,99	1,01	0,97	1 and 3
^{90}Sr/^{90}Y	1,00	1,05	—	1,13	—	1,19	—	4 and 5

NOTE — The factors are only given for those radiation qualities that are needed in the tests of this International Standard. A65 and A248 stand for the mean energy of the "A" series X-rays (see 8.1.4).

Annex B
(informative)

Evaluation of photon doses with personal photographic dosemeters

B.1 General

B.1.1 In specifying the required performance characteristics of film dosemeters, clause 7 differentiates between the responsibilities of, firstly the film manufacturer, secondly the manufacturer of the film holder, and thirdly the organization responsible for the choice of film, the holder and the method of dose evaluation.

Separate tests are specified for each of these entities.

Once the third organization has chosen the film holder it intends to use, it must decide upon a method of dose evaluation. A number of methods are available and the purpose of this annex is to give information on, and an example of the derivation of a suitable method.

B.1.2 The photon sensitivity of unfiltered photographic film varies markedly with radiation energy due to the different interaction processes that take place at different photon energies and due to absorption within the film itself and its wrapper. Typically, the ratio between the sensitivity to intermediate energy X-rays and to hard γ-rays is in the range 20 to 50. Therefore, if this detector is to be used for personal dosimetry, a means must be obtained to overcome this difficulty.

Usually the film is worn inside a holder which contains a number of metallic and plastic filters. These filters change the sensitivity of the film beneath them and the resulting image on the film is effectively used to obtain information on the incident radiation, so that corrections to the film sensitivity can be made in order to obtain a uniform response to energy. This type of dosemeter is referred to as a discriminating dosemeter, since it provides qualitative information on exposure in addition to dose. For example, the filter image can be used to provide information on the radiation type and its energy.

Photographic film dosemeters are still used extensively throughout the world for personal dosimetry and many different designs of film holder are in use. The subject can only therefore be treated here in general terms, with one specific design referred to as an example.

B.2 Radiation quantities

The radiation quantity the dosemeter is required to measure will affect the holder design, the method of type testing and the method of evaluation.

If the requirement is to measure a receptor quantity such as the ICRU operational quantities (see reference [4]) $H_p(10)$ and $H_p(0,07)$, then type testing should be carried out on a suitable phantom and the dosemeter should be designed to respond to backscatter from the wearer. Another possibility is a requirement to measure exposure, air kerma, or absorbed doses to tissue at the surface of the body. In this case the dosemeter should also be designed to respond to backscatter and it should be type-tested on a suitable phantom.

B.3 Characteristic curve

An important part of dose evaluation with a photographic film dosemeter is the characteristic curve of the emulsion (see reference [7]). Exposure can be expressed in terms of any radiation quantity for any radiation quality. For example, the quantity air kerma for hard γ-irradiation, i.e. γ-radiation from ^{226}Ra, ^{60}Co or ^{137}Cs, should be chosen and the optical density be measured under the most heavily filtered area of the film. The dose that corresponds to an optical density is called the apparent dose. Subsequently in any further dose evaluation, all optical densities are converted to apparent doses read from the curve.

B.4 Characteristic response of individual filter areas of the dosemeter

The derivation of evaluation methods is based on data concerning the variation in sensitivity with energy of each of the filter areas of the dosemeters (see reference [4]).

The procedure to obtain these data may be illustrated, using as an example the irradiation of dosemeters to photons to obtain the quantity $H_p(10)$, based on a CEC document (see reference [5] and footnote 6), follows.

a) Select an ISO reference radiation and set up the radiation beam with a calibrated monitor chamber (see figure B.1).

b) Design the collimation such the monitor chamber, the slab phantom and the dosemeters can be completely enveloped by the beam. The slab and the dosemeters should be irradiated at a distance of at least 2 m from the source.

c) In the absence of the slab and dosemeters and for a given indication on the monitor chamber, measure the air kerma (K_a) at the position to be occupied by the centre of the front surface of the phantom during the actual irradiation (see figure B.1).

d) Multiply the air kerma by the appropriate conversion coefficient (C) for $H_p(10,\alpha)$. The equivalent dose for $H_p(10,\alpha)$ is then given by (K_aC) for a monitor indication of M. Each unit on the monitor chamber thus corresponds to a dose equivalent of $(K_aC)/M$ for the quantity $H_p(10,\alpha)$. The calibration factor (A) of the monitor chamber is $A = (K_aC)/M$.

e) Place the slab phantom and dosemeter(s) in the beam such that the beam is incident on the dosemeters at angle α and with the centre of the sensitive volume of the dosemeter on the beam axis at the position at which the air kerma was measured in c) above [see figure B.1 b)].

f) Deliver a suitable value of the dose equivalent $H_p(10)$ to the dosemeter. Irradiate the dosemeter until the monitor chamber indicates a value of $M = H_p(10)/A$.

g) Process the dosemeter and determine the apparent doses beneath appropriate filters from the characteristic curve and compare the results with the conventional true value of $H_p(10,\alpha)$.

NOTE — If a number of dosemeters are irradiated simultaneously in the above manner, a correction for the nonuniform distance to the source may be necessary for those positioned off the beam axis.

It is suggested that the phantom be turned at the midpoint of the exposure such that the dosemeters are irradiated at an angle $-\alpha$, so that the irradiation is the average of the two symmetrical orientations $\pm\alpha$.

h) Repeat the above procedure for ISO reference radiations over the entire required energy range.

Using this method together with the characteristic curve described in B.3, sensitivity curves for each of the filter areas, in terms of $H_p(10)$, can be obtained relative to the radiation used to produce the characteristic curve as a function of photon energy. These data can be obtained for several angles of incidence (reference [5] recommends angles of 0°, 20°, 40° and 60°). A similar curve for the quantity $H_p(0,07)$ can be obtained in an identical manner using the conversion coefficients for this quantity.

6) The question of calibration and type testing of dosemeters is being addressed by ISO/TC 85/SC 2. In the meantime, the following information is taken from a CEC document and is included for illustrative purposes. Information on a single recommended set of coefficients for conversion of K_a into $H_p(10)$ is expected to be published shortly by a joint ICRP/ICRU Task Group.