BRITISH STANDARD

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1994

Radiation protection instrumentation —

Portable, transportable or installed equipment to measure X or gamma radiation for environmental monitoring —

Integrating assemblies

STANDARDS

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee NCE/2, Health, Physics Instrumentation, upon which the following bodies were represented:

AEA Technology
Association of University Radiation Protection Officers
British Nuclear Fuels plc
British Steel plc
Department of Trade and Industry (National Physical Laboratory)
Electricity Association
GAMBICA (BEAMA Ltd.)
Health and Safety Executive
Institute of Physical Sciences in Medicine (Ipsm)
Institute of Physics
Institution of Nuclear Engineers
Ministry of Defence
National Radiological Protection Board
Society for Radiological Protection

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Contents

National foreword

This British Standard has been prepared under the direction of the Engineering Sector Board and is identical with IEC 1017-2 : 1994 *Radiation protection instrumentation — Portable, transportable or installed equipment to measure X or gamma radiation for environmental monitoring —* Part 2 : *Integrating assemblies*, published by the International Electrotechnical Commission (IEC).

IEC 1017 was produced as a result of international discussions in which the United Kingdom took an active part.

Cross-references

International standard	Corresponding British Standard
IEC 86	BS 397 *Primary batteries*
IEC 278 : 1968 IEC 278A : 1974	BS 4308 : 1979 *Specification for documentation to be supplied with electronic measuring apparatus* (Identical)
IEC 359 : 1987	BS 4889 : 1990 *Method for specifying the performance of electrical and electronic measuring equipment* (Technically equivalent)
ISO 4037 : 1979	BS 5869 : 1980 *Specification for X and γ* reference radiations for calibrating dosemeters and dose ratemeters and for determining their response as a function of photon energy (Identical)
ISO 6980 : 1984	BS 6689 : 1986 *Specification for reference beta radiations for calibrating dosemeters and doseratemeters and for determining their response as a function of beta radiation energy* (Identical)

The Technical Committee has reviewed the provisions of IEC 50(391) : 1975, IEC 50(392) : 1976, IEC 68-2-27 : 1987, IEC 293 : 1968, IEC 293A : 1970 and IEC 1018 : 1991, to which normative reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

RADIATION PROTECTION INSTRUMENTATION –

PORTABLE, TRANSPORTABLE OR INSTALLED EQUIPMENT TO MEASURE X OR GAMMA RADIATION FOR ENVIRONMENTAL MONITORING –

Part 2: Integrating assemblies

Section 1: General

1.1 Scope and object

Irradiation of members of the public from external radiation produced by nuclear and other establishments is subject to control, and an essential part of control is measurement of the environmental radiation levels in the neighbourhood of these establishments[1].

The evaluation of the environmental air kerma from X and gamma radiation is difficult. The composition of the background air kerma is complex, with contributions from natural sources such as cosmic radiation and terrestrial radioactivity as well as from man-made radioactivity arising from the operation of nuclear facilities and fall-out from nuclear weapons tests. Furthermore, the natural background air kerma rate varies in time and space.

This part of IEC 1017 defines performance parameters for portable or installed integrating assemblies to measure the environmental air kerma. If regulations require other dose or exposure quantities to be used for the above purposes (for example, ambient dose equivalent), this standard may be applied to the performance characteristics of equipment to measure these other quantities. For example, the same numerical values for the requirements for the radiation characteristics would still apply, but the conventionally true values would be expressed in the other quantities (for example, ambient dose equivalent) and not in air kerma.

It is assumed in this standard that the term "air kerma" means the kerma to air at a point in the environmental radiation field which may include scattered radiation and that the radiation detector has a wall thick enough to give electron equilibrium.

This standard applies to portable or installed integrating assemblies intended to measure environmental air kerma due to X or gamma radiation of energy between 50 keV and 1,5 MeV[2] from 10 nGy up to 10 mGy (1 μrad up to 1 rad) by integration of the detector's signal, i.e. integration of pulse count rate, ionization current, etc. Passive devices such as film dosemeters or TLD are not covered by this standard. If the assembly is to be used to measure air kerma in the area surrounding a nuclear power station when 6 MeV radiation is present, it will be necessary to determine the response at this energy.

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[1] The requirements specified in this standard relate to normal operations of the establishment. Should the assembly be used under emergency conditions then the requirements of IEC 1018 should also be applied to the assembly, particularly with regard to overload characteristics.

[2] 50 keV to 1,5 MeV has been chosen to cover the energies of the chief environmental and man-made radionuclides that contribute to the environmental air kerma.

For the purpose of radiation protection, these assemblies comprise at least:

- a detection sub-assembly (for example, ionization chamber, GM counter tube, scintillation detector, etc.);
- a measuring sub-assembly including a display device, which may be connected to the detector sub-assembly either rigidly or by means of a flexible cable, or incorporated into a single assembly. The installed assembly may also comprise a continuous recorder (for example, chart or magnetic cassette recorder or telemetry equipment).

This standard specifies, for the assemblies described above, general characteristics, general test procedures, radiation characteristics, electrical, mechanical, safety and environmental characteristics and also the identification certificate.

This standard does not provide for the measurement of beta radiation.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 1017. At the time of publication the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 1017 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(391): 1975, *International Electrotechnical Vocabulary (IEV) – Chapter 391: Detection and measurement of ionizing radiation by electric means*

IEC 50(392): 1976, *International Electrotechnical Vocabulary (IEV) – Chapter 392: Nuclear instrumentation – Supplement to chapter 391*

IEC 68-2-27: 1987, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 86: *Primary batteries*

IEC 278: 1968, *Documentation to be supplied with electronic measuring apparatus*

IEC 278A: 1974, *First supplement*

IEC 293: 1968, *Supply voltages for transistorized nuclear instruments*

IEC 293A: 1970, *First supplement: Stabilized d.c. power supplies – Tolerances of voltages*

IEC 359: 1987, *Expression of the performance of electrical and electronic measuring equipment*
Amendment No. 1 (1991)

IEC 1018: 1991, *High range beta and photon dose and dose rate portable instruments for emergency radiation protection purposes*

ISO 4037: 1979, *X and gamma reference radiations for calibrating dosemeters and dose ratemeters and for determining their response as a function of photon energy*

Addendum 1: 1983, *High rate series of filtered X-radiations*

Addendum 2: 1989, *Photon reference radiations at energies between 4 MeV and 9 MeV*

Amendment 1: 1983, *Low rate series of filtered X-radiations*

ISO 6980: 1984, *Reference beta radiations for calibrating dosemeters and dose ratemeters and for determining their response as a function of beta radiation energy*

1.3 Definitions

Except as specified below, all technical terms are as defined in IEC 50, particularly IEC 50(391) and IEC 50(392) which will be replaced by IEC 50(393) and IEC 50(394), respectively, and IEC 359.

For the purposes of this part of IEC 1017, the following definitions apply:

1.3.1 **portable air kerma meter**: Assembly designed to be easily carried (see 2.1.3) and intended to measure the air kerma due to X or gamma radiation at various places, including one or several radiation detectors and associated sub-assemblies or basic function units.

1.3.2 **installed air kerma meter**: Installed air kerma meter normally fixed in position. It may be equipped with means of recording the air kerma, and with remote read-out capabilities such as telemetry.

1.3.3 **conventionally true value of a quantity**: Best estimate of the value of that quantity, determined by a primary or secondary standard or by a reference instrument that has been calibrated against a primary or secondary standard.

1.3.4 **error of indication**: Difference between the indicated value of a quantity K_I and the conventionally true value of that quantity at the point of measurement K_T.

1.3.5 **response**: Response, R, of an assembly is the ratio of the assembly's indicated value to the conventionally true value:

$$R = \frac{K_I}{K_T}$$

1.3.6 **relative error of indication**: Quotient expressed as a percentage of the error of indication of a quantity by the conventionally true value of the measured quantity. It may be expressed as:

$$I\,(\%) = \frac{K_I - K_T}{K_T} \times 100$$

1.3.7 **relative intrinsic error**: Relative error of indication of an assembly with respect to a quantity when subjected to a specified reference radiation under specified reference conditions.

1.3.8 **coefficient of variation**: Ratio V of the estimate of the standard deviation s to the arithmetic mean $\bar{x}$ of a set of n measurements x_i given by the following formula:

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

1.3.9 **reference point of an assembly**: Reference point of an assembly is a physical mark on the assembly to be used in order to position the assembly at a point where the conventionally true value of the quantity to be measured is known.

1.3.10 **point of test**: Point at which the reference point of the assembly is placed and at which the conventionally true value of air kerma is known. For all tests involving the use of radiation, the reference point of the assembly shall be placed at the point of test and, apart from the test for variation in response with angle of incidence, in the orientation indicated by the manufacturer, i.e. with the radiation field incident from the manufacturer's stated calibration direction.

1.3.11 **qualification tests**: Qualification tests are performed in order to verify that the requirements of a specification are fulfilled.

Qualification tests are sub-divided into type tests and routine tests, as defined below.

1.3.11a **type tests**: Test one or more devices made to a certain design to show that the design meets certain specifications. [IEV 151-04-15]

1.3.11b **routine tests**: Test to which each individual device is subjected during or after manufacture to ascertain whether it complies with certain criteria. [IEV 151-04-16]

1.3.12 **acceptance test**: Contractual test to prove to the customer that the device meets certain conditions of its specification. [IEV 151-04-20]

1.3.13 **supplementary tests**: Tests intended to provide supplementary information on certain characteristics of the assemblies.

1.4 Units

In the present standard the units of the International System (SI)[1] are used. The definitions of radiation quantities and dosimetric terms[2] are given in IEC 50(391) and IEC 50(392) which will be replaced by IEC 50(393) and IEC IEC 50(394) respectively. The corresponding old units (not SI) are indicated in parenthesis. Nevertheless, the following units may be used:

- for energy: electron-volt (symbol: eV)
  1 eV = 1,602 10^{-19} J;
- for time: year, (symbol: y), day (symbol: d), hour (symbol: h), minutes (symbol: min).

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

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[1] International Bureau of Weights and Measures: *Le Système International d'Unités (SI)*, 5th edition (1985).

[2] Report 33 of the International Commission on Radiation Units and Measurements (ICRU) (published April 1980) and Publication 26 of the International Commission on Radiation Protection (ICRP).

Section 2: Assembly design

2.1 General characteristics

2.1.1 *Effective range of measurement*

The effective range of measurement shall be not less than the following:

2.1.1.1 For assemblies with an analogue type of display (for example, linear or logarithmic), from 10 % to 100 % of the scale maximum angular deflection on each scale range.

2.1.1.2 For assemblies with a digital display, from the first non-zero indication in the second least significant digit up to the maximum indication on each range. (As an example, for a display with a maximum indication 199,9 the effective range must extend from 1,0 to 199,9.)

The indication shall be expressed in units of air kerma, for example Gy (rad). For most applications, the effective range of measurement shall be from 10 nGy (1 µrad) to 10 mGy (1 rad). The requirements of this standard are also applicable where an assembly has an upper limit lower or higher than 10 mGy (1 rad). Where more than one detector is used for measurement over the complete range, automatic switching shall be provided between the detectors and also for range changing, the changing of detector, measuring and read-out scale shall be simultaneous.

In the case of an assembly with linear scales, the scaling factor between adjacent ranges shall not exceed 10.

If an assembly with a logarithmic scale is provided with switched measurement ranges, there shall be an overlap of one decade between adjacent ranges.

If there is a control for setting to zero, or to another indication, it shall be effective in the presence of radiation.

2.1.2 *Ease of decontamination*

The assembly shall be designed and constructed in such a manner as to minimize the risk of it becoming contaminated in use and to facilitate decontamination.

2.1.3 *Portability*

The mass of a portable assembly should not exceed 4 kg. It shall be equipped with handles, straps or other means to facilitate operation whilst being carried.

2.1.4 *Installed assemblies*

By agreement between manufacturer and user, these assemblies may be provided with appropriate facilities for indicating faults, for example, loss of detector voltage, failure of electronics.

Section 3: Test procedures

3.1 General test conditions

3.1.1 *Nature of tests*

Unless otherwise specified in the individual clauses, all tests enumerated in this standard are to be considered as type tests.

3.1.2 *Reference conditions and standard test conditions*

Reference and standard test conditions are given in table 1. Reference conditions are those conditions to which the performance of the instrument is referred, and standard test conditions indicate the necessary tolerances in practical testing. Except where otherwise specified, the tests in this standard shall be performed under the standard test conditions given in the third column of table 1.

3.1.3 *Tests performed under standard test conditions*

Tests which are performed under standard test conditions are listed in table 2 which indicates, for each characteristic under test, the requirements according to the subclause where the corresponding test method is described. For these tests the values of temperature, pressure and relative humidity at the time of test shall be stated and the appropriate corrections made to give the response under reference conditions.

3.1.4 *Tests performed with variation of influence quantities*

For those tests intended to determine the effects of variations in the influence quantities given in table 3, all other influence quantities shall be maintained within the limits for the standard test conditions given in table 1, unless otherwise specified in the test procedure concerned.

3.1.5 *Reference gamma radiation*

All tests involving the use of gamma radiation, other than those given in 3.2.2. and 3.2.3, shall be carried out with the reference gamma radiation. ^{137}Cs sources shall be used as the reference gamma radiation. If ^{137}Cs sources are not available for all tests requiring reference gamma radiation, ^{60}Co sources may be used but, in this case, the results shall be corrected to the response to ^{137}Cs by allowing for the difference in response between ^{60}Co and ^{137}Cs.

3.2 Radiation characteristics

For the radiation tests, the scattered radiation at the point of test, in the absence of the assembly, shall contribute less than 5 % of the total air kerma at that point.

3.2.1 *Relative intrinsic error*

3.2.1.1 *Requirements*

Under standard test conditions, with the calibration controls adjusted according to the manufacturer's instructions, the relative intrinsic error of the assembly shall not exceed ±15 % over the whole effective range of measurement.

3.2.1.2 *Determination of relative intrinsic error*

a) *Source to be used*

The test shall be performed with sources of ^{137}Cs irradiating the assembly in the calibration direction. More than one ^{137}Cs source may be required in order to cover the complete range of air kerma indicated by the assembly. In this case, the relative activities of the sources used shall be such that the useful range of air kerma obtainable from each source at the point of test (by alteration of the distance between the source and the detector of the assembly) overlaps the useful range of air kerma obtainable from at least one of the other sources used. In this way, the air kerma from all sources used may be calibrated in terms of that from one particular source, which may be considered as the reference source.

b) *Tests to be performed*

A type test shall be carried out on at least one assembly of the series, and routine tests shall be performed on each assembly.

Type test

For assemblies with linear scales, the test shall be carried out on all the scales, and on at least three points on each of them, at approximately 30 %, 60 % and 90 % of the maximum value of each scale. For assemblies with a single scale, substantially logarithmic graduation, or with digital presentation, the test shall be performed for at least three values in each decade of air kerma. These shall be at approximately 20 %, 40 % and 80 % of each full decade reading.

Routine test

For assemblies with linear scales, the test shall be performed at a minimum of one point on each scale. One test point on each scale shall be between 50 % and 75 % of the maximum value for that scale.

For assemblies with a single scale, substantially logarithmic graduation, or digital presentation, the test shall be performed for one value in each decade of the air kerma measured.

c) *Method of calibration*

The gamma calibration of the assembly should be accomplished as follows:

- take the background reading K_{IB} of the assembly;
- expose the assembly to the reference gamma radiation source at a conventionally true air kerma of K_T and note the reading K_{IS};
- calculate the indicated value $K_I = K_{IS} - K_{IB}$;
- calculate the relative intrinsic error $I\,(\%) = \dfrac{K_I - K_T}{K_T} \times 100$.

It should be noted that this method of calibration is only applicable if the scattered radiation is less than 5 % (see clause 3.2). Where the scattered radiation is greater than 5 %, then these two measurements shall be replaced by one with the source present and the second with a 5 cm lead shadow shield whose shape is just sufficient to screen the detector from the direct radiation from the calibration source. The relative intrinsic error should then be calculated as above, using the readings of these two measurements.

Annex A gives more detailed information on calibration.

d) *Interpretation of the results*

For the purposes of this test, the conventionally true value of the air kerma at the point of test shall be known to within an uncertainty of ±10 %.

The requirements of 3.2.1.1 can be considered to be met if no single value of the relative intrinsic error exceeds ±25 %.

3.2.2 *Variation of response with radiation energy*

3.2.2.1 *Requirements*

The response, in the calibration direction, to incident radiation of energy between 50 keV and 1,5 MeV shall not differ by more than ±30 % from the response to the ^{137}Cs reference gamma radiation source.

For assemblies intended to be used for measuring air kerma in the vicinity of power reactors when 6 MeV gamma radiation from ^{16}N is present, the response to 6 MeV shall not differ by more than ±50 % from the response to the ^{137}Cs reference source.

The variation of response with radiation energy shall be issued with each assembly.

3.2.2.2 *Method of test*

The following energies selected from the list of reference radiations specified in ISO 4037 shall be used:

- filtered X-rays of 48 keV, 87 keV, 148 keV and 211 keV (see ISO 4037, amendment 1);

- gamma radiation from ^{241}Am (59,5 keV), ^{137}Cs (662 keV) and ^{60}Co (1,17 MeV and 1,33 MeV).

Where as required in 3.2.2.1, additional tests shall also be performed with 6 MeV gamma radiation (see ISO 4037, addendum 2), the results shall be expressed as the ratio of the indicated value to the conventionally true value of the air kerma for each radiation energy. In principle, it is desirable that this test be performed at the same air kerma for each radiation energy. In practice, this may not be possible, in which case the indicted air kerma at each radiation energy shall be corrected for the relative intrinsic error (interpolated if necessary) at that indicated air kerma for the reference gamma radiation source (see 3.2.1.2).

3.2.3 *Variation of response with angle of incidence*

This standard relates to detector assemblies with a wide angle of acceptance and having essentially circular symmetry in one plane, normally horizontal, in use. The standard recognizes the practical limitations of achieving a uniform sensitivity over 4 π. The following requirements are formulated for two possible detector configurations:

- configuration (a) where the orientation for calibration can be regarded as approximate to an axis of symmetry;
- configuration (b) where the orientation for calibration is normal to a direction that can be regarded as approximative to an axis of symmetry.

The manufacturers shall state the configuration used.

3.2.3.1 *Requirements*

Configuration (a)

The detector assembly shall be positioned with its direction of orientation, as specified by the manufacturers, along the axis of calibration.

1) The response of the assembly to radiation incident at angles to the calibration direction shall not vary by more than the following limits relative to the response in the calibration direction when the detector assembly is rotated about its reference point in a plane specified by the manufacturer but including the calibration direction:

for 662 keV	0° to ±120°	±20 %
for 59/60 keV	0° to ±90°	±30 %
	±90° to ±120°	±50 %

The manufacturer shall state the relative variation of the response beyond ±120°.

2) The assembly shall also be rotated in the plane perpendicular to the plane used in 1) above but still including the calibration direction. The variation in response relative to the response in the calibration direction shall be the same as 1) above.

3) The detector assembly shall also be rotated in the plane normal to the calibration direction, with the direction of radiation being in the plane of rotation, where the variation in response shall be not more than ±20 % for all angles for both 662 keV and 59/60 keV.

Configuration (b)

The detector assembly shall be positioned with its direction of orientation, as specified by the manufacturer, along the axis of calibration.

1) The response of the assembly relative to the response in the calibration direction to radiation incident at all angles to the calibration direction shall not vary more than ±20 % for both 662 keV and 59/60 keV when the detector assembly is rotated about its reference point in a plan specified by the manufacturer but including the calibration direction.

2) The response of the assembly to radiation incident, at angles to the calibration direction shall not vary by more than the following limits relative to the response in the calibration direction when the detector assembly is rotated about its reference point in

a plane perpendicular to the plane used in 1) above, but still including the calibration direction:

for 662 keV	0° to ±60°	±20 %
for 59/60 keV	0° to ±45°	±30 %
	±45° to ±60°	±50 %

The manufacturer shall state the relative variation of the response beyond ±60°.

3) The detector assembly shall also be rotated in the plane of rotation used in 2) above, but with the detector initially rotated through 90° in the plane of rotation used in 1) above. The variation in response in this plane shall be within limits given for 2) above.

3.2.3.2 *Method of test*

Mount the assembly so as to enable measurements to be made most conveniently at the required angles.

Configuration (a)

Expose the assembly in the calibration direction to the following reference radiations specified by ISO 4037 and determine the response to 60 keV X-radiation or 59,5 keV gamma radiation from ^{241}Am, and to 662 keV gamma radiation from ^{137}Cs.

1) The direction of radiation shall then be changed in steps of 15° in a plane including the calibration direction specified by the manufacturer and the response determined throughout the range of angles specified in 3.2.3.1 (a) 1) for the two radiations specified.

2) The procedure 1) above shall be repeated for the plane perpendicular to that used in 1) but still including the calibration direction.

3) The direction of the radiation shall also be changed every 45° in a plane normal to the calibration direction, 0° being in the plane of calibration direction, and the response determined for the two radiations specified.

Configuration (b)

Expose the assembly in the calibration direction to the following reference radiations specified by ISO 4037 and determine the response to 60 keV X-radiation or 59,5 keV gamma radiation from ^{241}Am and to 662 keV gamma radiation from ^{137}Cs.

1) The direction of radiation shall then be changed in steps of 45° in a plane including the calibration direction specified by the manufacturer and the response determined for the two radiations specified.

2) The direction of radiation shall then be changed in steps of 15° in a plane perpendicular to plane used in 1) above, but including the calibration direction and the response determined throughout the range of angles specified in 3.2.3.1 (b) 2) for the two radiations specified.

3) The procedure 2) above shall be repeated for the plane normal to the calibration direction, 0° being in the plane of the calibration direction.

3.2.4 *Retention of reading*

Assemblies designed to measure air kerma usually operate in one of the following ways:

a) The detector signal is integrated over a long period to provide the total air kerma over this measurement period, typically over one day, one week or one month or more. The measurement is either terminated automatically by an internal clock or it is terminated manually by the operator. The air kerma can be read visually or electronically by interfacing the assembly to a read-out system.

b) The detector signal is integrated over shorter periods which may be typically from 1 min up to 1 h. At the end of this shorter integration period, the integrated data is transferred to a buffer store and then to a storage device.

The assembly then re-sets itself to zero and continually repeats the cycle. The recorded data is then usually analysed by a centralized computer to provide more comprehensive data, such as the air kerma/average air kerma rate for each hour and the air kerma and average air kerma rate over a week or more.

For both operating methods it is important that the integrated signal should be accurately and precisely recorded. Where the display is to be visually read this should not drift or change significantly between the end of the integration period and the time at which it is read. The requirements for this are as follows.

3.2.4.1 *Requirements*

The reading at the automatic or manual termination of the integration period shall not change by more than ±2 % over the next hour.

3.2.4.2 *Method of test*

Expose the assembly to a source of radiation giving an air kerma corresponding to an indication between one-third and half the maximum value of each scale. When the integration period is complete, note the displayed reading.

Every 5 min up to 1 h from the end of the integration period, read the display. None of these 12 readings should differ by more than ±2 % compared to the initial reading.

3.2.5 *Response to other ionizing radiations*

Assemblies shall be designed so as to limit as far as practicable the influence of other ionizing radiations.

3.2.5.1 *Beta radiations*

a) *Requirements*

The design of the equipment shall be such that the response to beta radiation shall be less than 2 % up to an energy of 2,27 MeV. When the assembly is used for measuring the air kerma due to X and gamma radiation in the presence of beta radiation, the more energetic beta particles may penetrate into the sensitive volume of the detector. The minimum energy of beta particles that will penetrate into the sensitive volume of the detector shall be stated by the manufacturer as well as the response to $^{90}Sr/^{90}Y$.

b) *Method of test*

The response shall be measured to the beta radiation emitted by a $^{90}Sr/^{90}Y$ source (E_{max} = 2,27 MeV) in accordance with the recommendations of ISO 6980.

The response to beta radiation shall be quoted in terms of the air kerma indicated by the assembly per conventionally true absorbed beta dose in air or per absorbed dose in tissue, at the point of test.

3.2.5.2 *Neutron radiation or other ionizing radiation*

If the assembly is intended to be used in the presence of neutron radiation or other ionizing radiations, then the response to these radiations shall also be stated by the manufacturer if required by the purchaser.

A test for neutron response or to other ionizing radiations is not mandatory and need only be performed if this requirement is specified.

The method of test shall be subject to agreement between the manufacturer and the purchaser.

3.2.6 *Air kerma rate dependence*

3.2.6.1 *Requirements*

The response of the assembly should be such that its relative intrinsic error remains within the requirements of 3.2.1 for both:

a) all air kerma rates from 10 nGy h^{-1} to 10 mGy h^{-1} (1 µrad h^{-1} to 1 rad h^{-1}), and

b) a sudden change in the air kerma rate of approximately 10 mGy h^{-1} (1 rad h^{-1}).

3.2.6.2 *Method of test (type test only)*

a) The relative intrinsic error of an assembly shall not exceed ±15 % at 60 % of each dose scale maximum (linear scale) or 80 % of each decade (for logarithmic graduation or for digital presentation) when the assembly is exposed to a reference source at approximately the following air kerma rates: 1 µGy h^{-1}, 100 µGy h^{-1} and 10 mGy h^{-1} (100 µrad h^{-1}, 10 mrad h^{-1} and 1 rad h^{-1}).

b) Place the assembly in a background air kerma rate of less than 0,25 µGy h^{-1} (25 µrad h^{-1}).

Increasing the air kerma rate

For each of the assembly's integration times, at exactly half way through each integration time, expose the assembly at an air kerma rate of approximately 10 mGy h^{-1} (1 rad h^{-1}). Observe the reading at the end of the integration; this reading should be within ±15 % of the following air kerma: selected air kerma rate multiplied by half the selected integration time in hours.

Decreasing the air kerma rate

Expose the assembly to an air kerma rate of approximately 10 mGy h^{-1} (1 rad h^{-1}).

For each of the assembly's integration times, start the integration. At exactly half way through each selected integration time, remove the source and observe the reading at the end of each integration period. This reading should be within ±15 % of the following air kermas: selected air kerma rate multiplied by half the selected integration time in hours.

NOTE - For both tests in b), it may be necessary to reduce the exposure time to remain less than the maximum air kerma of the effective range of the assembly.

The reading, in this case, should be within ±15 % of the selected air kerma rate multiplied by the reduced exposure time in hours.

3.2.7 *Overload characteristics*

a) *Requirements*

For air kermas greater than that corresponding to the maximum value of the upper scale or decade, the indication of the assembly shall be off-scale at the higher end of the scale and shall remain so. For assemblies with more than one scale, this requirement shall apply to each scale.

b) *Method of test*

The assembly shall be submitted to an air kerma from a reference gamma radiation source of 10 times the maximum value of the scale for each scale.

The indication of the assembly shall remain off-scale at the higher end of the scale.

3.3 Electrical characteristics

3.3.1 *Zero drift*

This test is applicable to the assemblies fitted with a set zero adjustment available to the operator.

a) *Requirements*

After 30 min operation (under standard test conditions) the reading of the indicating meter that has been set to zero shall not differ, during the next 4 h, from zero by more than 2 % of the maximum value of each scale (analogue display).

For assemblies with a digital display the zero drift shall be stated by the manufacturer.

b) *Method of test*

Switch on the assembly and leave for a period of 30 min. The set zero adjustment shall then be adjusted to bring the indication to zero. For some assemblies with a non-linear scale, such a control is used to bring the indication to a reference point rather than to zero.

If this is the case, the control shall be set to bring the indication to the appropriate reference point. The assembly shall be left in this condition and the reading noted every 30 min for a further 4 h. The requirements of 3.3.1 a) shall be met.

3.3.2 *Warm-up time*

a) *Requirements*

The warm-up time shall be stated by the manufacturer.

b) *Method of test*

With the assembly switched off, expose the detection sub-assembly to a reference gamma radiation source that would provide an indication of at least half of the maximum value of the least sensitive scale. Switch on the assembly and note the readings of the assembly every 30 s up to 15 min after switching on.

Take sufficient readings 15 min after switching on and use the mean value of these as the "final value" of the indication. On the graph of the variation of indication as a function of time, draw a smooth curve that is the best fit to the observed indications. From the curve read the time corresponding to the indication that is within 10 % of this "final value". This time should be equal to or less than the warm-up time stated by the manufacturer.

3.3.3 *Power supplies*

3.3.3.1 *Battery operation*

a) *General*

Means shall be provided for checking the battery under conditions corresponding to maximum load.

Batteries may be arranged in any desired manner but preferably shall be individually replaceable. The correct polarity shall be clearly indicated on the assembly by the manufacturer.

b) *Primary batteries (non-rechargeable)*

When power is supplied by primary batteries, the capacity of these should be such that, after operation under standard test conditions for 40 h of intermittent use[1)] the indication of the assembly shall not differ by more than 10 % from that obtained after the initial 15 min stabilization time of operation.

When primary batteries are used, batteries R20 listed in IEC 86 shall be used.

[1)] 40 h intermittent use means 8 h of continuous use followed by 16 h with the assembly switched off, for five consecutive days.

c) *Secondary batteries (rechargeable)*

When power is supplied by secondary batteries, the capacity of these shall be such that after 12 h of continuous use, the indication of the assembly does not differ by more than 10 % from that obtained after the initial 15 min of operation.

If secondary batteries are used, it should be possible to recharge the batteries from the mains supply within 16 h. The use of a device which switches off the charger when the complete charge is obtained is recommended.

d) *Battery operation test*

New primary batteries or fully charged secondary batteries of the type indicated by the manufacturer shall be used for this test. Place the detector in a field of gamma radiation provided by the reference gamma radiation source at a position where the air kerma corresponds to approximately two-thirds of the maximum value on the least sensitive scale. Take sufficient readings (see 3.1.5). Leave the assembly continuously working in this radiation field for the period or periods given in 3.3.3.1 b) or 3.3.3.1 c), as appropriate. At the end of this time, again take sufficient readings and verify that this mean value does not differ from the original mean value by more than 10 %.

3.3.3.2 *Mains operation*

a) *Requirements*

Mains-operated assemblies shall be designed to operate from single-phase AC supply voltage in one of the following categories in accordance with IEC 293[1)].

- series I: 220 V;
- series II: 120 V and/or 240 V.

The assemby shall be capable of operating from mains with a supply voltage tolerance of +10 % and −12 %, and a supply frequency of 57 Hz to 61 Hz or 47 Hz to 51 Hz, according to the nominal frequency. The indication of dose shall not vary by more than ±10 % over those ranges of supply voltage and supply frequency.

b) *Method of test*

Place the detector in a field of gamma radiation provided by the reference gamma radiation source at a point where the air kerma measured over 5 min corresponds to approximately two-thirds of the maximum value on the most sensitive scale. With the supply voltage at its nominal value, take the mean of sufficient readings. Take sufficient readings with the supply voltage 10 % above the nominal value and sufficient readings with the supply voltage 12 % below the nominal value. The mean values shall not differ from that obtained with nominal voltage by more than ±10 %. The above test shall then be repeated at an air kerma corresponding to approximately two-thirds of maximum value of the least sensitive scale of the assembly.

[1)] IEC 293 makes reference to the third edition of IEC 38. Table 1 in that edition was, however, superseded by amendment 1 in which 220 V is no longer recommended for new systems; 230 V is recommended instead. IEC 293 may eventually be amended accordingly.

For assemblies with a logarithmic scale, this test shall be performed under the same conditions as above for two values of air kerma, corresponding to indications in the lowest and highest decade of air kerma respectively.

The above tests shall be repeated, but instead of changing the voltage the frequency shall be changed:

a) to 57 Hz and 61 Hz, and the readings at these frequencies shall not vary by more than ±10 % compared to the reading at 60 Hz.

b) à 47 Hz and 51 Hz, and the readings at these frequencies shall not vary by more than ±10 % compared to the reading at 50 Hz.

3.4 Mechanical characteristics

3.4.1 *Mechanical shocks*

Portable assemblies should be able to withstand, without affecting their performance, mechanical shocks from all directions involving an acceleration of 300 m s^{-2} for a time interval of 18 ms, the shape of the shock being semi-sinusoidal (see IEC 68-2-27). If the assembly is to be used in areas where earthquakes can occur then appropriate tests should be agreed between the purchaser and the manufacturer.

3.4.2 *Orientation of assembly (geotropism)*

a) *Requirements*

When exposed to the reference gamma radiation source in the calibration direction the indication of the assembly shall not vary by more than ±10 % from that indicated in the reference orientation of use for any orientation of the assembly.

The reference orientation shall be stated by the manufacturer.

b) *Method of test*

Although in principle it is desirable that this test be performed with the assembly in any orientation, in general only indicating meters are influenced by differences in orientation. The orientations tested may therefore either be confined to those that may be assumed by the meter with the assembly held in the hand and in which the reading scale would be visible to the operator or, alternatively, where the instrument is rotated about its detection axis and the reading recorded every 90°. This test shall be performed at an air kerma corresponding to approximately half the maximum value of the most sensitive scale or decade. During this test, the angle of incidence of radiation with respect to the assembly shall remain constant.

3.5 Environmental characteristics

3.5.1 *Ambient temperature*

a) *Requirements*

Over the ranges of temperature specified in table 3, the indication shall remain within the limits specified in that table.

b) *Method of test*

This test shall normally be carried out in a climatic box. It is not, in general, necessary to control the humidity of the air in the box unless the instrument is particularly sensitive to changes of humidity.

For this test, the assembly shall be exposed to a reference gamma radiation providing a sufficient indication under standard test conditions for the test to be carried out (see table 1).

The temperature shall be then maintained at each of its extreme values for at least 4 h, and the indication of the assembly measured during the last 30 min of this period. The limits of variation of indication shall be within the value given in table 3.

3.5.2 *Relative humidity*

a) *Requirements*

The variation in the indication due to the effect of relative humidity shall be within the limits in table 3.

b) *Method of test*

The test shall be carried out at a single temperature of 35 °C using a climatic box. For this test, the assembly shall be exposed to a reference gamma radiation providing a sufficient indication under standard test conditions for the test to be carried out.

The humidity shall then be maintained at each of its extreme values for at least 4 h and the indication of the assembly noted during the last 30 min of this period. The permitted variation of ±10 % in the indication, as specified in table 3, is additional to the permitted variations due to temperature alone.

3.5.3 *Atmospheric pressure*

The influence of atmospheric pressure is, in general, only significant for an unsealed detector using air as the detecting medium. In this case, the atmospheric pressure at which all tests are performed shall be stated, and the effects of variations in atmospheric pressure shall be stated by the manufacturer.

Representative tests at other atmospheric pressures shall be performed, if required.

3.5.4 *Sealing*

The manufacturer shall state the precautions that have been taken to prevent the ingress of moisture and describe the tests and results used to demonstrate the effectiveness of the sealing.

3.5.5 *External electromagnetic fields*

Unless special precautions are taken in the design of an assembly, it may be rendered inoperative or give incorrect indications of air kerma in the presence of external electromagnetic fields, particularly radio frequency fields.

a) *Requirements*

If the indication of an assembly is likely to be influenced by the presence of external electromagnetic fields, a warning to this effect shall be given by the manufacturer. If a manufacturer claims that an assembly is insensitive to electromagnetic fields, the range of frequencies and types of electromagnetic radiation in which the assembly has been tested shall be stated by the manufacturer, together with the maximum intensity used (see table 3).

b) *Method of test*

Owing to the great range of frequencies and types of electromagnetic radiation that may be encountered, the methods of test are not specified in this standard. They shall be subject to agreement between the manufacturer and the user. Particular care must be taken to detect any enhanced response at a particular frequency.

3.5.6 *External magnetic fields*

a) *Requirements*

If the indication of an assembly is likely to be influenced by the presence of external magnetic fields, a warning to this effect shall be given by the manufacturer and this shall also be stated in the instruction manual.

b) *Method of test*

This shall be subject to agreement between the manufacturer and the user.

3.5.7 *Storage*

All assemblies designed for use in temperate regions shall be designed to operate within the specification of this document following storage (or transport) without batteries, for a period of at least three months in the manufacturer's packaging at any temperature between −25 °C and +50 °C. In certain circumstances, more severe specifications may be required such as capability for withstanding air transport at low ambient pressure.

Section 4: Documentation

4.1 Documentation

4.1.1 *Type test report*

At the request of the purchaser, the manufacturer shall make available the report on the type tests performed to the requirements of this standard.

4.1.2 *Certificate*

A certificate shall be provided with each assembly with at least the following information in accordance with IEC 278:

- manufacturer's name or registered trade mark;
- type of the assembly and serial number;
- types of radiation the assembly is intended to measure;
- detector type;
- range limits for each measuring scale;
- reference point of the assembly, calibration direction and reference orientation relative to radiation sources;
- effective range of measurement and intrinsic error results;
- response as a function of radiation energy;
- response with angle of incidence;
- mass and dimensions of instrument;
- location and dimensions of the sensitive volume;
- materials of the wall surrounding the sensitive volume and surface mass of each of them (in mg cm^{-2});
- minimum energy of beta particles that will penetrate into the sensitive volume, the response to $^{90}Sr/^{90}Y$;
- power supply requirements;
- zero drift;
- results of temperature test (type test results).

4.2 Operation and maintenance manual

An operation and maintenance manual containing at least the following information in accordance with IEC 278:

- schematic electrical diagrams including spare parts list;
- operational details, maintenance and calibration procedures.

Table 1 – Reference conditions and standard test conditions

Influence quantities	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Reference gamma radiation source	^{137}Cs	^{137}Cs
Warm-up time	15 min	≥15 min
Ambient temperature	20 °C	18 °C to 22 °C (see note 1)
Relative humidity	65 %	50 % to 75 % (see note 1)
Atmospheric pressure	101,3 kPa	86 kPa to 106 kPa (see note 1)
Power supply voltage (see note 2)	Nominal power supply voltage	Nominal power supply voltage ±1 %
Power supply frequency (see note 2)	Nominal frequency	Nominal frequency ±1 %
Power supply waveforms (see note 2)	Sinusoidal	Sinusoidal with total harmonic distortion power less than 5 %
Gamma radiation back-ground	Air kerma rate of 0,1 $\mu Gy\ h^{-1}$ (10 $\mu rad\ h^{-1}$) or less, if practical	Less than air kerma rate of 0,25 $\mu Gy\ h^{-1}$ (25 $\mu rad\ h^{-1}$)
Angle of incidence of radiation	Calibration direction given by manufacturer	Direction given ±5°
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to the earth's magnetic field
Beta radiation background	Negligible	Negligible
Orientation of assembly (geotropism)	To be stated by the manufacturer	Stated orientation ±5 °
Assembly controls	Set up for normal operation	Set up for normal operation
Contamination by radioactive elements	Negligible	Negligible

NOTES

1 The values in the table are intended for test performed in temperate climates. In other climates the actual values of the quantities at the time of test shall be stated. Similarly, a lower limit of pressure of 70 kPa may be permitted at higher altitudes.

2 Only for installed assemblies which can also be operated from the mains.

Table 2 – Tests performed under standard test conditions

Characteristics under test	Requirements (subclause)	Method for test (subclause)
Retention of reading	3.2.4.1	3.2.4.2
Zero drift	3.3.1 a)	3.3.1 b)

Table 3 – Tests performed with variations of influence quantities

Characteristics under test or influence quantity	Range of value of influence quantity	Limits of variation of indication	Method of tests (subclause)
Relative intrinsic error	Effective range of measurement	±15 % 1) 3)	3.2.1.2 b) and c)
Radiation energy	50 keV to 1,5 MeV 6 MeV 2)	±30 % 3) ±50 % 3)	3.2.2.2 3.2.2.2
Angle of incidence (3.2.3.1)			
a1 and a2: for 662 keV	0° to ± 120°	±20 %	3.2.3.2
a1 and a2: for 59/60 keV	0° to ± 90°	±30 %	
a1 and a2: for 59/60 keV	±90° to ± 120°	±50 %	
for 662 keV and 59/60 keV	> ± 120°	Stated by manufacturer	
a3 for 662 keV and 59/60 keV	0° to ± 180°	±20 %	
b1 for 662 keV and 59/60 keV	0° to ± 180°	±20 %	3.2.3.2
b2 and b3: for 662 keV	0° to ± 60°	±20 %	
b2 and b3: for 59/60 keV	0° to ± 45°	±30 %	
b2 and b3: for 59/60 keV	±45° to ± 60°	±50 %	
b2 and b3: for 662 keV and 59/60 keV	> ± 60°	Stated by manufacturer	
Retention of reading	1 h	±2 %	3.2.4.2
Air kerma rate dependence	10 nGy h^{-1} to 10 mGy h^{-1}	≤ ± 15 %	3.2.6.2
Overload	Ten times maximum of range	More than full scale	3.2.7 b)
Other ionizing radiation:			
– beta	E_{max} = 2,27 MeV	< 2 %	3.2.5.1
– neutrons	To be stated by the manufacturer 6)	Response to be stated by manufacturer 6)	3.2.5.2
Warm-up time	To be stated by manufacturer	Less than or equal to manufacturer's time	3.3.2 b)

Table 3 – Tests performed with variations of influence quantities *(concluded)*

Characteristics under test or influence quantity	Range of values of influence quantity	Limits of variation of indication	Method of tests (subclauses)
Power supply voltage			
– primary batteries	After 40 h of intermittent use	±10 %[4]	3.3.3.1 b)
– secondary batteries	After 12 h of continuous use	±10 %[4]	3.3.3.1 c)
– A.C. mains (if applicable)	From 88 % to 110 % of nominal power supply voltage	±10 %[3]	3.3.3.2 b)
	From 57 Hz to 61 Hz or 47 Hz to 51 Hz	±10 %[3]	3.3.3.2 b)
Mechanical shocks	300 m s^{-2}	Operates within specifications	3.4.1
Orientation of assembly	Any	±10 %[3]	3.4.2 b)
Ambient temperature[5]	−10 °C to +40 °C −25 °C to +55 °C	±20 %[3] ±50 %[3]	3.5.1 b)
Relative humidity	40 % to 90 % at +35 °C	±10 %[3]	3.5.2 b)
Atmospheric pressure	[6]	[6]	3.5.3
Electromagnetic field of external origin	Stated by manufacturer[6]	Stated by manufacturer[6]	3.5.5 b)
Magnetic induction of external origin	Stated by manufacturer[6]	Stated by manufacturer[6]	3.5.6 b)

NOTES

1) This error is additional to the uncertainty associated with the determination of the conventionally true air kerma (see 3.2.1.2 d)).

2) This additional requirement is applicable only to assemblies used for measuring air kerma in the vicinity of power reactors when 6 MeV gamma radiation from ^{16}N is present.

3) Of the indication under standard test conditions.

4) Of the initial indication.

5) Assemblies intended for temperate climates. In hotter or colder climates other limits may be specified. For assemblies intended for operation at very low temperatures, means of heating the batteries may be provided.

6) No general specification. Range of values of influence quantities and limits of variation of indication to be specified, if required.

Annex A
(informative)

Calibration of air kerma integrating assemblies

The calibration of an assembly at environmental air kerma levels requires a detailed knowledge of the detector's response to the different components of the background. The cosmic radiation response and the internal background of each assembly should be determined[1].

The indication K_I, of an assembly that is irradiated by a calibration source may be represented by:

$$K_I = R_c K_c + R_e K_e + R_s K_s + R_i$$

where K_I is the instrument indication in appropriate units of charge, voltage, counts or meter indication in Gy h^{-1}. K_c and K_e are the air kerma from the cosmic and environmental gamma radiations in the calibration room, respectively. K_s is the conventionally true air kerma from the calibration source. R_c, R_e and R_s are the responses of the assembly to cosmic radiation, to the environmental gamma radiation and the gamma radiation from the calibration source, respectively. R_i is the contribution to the reading arising from any internal radioactive contamination or from the electronic noise of the instrument.

For many detectors, R_c, R_e and R_s are usually not equal and the factor, R_e depends on the photon energy, so that the value R_s, derived from a laboratory calibration with point sources or beams, will not be equal to R_e and cannot be directly used for field measurements. To determine R_c, R_e, R_s and R_i it is necessary to measure each response separately by elimination of the other three influence quantities:

a) By determining how R_s varies with energy (see 3.2.2) and weighting the appropriate R_s values by the environmental energy spectrum, a value of R_e applicable to the field use of the assembly can be calculated.

b) The response R_i due to the internal background of any instrument can be estimated, for example, by observing the instrument reading when it is taken to great depths below ground. At a depth of 600 m, cosmic radiation is effectively eliminated and by placing the detector within a 10 cm thick lead shield its response to the radiation from the local rocks can also be virtually eliminated.

For ionisation chambers, R_i can normally be considered as due to intrinsic alpha radioactivity in the chamber. It can be estimated by placing the chamber in a shielded low background facility and monitoring the electrometer output with a short time constant recorder.

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[1] BCRU, *A guide to the measurement of environmental gamma radiation*, J.A.B. Gibson, I.M.G. Thompson and F.W. Spiers, 1993.

Alpha pulses can be identified by large spikes produced in the recorder output. Periodic checks for leakage current and for insulator stresses should also be made. The unidirectional currents arising from stress within the insulator can be determined by making measurements with both positive and negative polarizing voltages.

The internal background of any instrument should not change significantly during its life because the radionuclide present have long half-lives. Nevertheless, occasional checks are advisable since the instrument may itself become contaminated from external sources.

c) The determination of the cosmic response, R_c can be made either experimentally or from a theoretical calculation of the interaction of the cosmic rays in the detector. The experimental measurement of the cosmic ray response can be made in a boat constructed from material of low radioactivity, on a freshwater lake or reservoir or at sea at about a quarter to half a mile from the land.

d) The X or gamma ray calibration of the instrument, R_s, may be accomplished as follows:

i) the background reading, K_{IB}, of the instrument is first taken before exposure to the calibration source;

ii) the assembly is then exposed to the source and the K_{IS} reading noted;

iii) $$R_s = \frac{K_{IS} - K_{IB}}{\text{conventionally true air kerma from source, } K_T}$$

This method will eliminate the response due to cosmic radiation, that due to the calibration laboratory background air kerma and that from the R_I contribution. It should be noted, however, that it is only applicable if the scattered radiation from the source is negligible. Where significant scattered radiation is present then these two measurements shall be replaced by one with the source present and a second with a 5 cm deep lead shadow shield whose shape is just sufficient to screen the detector from the direct radiation from the calibration source and which is placed between the detector and the source. Subtraction of the lead shield reading allows the response to the source primary radiation only to be determined.

List of references

See national foreword.

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