

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Medical electrical equipment – Dosimeters with ionization chambers as used in radiotherapy

Appareils électromédicaux – Dosimètres à chambres d'ionisation utilisés en radiothérapie



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CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope and object.....	9
1.1 Scope.....	9
1.2 Object	9
2 Normative references	9
3 Terms and definitions	10
4 General requirements	22
4.1 BASIC SAFETY and ESSENTIAL PERFORMANCE.....	22
4.2 Performance requirements	22
4.3 REFERENCE VALUES and STANDARD TEST VALUES.....	22
4.4 General test conditions and methods.....	23
4.4.1 STANDARD TEST CONDITIONS.....	23
4.4.2 Test of components	23
4.4.3 RATED or EFFECTIVE RANGE of dose (or KERMA) rates	23
4.4.4 UNCERTAINTY OF MEASUREMENT.....	24
4.4.5 Adjustments during test	24
4.4.6 Test conditions particular to CHAMBER ASSEMBLIES.....	24
4.4.7 Test conditions particular to MEASURING ASSEMBLIES.....	24
4.4.8 Test conditions particular to STABILITY CHECK DEVICES	25
4.4.9 Use of STABILITY CHECK DEVICES	25
4.5 Summary tables	25
4.6 Classification of equipment according to LIMITS OF VARIATION	32
4.6.1 FIELD-CLASS DOSIMETER.....	32
4.6.2 REFERENCE-CLASS DOSIMETER.....	32
4.6.3 SCANNING-CLASS DOSIMETER	32
5 CHAMBER ASSEMBLY performance requirements	33
5.1 General.....	33
5.2 General performance requirements for (RADIOTHERAPY) IONIZATION CHAMBERS.....	33
5.2.1 CHAMBER ASSEMBLY LEAKAGE CURRENT without IRRADIATION.....	33
5.2.2 Stability	33
5.2.3 STABILIZATION TIME	34
5.2.4 Post-irradiation leakage.....	34
5.2.5 RATED or EFFECTIVE RANGE of dose rate (continuous radiation).....	35
5.2.6 Maximum RATED dose per pulse (pulsed radiation)	36
5.2.7 RATED RANGE of field sizes.....	37
5.2.8 STRAY RADIATION	38
5.2.9 Guard/collector insulation	38
5.2.10 Cable microphony.....	39
5.2.11 Polarity of polarizing voltage effect	39
5.2.12 ELECTROMAGNETIC COMPATIBILITY	40
5.3 Performance requirements particular to SHELL CHAMBERS.....	40
5.3.1 Dependence on RADIATION QUALITY	40
5.3.2 RATED RANGE of field sizes.....	43
5.3.3 Chamber orientation	44
5.4 Performance requirements particular to PARALLEL-PLATE CHAMBERS	44

5.4.1	Dependence on RADIATION QUALITY	46
5.4.2	Chamber orientation	47
5.5	Performance requirements particular to VENTED CHAMBERS	47
5.5.1	Atmospheric pressure change	48
5.5.2	Temperature.....	48
5.5.3	Humidity	48
5.6	Performance requirements particular to SEALED CHAMBERS.....	49
5.6.1	Atmospheric pressure change	49
5.6.2	Temperature.....	49
6	MEASURING ASSEMBLY performance requirements	50
6.1	General	50
6.2	General performance requirements for RADIOTHERAPY DOSIMETERS	50
6.2.1	EFFECTIVE RANGES	50
6.2.2	RESOLUTION of the display or data output terminal	51
6.2.3	Repeatability	51
6.2.4	Long-term stability	51
6.2.5	STABILIZATION TIME	52
6.2.6	ELECTROMAGNETIC COMPATIBILITY	52
6.3	Performance requirements particular to dosimeters	53
6.3.1	ZERO DRIFT	53
6.3.2	ZERO SHIFT.....	54
6.3.3	NON-LINEARITY	55
6.3.4	Range changing	56
6.3.5	Dead time.....	57
6.3.6	Temperature.....	57
6.3.7	Humidity	57
6.3.8	STRAY RADIATION effect	58
6.3.9	Charge leakage	58
6.3.10	Dose rate dependence of dosimeters.....	59
6.4	Performance requirements particular to dose rate meters.....	60
6.4.1	ZERO DRIFT	60
6.4.2	ZERO SHIFT.....	61
6.4.3	NON-LINEARITY	61
6.4.4	Range changing	62
6.4.5	RESPONSE TIME	64
6.4.6	Temperature.....	65
6.4.7	Humidity	65
6.4.8	STRAY RADIATION effect	66
6.5	Performance requirements particular to battery-operated MEASURING ASSEMBLIES.....	66
6.6	Performance requirements particular to supply mains-operated MEASURING ASSEMBLIES.....	67
6.6.1	MAINS VOLTAGE – static	67
6.6.2	MAINS VOLTAGE – VARIATION during a measurement.....	67
7	STABILITY CHECK DEVICE performance requirements.....	68
7.1	General	68
7.2	General performance requirements for STABILITY CHECK DEVICES.....	68
7.2.1	Long-term stability.....	68
7.2.2	Repeatability	68

8	Constructional requirements as related to PERFORMANCE CHARACTERISTICS	69
8.1	Constructional requirements on CHAMBER ASSEMBLIES	69
8.2	Constructional requirements on MEASURING ASSEMBLIES	69
8.2.1	Adjustment of RESPONSE	69
8.2.2	Display device	69
8.2.3	Battery indication and compensation	70
8.2.4	Input current threshold	70
8.2.5	Automatic termination of measurement in the dose mode	70
8.3	Constructional requirements on STABILITY CHECK DEVICES	70
8.3.1	Output of the STABILITY CHECK DEVICES	70
8.3.2	Constructional requirements particular to a radioactive type STABILITY CHECK DEVICE	71
8.3.3	Constructional requirements particular to an overall STABILITY CHECK DEVICE	71
8.4	Constructional requirements on PHANTOMS and build-up caps	71
9	Marking	72
9.1	Marking required on CHAMBER ASSEMBLY	72
9.1.1	Information required in IEC 60601-1	72
9.1.2	Other information	73
9.1.3	Compliance check	73
9.2	Marking required on MEASURING ASSEMBLY	73
9.2.1	CHAMBER ASSEMBLY in contact with the PATIENT	73
9.2.2	CHAMBER ASSEMBLY not in contact with the PATIENT	73
9.2.3	Each MEASURING ASSEMBLY	73
9.2.4	MEASURING ASSEMBLY with a display scaled in dose	74
9.2.5	Multi-range MEASURING ASSEMBLY	74
9.2.6	MEASURING ASSEMBLY with more than one chamber	74
9.2.7	Graphical symbols	74
9.2.8	Compliance check	74
9.3	Marking required on STABILITY CHECK DEVICE	74
9.3.1	General	74
9.3.2	STABILITY CHECK DEVICE containing a RADIOACTIVE SOURCE	74
9.3.3	Device which contributes to protection against IONIZING RADIATION	74
9.3.4	Compliance check	74
9.4	Marking required on PHANTOM or build-up cap	75
10	ACCOMPANYING DOCUMENTS	75
10.1	ACCOMPANYING DOCUMENTS for CHAMBER ASSEMBLY	75
10.1.1	INSTRUCTIONS FOR USE of CHAMBER ASSEMBLY	75
10.1.2	Test sheet for CHAMBER ASSEMBLY	77
10.1.3	Calibration certificate for CHAMBER ASSEMBLY	77
10.2	ACCOMPANYING DOCUMENTS for MEASURING ASSEMBLY	78
10.2.1	INSTRUCTIONS FOR USE of MEASURING ASSEMBLY	78
10.2.2	Test sheet for MEASURING ASSEMBLY	80
10.2.3	Calibration certificate for MEASURING ASSEMBLY	80
10.3	ACCOMPANYING DOCUMENTS for STABILITY CHECK DEVICE	81
10.3.1	INSTRUCTIONS FOR USE of STABILITY CHECK DEVICE	81
10.3.2	Test sheet for STABILITY CHECK DEVICE	81
10.3.3	Measurement certificate for STABILITY CHECK DEVICE	81
10.4	ACCOMPANYING DOCUMENTS for PHANTOMS and build-up caps	

Annex A (informative) Values, error and UNCERTAINTY	84
Annex B (normative) Test equipment for cable microphony	85
Annex C (normative) UNCERTAINTY OF MEASUREMENT	86
Bibliography.....	95
Index of defined terms used in this standard	96
Figure 1 – Tolerance of depth in PHANTOM.....	72
Figure 2 – Tolerance of lateral position in PHANTOM	72
Figure A.1 – Graphical illustration of values, error and UNCERTAINTY	84
Figure B.1 – Test equipment for cable microphony.....	85
Figure C.1 – PROBABILITY DISTRIBUTIONS for the PERFORMANCE CHARACTERISTICS to be within the LIMITS OF VARIATION $\pm L$ and the expression of their VARIANCES in terms of L	88
Table 1 – REFERENCE CONDITIONS and STANDARD TEST CONDITIONS – CHAMBER ASSEMBLY	26
Table 2 – REFERENCE CONDITIONS and STANDARD TEST CONDITIONS – MEASURING ASSEMBLY	27
Table 3 – Limits of PERFORMANCE CHARACTERISTICS at STANDARD TEST CONDITIONS – CHAMBER ASSEMBLY	27
Table 4 – Limits of PERFORMANCE CHARACTERISTICS at STANDARD TEST CONDITIONS – MEASURING ASSEMBLY	28
Table 5 – LIMITS OF VARIATION of PERFORMANCE CHARACTERISTICS for effects of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS – CHAMBER ASSEMBLY.....	29
Table 6 – LIMITS OF VARIATION of PERFORMANCE CHARACTERISTICS for effects of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS – MEASURING ASSEMBLY.....	31
Table 7 – LIMITS OF VARIATION of PERFORMANCE CHARACTERISTICS for effects of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS – chamber and MEASURING ASSEMBLIES combined	32
Table C.1 – Estimate of COMBINED STANDARD UNCERTAINTY for performance of a hypothetical dosimeter	90
Table C.2 – A hypothetical example of the assessment of the UNCERTAINTIES on the output measurement of an X-ray set using a FIELD-CLASS DOSIMETER.....	94

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**MEDICAL ELECTRICAL EQUIPMENT –
DOSIMETERS WITH IONIZATION CHAMBERS
AS USED IN RADIOTHERAPY**

FOREWORD

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International Standard IEC 60731 has been prepared by subcommittee 62C: Equipment for radiotherapy, nuclear medicine and radiation dosimetry of IEC technical committee 62: Electrical equipment in medical practice.

This third edition cancels and replaces the second edition published in 1997 and its Amendment 1 (2002) and constitutes a technical revision. The technical modifications versus the second edition of this standard concerns performance requirements of RADIOTHERAPY DOSIMETERS intended for the measurement of ABSORBED DOSE TO WATER or AIR KERMA in heavy ion RADIATION FIELDS and SCANNING-CLASS DOSIMETERS normally used for relative dose distribution measurements with a SCANNING SYSTEM such as an automatic water PHANTOM.

The text of this standard is based on the following documents:

FDIS	Report on voting
62C/506/FDIS	62C/511/RVD

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

In this standard, the following print types are used:

- requirements, compliance with which can be tested, and definitions: in roman type;
- explanations, advice, general statements, exceptions and notes: in small roman type;
- *test specifications: in italic type;*
- terms used throughout this particular standard that have been listed in the Index of defined terms and defined in Clause 3, or in other standards: SMALL CAPITALS.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This International Standard is applicable to the performance of RADIOTHERAPY DOSIMETERS with IONIZATION CHAMBERS as used in RADIOTHERAPY.

The effectiveness of treatment of PATIENTS receiving RADIOTHERAPY depends on the accuracy of the dose of radiation received, as well as on the accuracy of their spatial distribution. An excessive dose can lead to excessive tissue damage, while an insufficient dose will not provide the therapeutic benefit sought. The equipment covered by this standard plays an essential part in achieving the required accuracy.

This standard is not concerned with the safety aspects of dosimeters. The relevant IEC standards covering safety depend upon the way in which the dosimeter is used:

- if it is used in the PATIENT environment, the requirements for safety applying to dosimeters with IONIZATION CHAMBERS as used in RADIOTHERAPY are contained in IEC 60601-1;
- if it is not used in the PATIENT environment, then the safety requirements for dosimeters with IONIZATION CHAMBERS as used in RADIOTHERAPY are contained in IEC 61010-1.

Dosimeters which comply with this standard should nevertheless be used in accordance with the relevant national or international dosimetry protocol (code of practice). In particular, measurements should be made to determine the ion collection efficiency and polarity effect of the chamber under the exact conditions of use.

MEDICAL ELECTRICAL EQUIPMENT – DOSIMETERS WITH IONIZATION CHAMBERS AS USED IN RADIOTHERAPY

1 Scope and object

1.1 Scope

This International Standard specifies the performance requirements of RADIOTHERAPY DOSIMETERS, intended for the measurement of ABSORBED DOSE TO WATER or AIR KERMA (and their rates and spatial distributions) in PHOTON, ELECTRON, proton or heavy ion RADIATION FIELDS as used in RADIOTHERAPY.

The DOSE MONITORING SYSTEMS incorporated in RADIOTHERAPY treatment machines are not covered by this standard, neither are the re-entrant IONIZATION CHAMBERS used for BRACHYTHERAPY source calibration and constancy check devices.

This standard is applicable to the following types of dosimeter:

- a) FIELD-CLASS DOSIMETERS normally used for
 - 1) the measurement of KERMA or dose in a RADIATION BEAM, either in air or in a PHANTOM;
 - 2) in vivo skin surface or intracavitary measurements of dose on PATIENTS.
- b) REFERENCE-CLASS DOSIMETERS normally used for the calibration of FIELD-CLASS DOSIMETERS;

NOTE REFERENCE-CLASS DOSIMETERS may be used as FIELD-CLASS DOSIMETERS.
- c) SCANNING-CLASS DOSIMETERS normally used for relative dose distribution measurements with a SCANNING SYSTEM such as an automatic water PHANTOM.

1.2 Object

The object of this standard is:

- to establish requirements for a satisfactory level of performance for RADIOTHERAPY DOSIMETERS;
- to standardize methods for the determination of compliance with this level of performance.

Three levels of performance are specified:

- a lower level of performance applying to FIELD-CLASS DOSIMETERS;
- a higher level of performance applying to REFERENCE-CLASS DOSIMETERS;
- a specific level of performance applying to SCANNING-CLASS DOSIMETERS.

2 Normative references

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

IEC 60417, *Graphical symbols for use on equipment*

IEC 60601-1:2005, *Medical electrical equipment – Part 1: General requirements for basic safety and essential performance*

IEC 60601-1-2:2007, *Medical electrical equipment – Part 1-2: General requirements for basic safety and essential performance – Collateral standard: Electromagnetic compatibility – Requirements and tests*

IEC 60601-1-3:2008, *Medical electrical equipment – Part 1-3: General requirements for basic safety and essential performance – Collateral Standard: Radiation protection in diagnostic X-ray equipment*

IEC 60601-2-8:2010, *Medical electrical equipment – Part 2-8: Particular requirements for the basic safety and essential performance of therapeutic X-ray equipment operating in the range 10 kV to 1 MV*

IEC/TR 60788:2004, *Medical electrical equipment – Glossary of defined terms*

IEC 60976:2007, *Medical electrical equipment – Medical electron accelerators – Functional performance characteristics*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

IEC 61187, *Electrical and electronic measuring equipment – Documentation*

IEC 61267:2005, *Medical diagnostic X-ray equipment – Radiation conditions for use in the determination of characteristics*

IEC 61676:2002, *Medical electrical equipment – Dosimetric instruments used for non-invasive measurement of X-ray tube voltage in diagnostic radiology*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99:2007, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

ISO 3534-1:2006, *Statistics – Vocabulary and symbols – Part 1: General statistical terms and terms used in probability*

3 Terms and definitions

For the purpose of this International Standard the terms and definitions listed in index of defined terms and the following apply.

NOTE The definitions given in this standard are generally in agreement with those in IEC TR 60788:2004 and ISO International vocabulary of basic and general terms in metrology, except that some definitions have been made more restricted. Any such special definitions should be regarded as applying only to this standard.

Any terms not defined in this standard have the meanings defined in the above publications or are assumed to be in general scientific usage.

Throughout this standard:

- if no material is specified, the term "ABSORBED DOSE" or "dose" means "ABSORBED DOSE TO WATER (in water)" and the term "KERMA" means "AIR KERMA (in air)";
- when the quantity "AIR KERMA (in air)" in units "Gy" is used, the quantity "EXPOSURE" in units "C/kg" is also allowable;

- the term “heavy ion” addresses the range of nuclides from 2-He to 18-Ar in accordance with IAEA Technical Report 398 [2]¹⁾.

3.1

RADIOTHERAPY DOSIMETER

equipment, consisting of a MEASURING ASSEMBLY and one or more CHAMBER ASSEMBLIES, for the measurement of AIR KERMA, ABSORBED DOSE, or their corresponding rates or spatial distributions, in PHOTON, ELECTRON, proton and heavy ion radiation as used in RADIOTHERAPY

NOTE A RADIOTHERAPY DOSIMETER may include the following components:

- one or more STABILITY CHECK DEVICES;
- one or more PHANTOMS or build-up caps.
- one or more extension cables;

3.1.1

CHAMBER ASSEMBLY

IONIZATION CHAMBER and all other parts to which the chamber is permanently attached, except the MEASURING ASSEMBLY

NOTE It includes the electrical fitting and any permanently attached cable.

3.1.1.1

IONIZATION CHAMBER

IONIZING RADIATION detector consisting of a chamber filled with air, in which an electric field insufficient to produce gas multiplication, is provided for the collection at the electrodes of charges associated with the ions and the ELECTRONS produced in the measuring volume of the detector by IONIZING RADIATION

NOTE 1 For this standard, the IONIZATION CHAMBER is considered to consist of the measuring volume, the collecting electrode, the guard electrode (if any), the outer electrode (which consists of the chamber wall and possibly a conducting coating), those parts of the insulator adjacent to the measuring volume, the build-up cap and water-proof housing (if any).

NOTE 2 There are several categories of IONIZATION CHAMBER (see 3.1.1.1.1 to 3.1.1.1.7).

3.1.1.1.1

SHELL CHAMBER

IONIZATION CHAMBER with a measuring volume of between 0,1 cm³ and 1,0 cm³ bounded by a rigid outer electrode mounted on a supporting stem

NOTE 1 The measuring volume is usually symmetrical about the axis of the stem and the chamber is intended to be used with the axis of symmetry perpendicular to the axis of the RADIATION BEAM.

NOTE 2 There are two types of SHELL CHAMBER: THIMBLE CHAMBER and SPHERICAL CHAMBER (see 3.1.1.1.1.1 and 3.1.1.1.1.2).

3.1.1.1.1.1

THIMBLE CHAMBER

SHELL CHAMBER whose outer electrode takes the form of a rigid cylindrical wall closed at one end and mounted at the other on the supporting stem

3.1.1.1.1.2

SPHERICAL CHAMBER

SHELL CHAMBER whose outer electrode takes the form of a rigid spherical wall mounted on the supporting stem

1) Figures in square brackets refer to the Bibliography.

3.1.1.1.2

PARALLEL-PLATE CHAMBER

IONIZATION CHAMBER with a measuring volume of between approximately 0,01 cm³ and 0,5 cm³ bounded by parallel electrodes

NOTE The chamber is intended to be used with the electrodes perpendicular to the axis of the RADIATION BEAM.

3.1.1.1.3

VENTED CHAMBER

IONIZATION CHAMBER constructed in such a way as to allow the air inside the measuring volume to communicate freely with the atmosphere such that corrections to the RESPONSE for changes in air density need to be made

3.1.1.1.4

SEALED CHAMBER

IONIZATION CHAMBER constructed in such a way as to restrict the pathway between the air inside the measuring volume and the atmosphere sufficiently to ensure that the RESPONSE of the chamber is independent of changes in ambient conditions over a period of time stated by the MANUFACTURER

3.1.1.1.5

UNGUARDED IONIZATION CHAMBER

IONIZATION CHAMBER in which the guard conductor in the cable surrounding the centre (signal) conductor terminates in the cable and does not extend into the stem or body of the CHAMBER ASSEMBLY

3.1.1.1.6

PARTIALLY GUARDED IONIZATION CHAMBER

IONIZATION CHAMBER in which the guard conductor in the cable surrounding the centre (signal) conductor extends well into the stem or body of the CHAMBER ASSEMBLY but does not enter the air in the chamber

3.1.1.1.7

GUARDED IONIZATION CHAMBER

IONIZATION CHAMBER in which the guard conductor in the stem or body of the CHAMBER ASSEMBLY is continuous with a guard electrode that is in contact with the air inside the chamber

3.1.2

MEASURING ASSEMBLY

device to measure the charge (or current) from the IONIZATION CHAMBER and convert it into a form suitable for displaying the values of dose or KERMA or their corresponding rates

3.1.3

STABILITY CHECK DEVICE

device which enables the stability of RESPONSE of the MEASURING ASSEMBLY and/or CHAMBER ASSEMBLY to be checked

NOTE The STABILITY CHECK DEVICE may be a purely electrical device, or a RADIATION SOURCE, or it may include both.

3.2

INDICATED VALUE

value of a quantity derived from the reading of an instrument together with any scale factors indicated on the CONTROL PANEL of the instrument

NOTE The INDICATED VALUE is equivalent to the "uncorrected observations" shown in Figure A.1.

3.3

TRUE VALUE

value of the physical quantity to be measured by an instrument

NOTE The TRUE VALUE is equivalent to the "value of MEASURAND" shown in Figure A.1.

3.4

CONVENTIONAL TRUE VALUE

value used instead of the TRUE VALUE when calibrating or determining the performance of an instrument, since in practice the TRUE VALUE is unknown and unknowable

NOTE 1 The CONVENTIONAL TRUE VALUE will usually be the value determined by the WORKING STANDARD with which the instrument under test is being compared.

NOTE 2 The possible bounds within which the CONVENTIONAL TRUE VALUE will lie are equivalent to the "values of MEASURAND due to incomplete definition" shown in Figure A.1.

3.4.1

STANDARD

<metrology> instrument which defines, represents physically, maintains or reproduces the unit of measurement of a quantity (or a multiple or submultiple of that unit) in order to transfer it to other instruments by comparison

3.4.1.1

NATIONAL STANDARD

<metrology> STANDARD recognized by an official national decision as the basis for fixing the values and UNCERTAINTIES in that country of all other STANDARDS of the given quantity

3.4.1.2

WORKING STANDARD

<metrology> STANDARD which is traceable to the NATIONAL STANDARD

3.5

MEASURED VALUE

best estimate of the TRUE VALUE of a quantity, being derived from the INDICATED VALUE of an instrument together with the application of all relevant CORRECTION FACTORS and the CALIBRATION FACTOR

NOTE The MEASURED VALUE is the "final result of measurement" shown in Figure A.1.

3.5.1

ERROR OF MEASUREMENT

difference remaining between the MEASURED VALUE of a quantity and the TRUE VALUE of that quantity

3.5.2

OVERALL UNCERTAINTY

UNCERTAINTY associated with the MEASURED VALUE

NOTE 1 I.e. it represents the bounds within which the ERROR OF MEASUREMENT is estimated to lie.

NOTE 2 For the purpose of this standard the OVERALL UNCERTAINTY may be taken as the EXPANDED UNCERTAINTY corresponding to a confidence level of 95 % (see Annex A).

3.5.3

EXPANDED UNCERTAINTY

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the MEASURAND

3.6

CORRECTION FACTOR

dimensionless multiplier which corrects the INDICATED VALUE of an instrument from its value when operated under particular conditions to its value when operated under stated REFERENCE CONDITIONS

3.7

INFLUENCE QUANTITY

any external quantity that may affect the performance of an instrument

NOTE See Table 5, Table 6 and Table 7 for examples of INFLUENCE QUANTITIES.

3.8

INSTRUMENT PARAMETER

any internal property of an instrument that may affect the performance of this instrument

NOTE See Table 5, Table 6 and Table 7 for examples of INSTRUMENT PARAMETERS.

3.9

REFERENCE VALUE

particular value of an INFLUENCE QUANTITY or INSTRUMENT PARAMETER chosen for the purposes of reference

NOTE I.e. the value of an INFLUENCE QUANTITY (or INSTRUMENT PARAMETER) at which the CORRECTION FACTOR for dependence on that INFLUENCE QUANTITY (or INSTRUMENT PARAMETER) is unity.

3.9.1

REFERENCE CONDITIONS

conditions under which all INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS have their REFERENCE VALUES

3.10

STANDARD TEST VALUES

value, values, or range of values of an INFLUENCE QUANTITY or INSTRUMENT PARAMETER, which are permitted when carrying out calibrations or tests on another INFLUENCE QUANTITY or INSTRUMENT PARAMETER

3.10.1

STANDARD TEST CONDITIONS

conditions under which all INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS have their STANDARD TEST VALUES

3.11

PERFORMANCE CHARACTERISTIC

one of the quantities used to define the performance of an instrument

NOTE E.g. RESPONSE or LEAKAGE CURRENT.

3.11.1

RESPONSE

<CHAMBER ASSEMBLY with MEASURING ASSEMBLY> quotient of the INDICATED VALUE divided by the CONVENTIONAL TRUE VALUE at the position of the REFERENCE POINT of the IONIZATION CHAMBER

<MEASURING ASSEMBLY> quotient of the INDICATED VALUE divided by the input charge or current

<IONIZATION CHAMBER> quotient of the ionization charge or current divided by the CONVENTIONAL TRUE VALUE

3.11.1.1**SPECIFIED ENERGY RESPONSE**

RESPONSE of an IONIZATION CHAMBER calculated or measured for that type of chamber as a function of RADIATION QUALITY

3.11.2**RESOLUTION**

<digital display> smallest change of reading to which a numerical value can be assigned without further interpolation

<analogue display> smallest fraction of a scale interval that can be determined by an observer under specified conditions

<digital display> smallest significant increment of the reading

3.11.3**EQUILIBRATION TIME**

time taken for a reading to reach and remain within a specified deviation from its final steady value after a sudden change in an INFLUENCE QUANTITY has been applied to the instrument

3.11.4**RESPONSE TIME**

time taken for a reading to reach and remain within a specified deviation from its final steady value after a sudden change in the quantity being measured

3.11.5**STABILIZATION TIME**

time taken for a stated PERFORMANCE CHARACTERISTIC to reach and remain within a specified deviation from its final steady value after the MEASURING ASSEMBLY has been switched on and the polarizing voltage has been applied to the IONIZATION CHAMBER

3.11.6**CHAMBER ASSEMBLY LEAKAGE CURRENT**

leakage current

any current in the signal path arising in the CHAMBER ASSEMBLY which is not produced by ionization in the measuring volume

NOTE It is distinguished from ZERO DRIFT or ZERO SHIFT which arise in the MEASURING ASSEMBLY.

3.11.7**MEASURING ASSEMBLY ZERO DRIFT**

zero drift

continuous change in the near zero reading of the MEASURING ASSEMBLY in the "measure" condition with no signal present

3.11.8**MEASURING ASSEMBLY ZERO SHIFT**

zero shift

sudden change in the near zero reading of the MEASURING ASSEMBLY when the setting control is changed from the "zero" condition to the "measure" condition, with no signal present

3.11.9**NON-LINEARITY**

deviation from linearity

NOTE Quantified as follows: on each range the half full reading M is taken as a reference; the input signal Q required to produce this REFERENCE SCALE READING is measured. At another reading m produced by an input signal q , the percentage deviation from linearity is given by:

$$100 \cdot ((m \cdot Q / M \cdot q) - 1)$$

For a MEASURING ASSEMBLY set to the "dose" mode, the input signal is electric charge; for a MEASURING ASSEMBLY set to the "dose rate" mode, the input signal is electric current.

3.12

VARIATION

relative difference, $\Delta y/y$, between the values of a PERFORMANCE CHARACTERISTIC y , when one INFLUENCE QUANTITY (or INSTRUMENT PARAMETER) assumes successively two specified values, the other INFLUENCE QUANTITIES (and INSTRUMENT PARAMETERS) being kept constant at the STANDARD TEST VALUES (unless other values are specified)

3.13

LIMITS OF VARIATION

maximum permitted VARIATION of a PERFORMANCE CHARACTERISTIC

NOTE If LIMITS OF VARIATION are stated as $\pm L$ %, the VARIATION $\Delta y/y$, expressed as a percentage, shall remain in the range from $-L$ % to $+L$ %.

3.14

EFFECTIVE RANGE OF INDICATED VALUES

EFFECTIVE RANGE

range of INDICATED VALUES for which an instrument complies with a stated performance

NOTE 1 The maximum (minimum) effective INDICATED VALUE is the highest (lowest) in this range.

NOTE 2 The concept of EFFECTIVE RANGE may, for example, also be applied to readings and to related quantities not directly indicated by the instrument e.g. input current.

3.15

RATED RANGE OF USE

RATED RANGE

range of values of an INFLUENCE QUANTITY or INSTRUMENT PARAMETER within which the instrument will operate within the LIMITS OF VARIATION

NOTE Its limits are the maximum and minimum RATED VALUES.

3.15.1

MINIMUM RATED RANGE

least range of an INFLUENCE QUANTITY or INSTRUMENT PARAMETER over which the instrument shall operate within the specified LIMITS OF VARIATION

3.16

REFERENCE POINT OF THE CHAMBER

REFERENCE POINT

point of an IONIZATION CHAMBER, which during the calibration of the chamber, is brought to coincidence with the point at which the CONVENTIONAL TRUE VALUE is specified

3.17

MEDICAL ELECTRICAL EQUIPMENT

ME EQUIPMENT

electrical equipment having an APPLIED PART or transferring energy to or from the PATIENT or detecting such energy transfer to or from the PATIENT and which is:

- a) provided with not more than one connection to a particular SUPPLY MAINS; and
- b) intended by its MANUFACTURER to be used:
 - 1) in the diagnosis, treatment, or monitoring of a PATIENT; or
 - 2) for compensation or alleviation of disease, injury or disability

[IEC 60601-1:2005, 3.63]

3.18**SUPPLY MAINS**

source of electrical energy not forming part of ME EQUIPMENT or ME SYSTEM

[IEC 60601-1:2005, 3.120]

3.19**PATIENT**

living being (person or animal) undergoing a medical, surgical or dental procedure

[IEC 60601-1:2005, 3.76]

3.20**TOOL**

extra-corporeal object that can be used to secure or release fasteners or to make adjustments

[IEC 60601-1:2005, 3.127]

3.21**CALIBRATION FACTOR**

<CHAMBER ASSEMBLY with an associated MEASURING ASSEMBLY> factor which converts the INDICATED VALUE, corrected to stated REFERENCE CONDITIONS, to the CONVENTIONAL TRUE VALUE at the position of the REFERENCE POINT of the IONIZATION CHAMBER

<IONIZATION CHAMBER calibrated on its own without a specified MEASURING ASSEMBLY> factor which converts the ionization charge or current, corrected to REFERENCE CONDITIONS, to the CONVENTIONAL TRUE VALUE at the position of the REFERENCE POINT OF THE CHAMBER

NOTE This is the reciprocal of RESPONSE under REFERENCE CONDITIONS.

3.22**REFERENCE INDICATED VALUE**

INDICATED VALUE at which the CALIBRATION FACTOR of an instrument is determined

3.23**REFERENCE SCALE READING**

reading corresponding to the REFERENCE INDICATED VALUE

3.24**FIELD-CLASS DOSIMETER**

dosimeter whose performance and stability are sufficient for it to be used to make ordinary routine measurements

3.25**REFERENCE-CLASS DOSIMETER**

dosimeter whose performance and stability are sufficient for it to be used to calibrate other dosimeters

3.26**SCANNING-CLASS DOSIMETER**

dosimeter whose performance and stability are sufficient for it to be used to measure relative dose distributions in connection with a SCANNING SYSTEM

3.27**SCANNING SYSTEM**

apparatus to displace an IONIZATION CHAMBER in order to measure the spatial dose or dose rate distribution of a RADIATION BEAM

3.28

TYPE TEST

test on a representative sample of the equipment with the objective of determining if the equipment, as designed and manufactured, can meet the requirements of this standard

[IEC 60601-1:2005, 3.135]

NOTE The purpose of the TYPE TEST is to verify whether or not the design of the instrument renders it capable of meeting the requirements of the specification.

3.29

ROUTINE TEST

test carried out on all instruments of a production or delivery batch

3.30

ABSORBED DOSE TO WATER

D

quotient of $d\bar{\varepsilon}$ by dm where $d\bar{\varepsilon}$ is the mean energy imparted by IONIZING RADIATION to water of mass dm

NOTE 1 The unit of ABSORBED DOSE TO WATER is Gy (where $1 \text{ Gy} = 1 \text{ J}\cdot\text{kg}^{-1}$).

NOTE 2 This definition is derived from the definition in C.4 of ICRU 33 [1]²⁾.

3.30.1

ABSORBED DOSE RATE TO WATER

$\dot{D}$

quotient of dD by dt , where dD is the increment of ABSORBED DOSE TO WATER in the time interval dt

NOTE 1 The unit of ABSORBED DOSE RATE TO WATER is $\text{Gy}\cdot\text{s}^{-1}$ ($\text{Gy}\cdot\text{min}^{-1}$; $\text{Gy}\cdot\text{h}^{-1}$).

NOTE 2 This definition is derived from the definition in C.5 of ICRU 33 [1].

3.31

AIR KERMA

K

quotient of dE_{tr} by dm where dE_{tr} is the sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged ionizing particles in air of mass dm

NOTE 1 The unit of AIR KERMA is Gy (where $1 \text{ Gy} = 1 \text{ J}\cdot\text{kg}^{-1}$).

NOTE 2 This definition is derived from the definition in C.6 of ICRU 33 [1].

3.31.1

AIR KERMA RATE

$\dot{K}$

quotient of dK by dt , where dK is the increment of AIR KERMA in the time interval dt

NOTE 1 The unit of AIR KERMA RATE is $\text{Gy}\cdot\text{s}^{-1}$ ($\text{Gy}\cdot\text{min}^{-1}$; $\text{Gy}\cdot\text{h}^{-1}$).

NOTE 2 This definition is derived from the definition in C.7 of ICRU 33 [1].

3.32

EXPOSURE

X

quotient of dQ by dm where dQ is the absolute value of the total charge of the ions of one sign produced in air when all the ELECTRONS (negatrons and positrons) liberated by PHOTONS in air of mass dm are completely stopped in air

²⁾ Numbers in square brackets refer to the Bibliography.

NOTE 1 The unit of EXPOSURE is $C \cdot kg^{-1}$.

NOTE 2 This definition is derived from the definition in C.8 of ICRU 33 [1].

3.32.1

EXPOSURE RATE

$\dot{X}$
quotient of dX by dt , where dX is the increment of EXPOSURE in the time interval dt

NOTE 1 The unit of EXPOSURE RATE is $C \cdot kg^{-1} \cdot s^{-1}$ ($C \cdot kg^{-1} \cdot min^{-1}$; $C \cdot kg^{-1} \cdot h^{-1}$).

NOTE 2 This definition is derived from the definition in C.9 of ICRU 33 [1].

3.33

ACCOMPANYING DOCUMENT

document accompanying ME EQUIPMENT, an ME SYSTEM, equipment or an ACCESSORY and containing information for the RESPONSIBLE ORGANIZATION or OPERATOR, particularly regarding BASIC SAFETY and ESSENTIAL PERFORMANCE

[IEC 60601-1:2005, 3.4]

3.34

INSTRUCTIONS FOR USE

those parts of ACCOMPANYING DOCUMENTS giving the necessary information for safe and proper use and operation of the equipment

[IEC TR 60788:2004, rm-82-02]

3.35

RESPONSIBLE ORGANIZATION

entity accountable for the use and maintenance of an ME EQUIPMENT or an ME SYSTEM

[IEC 60601-1:2005, 3.101]

3.36

OPERATOR

person handling equipment

[IEC 60601-1:2005, 3.73]

3.37

MANUFACTURER

natural or legal person with responsibility for the design, manufacture, packaging, or labelling of ME EQUIPMENT, assembling an ME SYSTEM, or adapting ME EQUIPMENT or an ME SYSTEM, regardless of whether these operations are performed by that person or on that person's behalf by a third party

[IEC 60601-1:2005, 3.55]

3.38

COVARIANCE

COVARIANCE of two RANDOM VARIABLES is a measure of their mutual dependence. The COVARIANCE of RANDOM VARIABLES y and z is defined by

$$\text{cov}(y,z) = \text{cov}(z,y) = E \{ [y - E(y)][z - E(z)] \}$$

which leads to

$$\text{cov}(y,z) = \text{cov}(z,y)$$

$$= \iint (y - \mu_y)(z - \mu_z) p(y,z) dy dz$$

$$= \iint y z p(y,z) dy dz - \mu_y \mu_z$$

where $p(y,z)$ is the joint PROBABILITY DENSITY FUNCTION of two variables y and z . The COVARIANCE $\text{cov}(y,z)$ [also denoted by $v(y,z)$] may be estimated by $s(y_i, z_i)$ obtained from n independent pairs of simultaneous observations y_i and z_i of y and z ,

$$s(y_i, z_i) = \frac{1}{n-1} \sum_{i=1}^n (y_i - \bar{y})(z_i - \bar{z})$$

$$\text{where } \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \text{ and } \bar{z} = \frac{1}{n} \sum_{i=1}^n z_i$$

NOTE The estimated COVARIANCE of the two means $\bar{y}$ and $\bar{z}$ is given by $s(\bar{y}, \bar{z}) = s(y_i, z_i)/n$.

[ISO/IEC GUIDE 98-3:2007, definition C.3.4]

3.39

COMBINED STANDARD UNCERTAINTY

STANDARD UNCERTAINTY of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the VARIANCES or COVARIANCES of these other quantities weighted according to how the measurement result varies with changes in these quantities

[ISO/IEC GUIDE 98-3:2007, 2.3.4]

3.40

COVERAGE FACTOR

numerical factor used as a multiplier of the COMBINED STANDARD UNCERTAINTY in order to obtain an EXPANDED UNCERTAINTY

[ISO/IEC GUIDE 98-3:2007, 2.3.6]

3.41

DEGREES OF FREEDOM

number of terms in a sum minus the number of constraints on the terms of the sum

[ISO 3534-1:2006, 2.54]

3.42

DISTRIBUTION FUNCTION OF A RANDOM VARIABLE X

DISTRIBUTION FUNCTION

$F(x)$

function of x giving the probability of the EVENT $(-\infty, x)$

[ISO 3534-1:2006, 2.7]

3.43

PROBABILITY DISTRIBUTION

PROBABILITY MEASURE induced by a RANDOM VARIABLE

NOTE The probability on the whole set of values of the RANDOM VARIABLE equals 1.

[ISO 3534-1:2006, 2.11]

3.44**PROBABILITY DENSITY FUNCTION** $f(x)$

non-negative function which when integrated from $-\infty$ to x gives the DISTRIBUTION FUNCTION evaluated at x of a CONTINUOUS DISTRIBUTION

NOTE $f(x)dx$ is the "probability element" , $f(x)dx = P_r(x < X < x+dx)$.

[ISO 3534-1:2006, 2.26]

3.45**RANDOM VARIABLE**

function defined on a SAMPLE SPACE where the values of the function are ordered k -tuplets of real numbers

[ISO 3534-1:2006, 2.10]

NOTE 1 A RANDOM VARIABLE that may take only isolated values is said to be "discrete". A RANDOM VARIABLE that may take on any value within a finite or infinite interval is said to be "continuous".

NOTE 2 The PROBABILITY OF AN EVENT A is denoted, by $P_r(A)$ or $P(A)$.

3.46**STANDARD DEVIATION** σ

positive square root of the VARIANCE

[ISO 3534-1:2006, 2.37]

NOTE Whereas a type A STANDARD UNCERTAINTY is obtained by taking the square root of the statistically evaluated VARIANCE, it is often more convenient to evaluate a non-statistical equivalent STANDARD DEVIATION first and then to obtain the equivalent VARIANCE by squaring the STANDARD DEVIATION.

3.47**STANDARD UNCERTAINTY**

UNCERTAINTY of the result of a measurement expressed as a STANDARD DEVIATION

[ISO/IEC GUIDE 98-3:2007, 2.3.1]

3.48**TYPE A EVALUATION OF STANDARD UNCERTAINTY**

TYPE A EVALUATION

method of evaluation of UNCERTAINTY by the statistical analysis of series of observations

[ISO/IEC GUIDE 98-3:2007, 2.3.2]

NOTE For convenience this is sometimes called the type A STANDARD UNCERTAINTY.

3.49**TYPE B EVALUATION OF STANDARD UNCERTAINTY**

TYPE B EVALUATION

method of evaluation of UNCERTAINTY by means other than the statistical analysis of series of observations

[ISO/IEC GUIDE 98-3:2007, 2.3.3]

NOTE For convenience this is sometimes called the type B STANDARD UNCERTAINTY.

3.50

MEASUREMENT UNCERTAINTY

UNCERTAINTY OF MEASUREMENT

UNCERTAINTY

non-negative parameter characterizing the dispersion of the QUANTITY VALUES being attributed to a MEASURAND, based on the information used

[ISO/IEC GUIDE 99:2007, 2.26]

3.51

VARIANCE

V

MOMENT OF ORDER r where r equals 2 in the CENTRED PROBABILITY DISTRIBUTION of the RANDOM VARIABLE

[ISO 3534-1:2006, 2.36]

4 General requirements

4.1 BASIC SAFETY and ESSENTIAL PERFORMANCE

During the IMMUNITY tests for ELECTROMAGNETIC COMPATIBILITY (see 6.2.6) BASIC SAFETY and ESSENTIAL PERFORMANCE shall be guaranteed.

ESSENTIAL PERFORMANCE is guaranteed if the limits listed in Table 7 are not exceeded during the IMMUNITY tests. ESSENTIAL PERFORMANCE is also ensured if during the IMMUNITY tests the reading of the MEASURING ASSEMBLY, or the data output, are clearly characterized as invalid, e.g. by means of a warning message or in case of a latch-up.

NOTE Examples of warning messages for invalid readings are high voltage error or overload messages.

4.2 Performance requirements

For a complete dosimeter to comply with this standard, each of its components shall comply with the individual requirements in the appropriate clauses or subclauses in addition to the general requirements. The MANUFACTURER shall state whether a TYPE TEST or a ROUTINE TEST was used for a particular parameter.

For equipment which does not fulfil all the requirements of this standard, information shall be provided about those clauses with which it does not comply.

The performance requirements to be met

- for the CHAMBER ASSEMBLY are given in Clause 5;
- for the MEASURING ASSEMBLY are given in Clause 6;
- for the STABILITY CHECK DEVICE are given in Clause 7.

4.3 REFERENCE VALUES and STANDARD TEST VALUES

The MANUFACTURER shall state, either in the INSTRUCTIONS FOR USE, or on the test sheets, the REFERENCE VALUE of each of the INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS as listed in Table 1 and Table 2.

For those INFLUENCE QUANTITIES that can be controlled,

- a) the REFERENCE VALUE shall be the value customarily used during the radiation calibration of the equipment;
- b) the STANDARD test value shall be the REFERENCE VALUE.

4.4 General test conditions and methods

4.4.1 STANDARD TEST CONDITIONS

The STANDARD TEST CONDITIONS, as defined by the STANDARD TEST VALUES listed in Table 1 and Table 2, shall be met during the test procedure, except

- a) for the INFLUENCE QUANTITY under investigation;
- b) where local conditions of temperature and relative humidity are outside the STANDARD TEST CONDITIONS. In this case, the tester shall justify the validity of the test results.

4.4.2 Test of components

The following requirements apply:

- a) The preferred procedure for verifying that the performance requirements are met is to test the components separately, in which case:
 - tests on the IONIZATION CHAMBER shall be performed using a "high-precision" MEASURING ASSEMBLY;
 - tests on the MEASURING ASSEMBLY shall be carried out using a "high-precision" current or charge source as required, connected to the input.

In this context, "high precision" means that the PERFORMANCE CHARACTERISTICS of the test equipment shall be such that they perturb the value of the particular PERFORMANCE CHARACTERISTIC being measured by less than one-quarter of the LIMITS OF VARIATION.

- b) Any tests may be carried out using the complete dosimeter, in particular this is the preferred method for investigating the effects of radio-frequency electromagnetic fields and ELECTROSTATIC DISCHARGES on a cable-connected IONIZATION CHAMBER supplied with a MEASURING ASSEMBLY as a system. Some tests performed with the whole system cannot give information as to whether the origin of a VARIATION lies in the CHAMBER ASSEMBLY or in the MEASURING ASSEMBLY (e.g. LEAKAGE CURRENT and ZERO DRIFT). If a complete system is tested and the relevant INFLUENCE QUANTITY affects both parts, the quadratic sum of the separate LIMITS OF VARIATION may be taken as an overall limit of VARIATION.
- c) When a CHAMBER ASSEMBLY and a MEASURING ASSEMBLY are tested separately, but supplied as a system, the two components shall be connected and the combined equipment shall have a measured overall RESPONSE within $\pm 0,5$ % of the overall RESPONSE calculated from the RESPONSES of the separate assemblies.

4.4.3 RATED or EFFECTIVE RANGE of dose (or KERMA) rates

NOTE 1 In the case of dose (or KERMA) measurements, the dose rate (or KERMA rate) can be regarded as an INFLUENCE QUANTITY. In this case, the term RATED RANGE of dose rate (or KERMA rate) is applicable.

NOTE 2 In the case of dose rate (or KERMA rate) measurements, this quantity is an INDICATED VALUE. In this case, the term EFFECTIVE RANGE of dose rate (or KERMA rate) is used.

The following requirements apply:

- a) When a CHAMBER ASSEMBLY is tested separately, the RATED or EFFECTIVE RANGE of dose (or KERMA) rates shall fulfil the appropriate requirements in Clause 5.
- b) When a MEASURING ASSEMBLY is tested separately, the equivalent parameter is determined as the RATED or EFFECTIVE RANGE of input currents and this shall fulfil the appropriate requirements in Clause 6.
- c) When however, by choice or necessity, the chamber and MEASURING ASSEMBLIES are tested together, the RATED or EFFECTIVE RANGE of dose (or KERMA) rates shall fulfil the relevant requirements in both Clauses 5 and 6.

4.4.4 UNCERTAINTY OF MEASUREMENT

When measurements of VARIATION are made to verify that equipment complies with specified LIMITS OF VARIATION, the OVERALL UNCERTAINTY of these measurements of VARIATION should be negligible compared with the specified LIMITS OF VARIATION.

If this is not possible, the OVERALL UNCERTAINTY of the measurement of VARIATION shall be taken into account in the evaluation of the equipment under test by adding the OVERALL UNCERTAINTY to the LIMITS OF VARIATION allowed.

If the OVERALL UNCERTAINTY exceeds one-fifth of the LIMITS OF VARIATION for any PERFORMANCE CHARACTERISTIC, then this shall be stated.

NOTE For the purpose of this STANDARD the OVERALL UNCERTAINTY may be taken as the EXPANDED UNCERTAINTY corresponding to a confidence level of 95 % (see Annex A).

4.4.5 Adjustments during test

Compliance tests shall be performed with the instrument ready for use (including ACCESSORIES if any), after the STABILIZATION TIME and after making preliminary adjustments as necessary. During tests, adjustments may be repeated at intervals as long as such an adjustment does not interfere with the effect to be verified. For example, the zero setting may be adjusted whenever necessary except during tests for measuring ZERO DRIFT and ZERO SHIFT.

4.4.6 Test conditions particular to CHAMBER ASSEMBLIES

When testing compliance with the performance requirements in Clause 5 (except for those in 5.2.1, 5.2.3 and 5.2.10) the polarizing voltage may be applied to the chamber for 1 h before taking a measurement.

4.4.7 Test conditions particular to MEASURING ASSEMBLIES

The following requirements apply:

- a) Tests on the effect of electromagnetic fields and ELECTROSTATIC DISCHARGES shall be made with the type of CHAMBER ASSEMBLY normally supplied connected to the input of the MEASURING ASSEMBLY.
- b) Tests on ZERO DRIFT and ZERO SHIFT shall be made with the input of the MEASURING ASSEMBLY disconnected and shielded with a conducting grounded (earthed) screen, for example a metal dust cap.
- c) Unless otherwise specified in the detailed instructions for testing, all other tests shall be made with a source of either electric charge or current connected to the input of the MEASURING ASSEMBLY as follows:
 - 1) measurements on dosimeters shall be made with a charge source connected to the input. This circuit shall be able to inject variable accurately known discrete amounts of charge to the input either
 - aa) by charging or discharging a capacitor through a resistor (to limit the peak current to less than the maximum RATED input current), or
 - bb) by applying a constant current for a known time (where this constant current is less than the maximum RATED input current).

The output of this charge source shall have been calibrated before use and be traceable to a NATIONAL STANDARD (either directly to a charge STANDARD or indirectly to voltage and capacitance STANDARDS or to voltage, resistance and time STANDARDS);

- 2) measurements on dose rate meters shall be made with a current source connected to the input. This circuit shall be able to inject variable accurately known constant currents to the input.

The output of this current source shall have been calibrated before use and be traceable to a NATIONAL STANDARD (either directly to a current STANDARD or indirectly to voltage and resistance STANDARDS).

NOTE 1 If tests are being made on a dosimeter/dose rate meter with signal/guard input terminals which are at the polarizing voltage away from ground (earth) then the output circuit of the charge or current source will need to be "floating";

NOTE 2 The output circuit of the charge source needs to have a sufficiently high impedance so as not to cause a measurable increase in ZERO DRIFT or charge leakage;

NOTE 3 The output circuit of the current source should not influence the measured current. Some electrometers have FET protecting input resistors which may influence the current from non-ionization chamber type current sources.

4.4.8 Test conditions particular to STABILITY CHECK DEVICES

When testing compliance with the performance requirements in Clause 7, the reference MEASURING ASSEMBLY used shall be either that type intended to be checked by the STABILITY CHECK DEVICE or another instrument of equivalent or superior performance.

Additionally, in the case of an overall STABILITY CHECK DEVICE the reference CHAMBER ASSEMBLY used shall be one of a type intended to be checked by the STABILITY CHECK DEVICE.

4.4.9 Use of STABILITY CHECK DEVICES

Wherever a test method suggests the use of a STABILITY CHECK DEVICE but a suitable STABILITY CHECK DEVICE is not available, then it is permissible to use an external caesium-137 or cobalt-60 GAMMA RADIATION beam together with a reliable method for positioning the IONIZATION CHAMBER in a reproducible field.

4.5 Summary tables

Table 1 and Table 2 summarize the reference and STANDARD TEST VALUES.

Table 3 and Table 4 summarize the performance requirements (for FIELD-CLASS DOSIMETERS) under STANDARD TEST CONDITIONS.

Table 5, Table 6 and Table 7 summarize the RATED RANGES of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS and the specified LIMITS OF VARIATION for FIELD-CLASS DOSIMETERS of the PERFORMANCE CHARACTERISTICS affected.

The tables do not give the complete detail which is given in Clauses 5 and 6.

Table 1 – REFERENCE CONDITIONS and STANDARD TEST CONDITIONS – CHAMBER ASSEMBLY

INFLUENCE QUANTITY OR INSTRUMENT PARAMETER	REFERENCE VALUES	STANDARD TEST VALUES
<u>ALL IONIZATION CHAMBERS</u>		
Field size	As at calibration	REFERENCE VALUE
Chamber orientation	As at calibration	REFERENCE VALUE
Source-chamber distance	As at calibration	REFERENCE VALUE
Depth of chamber in PHANTOM (g/cm ²)	As at calibration	REFERENCE VALUE
Source to PHANTOM distance	As at calibration	REFERENCE VALUE
Material of PHANTOM	As at calibration	Reference material
Temperature	+20 °C	+15 °C to +25 °C
Relative humidity	50 %	30 % to 75 %
Ambient pressure	101,3 kPa	Atmospheric pressure
External fields	Zero	So small as not to affect the reading
STRAY RADIATION in X-ray room	Zero	As small as possible
Dose rate	As at calibration	EFFECTIVE RANGE
Polarizing voltage	Stated by the MANUFACTURER	REFERENCE VALUE ±10 %
STABILIZATION TIME	1 h after switch-on	> 15 min after switch-on
<u>SHELL CHAMBERS</u>		
RADIATION QUALITY:		
– X-RADIATION in free air	1,8 mm Cu HVL	REFERENCE VALUE
– X- and γ -radiation in free air	⁶⁰ Co	REFERENCE VALUE
– X- and γ -radiation in PHANTOM	⁶⁰ Co	REFERENCE VALUE
– high-energy X- and γ -radiation	⁶⁰ Co	REFERENCE VALUE
– ELECTRONS	⁶⁰ Co or ELECTRONS as at calibration	REFERENCE VALUE
– protons	⁶⁰ Co	REFERENCE VALUE
– heavy ions	⁶⁰ Co	REFERENCE VALUE
<u>PARALLEL-PLATE CHAMBERS</u>		
RADIATION QUALITY:		
– X-RADIATION	0,36 mm Al HVL, tungsten anode	REFERENCE VALUE
– ELECTRONS	⁶⁰ Co or ELECTRONS as at calibration	REFERENCE VALUE
– protons	⁶⁰ Co	REFERENCE VALUE
– heavy ions	⁶⁰ Co	REFERENCE VALUE

Table 2 – REFERENCE CONDITIONS and STANDARD TEST CONDITIONS – MEASURING ASSEMBLY

INFLUENCE QUANTITY or INSTRUMENT PARAMETER	REFERENCE VALUES	STANDARD TEST VALUES
Temperature	+20 °C	+15 °C to +25 °C
Relative humidity	50 %	30 % to 75 %
STRAY RADIATION at MEASURING ASSEMBLY	Zero	< 7,5 µSv/h
Battery condition	New batteries	Within useful life
MAINS VOLTAGE	Nominal	Nominal ±1 %
Mains frequency	Nominal	Nominal ±1 Hz
Reading	As at calibration	REFERENCE SCALE READING
Range	As at calibration	Reference range
Input current	Stated by the MANUFACTURER	REFERENCE VALUE
Operating position	Stated by the MANUFACTURER	Reference position
STABILIZATION TIME	1 h after switch-on	> 15 min after switch-on

Table 3 – Limits of PERFORMANCE CHARACTERISTICS at STANDARD TEST CONDITIONS – CHAMBER ASSEMBLY

PERFORMANCE CHARACTERISTICS	Limits	Subclause
LEAKAGE CURRENT	±0,5 % ^a	5.2.1
Long-term stability	±1,0 % ^b	5.2.2.1
Accumulated dose stability	±1,0 % ^c	5.2.2.2
^a Of ionization current produced by minimum RATED or effective dose rate. ^b Of RESPONSE per year for cobalt-60 or caesium-137 GAMMA RADIATION. ^c Of RESPONSE per 10 ⁴ Gy for any RADIATION QUALITY in the RATED RANGE.		

Table 4 – Limits of PERFORMANCE CHARACTERISTICS at STANDARD TEST CONDITIONS – MEASURING ASSEMBLY

PERFORMANCE CHARACTERISTICS	Limits	Subclause
RESOLUTION	$\pm 0,5 \%$ ^a	6.2.2
Repeatability	$\pm 0,5 \%$ ^b	6.2.3
Long-term stability	$\pm 1,0 \%$ ^c	6.2.4
ZERO DRIFT – dosimeter	$\pm 1,0 \%$ ^d	6.3.1
ZERO DRIFT – dose rate meter	$\pm 1,0 \%$ ^e	6.4.1
ZERO SHIFT – dosimeter	$\pm 1,0 \%$ ^f	6.3.2
ZERO SHIFT – dose rate meter	$\pm 1,0 \%$ ^e	6.4.2
NON-LINEARITY – dosimeter	$\pm 0,5 \%$ ^g	6.3.3
NON-LINEARITY – dose rate meter	$\pm 1,0 \%$ ^g	6.4.3
RESPONSE TIME	< 3 s	6.4.5
^a Of minimum effective reading. ^b Relative STANDARD DEVIATION at minimum effective INDICATED VALUE. ^c Of RESPONSE per year to input charge or current in the RATED or EFFECTIVE RANGE. ^d Of rate of change of INDICATED VALUE produced by minimum RATED or effective input current. ^e Of the INDICATED VALUE produced by minimum RATED or effective input current. ^f Of minimum effective INDICATED VALUE. ^g Of RESPONSE at 0,5 full reading on each range.		

Table 5 – LIMITS OF VARIATION of PERFORMANCE CHARACTERISTICS for effects of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS – CHAMBER ASSEMBLY

INFLUENCE QUANTITY or INSTRUMENT PARAMETER	MINIMUM RATED RANGE	LIMITS OF VARIATION	Note	Sub-clause
<u>ALL IONIZATION CHAMBERS</u>				
STABILIZATION TIME	15 min to 2 h	±0,5 %	a	5.2.3
Post-irradiation leakage	5 s after IRRADIATION ^k	±1,0 %	b	5.2.4
Minimum dose rate	As specified by MANUFACTURER	±0,5 %	c	5.2.5.1
Maximum dose rate	As specified by MANUFACTURER	– 1,0 %	a	5.2.5.2
Maximum ABSORBED DOSE per pulse	As stated by MANUFACTURER	– 1,0 %	a	5.2.6
STRAY RADIATION effect	Specified conditions	±1,0 %	a	5.2.8
Guard/collector insulation	±1 V ^k	$\geq 1 \times 10^{11} \Omega$	–	5.2.9
Cable microphony	Specified conditions	±0,1 pA	–	5.2.10
Polarity of polarizing voltage	Maximum permitted positive and negative values	1,0 %	d	5.2.11
<u>SHELL CHAMBERS</u>				
RADIATION QUALITY:				
– X-RADIATION in free air	2 mm Al to 3 mm Cu HVL (70 kV to 250 kV or 30 keV to 140 keV)	±2,0 %	e, f	5.3.1.2
– X- and γ -radiation in free air	1,8 mm Cu HVL to ⁶⁰ Co (200 kV or 100 keV to 1,33 MeV)	±4,0 %	g, f	5.3.1.3
– X- and γ -radiation in <u>PHANTOM</u>	0,42 mm Cu HVL to ⁶⁰ Co (140 kV or 60 keV to 1,33 MeV)	±4,0 %, or ±2,0 %	g, f h, f	5.3.1.4
– high-energy X- and γ -radiation in <u>PHANTOM</u>	⁶⁰ Co to 25 MV	±2,0 %	h	5.3.1.5
– ELECTRONS in PHANTOM	9 MeV to 25 MeV	±2,0 %	h	5.3.1.6
– protons in PHANTOM	50 MeV to 250 MeV	±2,0 %	h	5.3.1.77
– heavy ions in PHANTOM	100 MeV/u to 450 MeV/u	±2,0 %	h	5.3.1.88
Field size – Stem scatter	As specified by MANUFACTURER	±1,0 %	a	5.3.2.2
Field size – Stem leakage	As specified by MANUFACTURER	±0,5 %	a	5.3.2.3
Orientation – Rotation	0° to 360°	±0,5 %	a	5.3.3.1
Orientation – Tilt	±5°	±1,0 %	a	5.3.3.2
<u>PARALLEL-PLATE CHAMBERS</u>				
RADIATION QUALITY:				
– X-RADIATION	0,05 mm Al to 2 mm Al HVL (12 kV to 70 kV or 8 keV to 30 keV)	±2,0 %	e, f	5.4.1.1
– ELECTRONS in PHANTOM	5 MeV to 25 MeV	±1,0 %	i	5.4.1.2
– PROTONS in PHANTOM	50 MeV to 250 MeV	±2,0 %	i	5.4.1.3
– heavy ions in PHANTOM	100 MeV/u to 450 MeV/u	±2,0 %	i	5.4.1.4
Field size	As specified by MANUFACTURER	±2,0 %	a	5.2.7
Orientation – Tilt	±5°	±1,0 %	a	5.4.2

Table 5 (concluded)

INFLUENCE QUANTITY or INSTRUMENT PARAMETER	MINIMUM RATED RANGE	LIMITS OF VARIATION	Note	Sub-clause
<u>VENTED CHAMBERS</u>				
Atmospheric pressure change	$\pm 5\%$ to $\pm 10\%$ ^k	< 10 s	j	5.5.1
Temperature	+15 °C to +35 °C	$\pm 1,0\%$	a	5.5.2
Humidity:	–	–	–	–
– LEAKAGE CURRENT	20 % to 80 % RH (< 20 g·m ⁻³)	$\pm 1,0\%$	c	5.5.3.2
– RESPONSE	20 % to 80 % RH (< 20 g·m ⁻³)	$\pm 0,5\%$	a	5.5.3.3
<u>SEALED CHAMBERS</u>				
Atmospheric pressure change	$\pm 10\%$ ^k	$\pm 1,0\%$	a	5.6.1
Temperature	+10 °C to +40 °C	$\pm 1,0\%$	a	5.6.2
^a Percentage change of RESPONSE within the RATED RANGE for the respective quantity. ^b LEAKAGE CURRENT as percentage of ionization current during previous 10 min IRRADIATION. ^c LEAKAGE CURRENT as percentage of ionization current produced by minimum RATED or effective dose rate. ^d Percentage change of RESPONSE caused by reversal of polarity under specified IRRADIATION conditions, measured after stabilization of RESPONSE at each polarity. ^e Percentage change of RESPONSE for AIR KERMA over the RATED RANGE of RADIATION QUALITY. ^f The MINIMUM RATED RANGE of X-RAY TUBE VOLTAGE is expressed in kV. The MINIMUM RATED RANGE of mean energy is expressed in keV or MeV. In each case, the mean energy value given is that of a mono-energetic PHOTON of the same HVL rather than the mean energy derived from the radiation spectrum. ^g Percentage difference between the AIR KERMA RESPONSE at the reference RADIATION QUALITY and the AIR KERMA RESPONSE at other specified RADIATION QUALITIES within the RATED RANGE. ^h Percentage change of RESPONSE from a SPECIFIED ENERGY RESPONSE for ABSORBED DOSE TO WATER over the RATED RANGE of RADIATION QUALITY. ⁱ Percentage of change of perturbation factor from unity. ^j Time required for the change in ionization current to reach 90 % of its final value. ^k This is a test parameter not a true RATED RANGE.				

Table 6 – LIMITS OF VARIATION of PERFORMANCE CHARACTERISTICS for effects of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS – MEASURING ASSEMBLY

INFLUENCE QUANTITY or INSTRUMENT PARAMETER	MINIMUM RATED RANGE	Limits of VARIATION	Note	Subclause
<u>All MEASURING ASSEMBLIES</u>				
STABILIZATION TIME	15 min to 6 h	±0,5 %	a	6.2.5
<u>Dosimeters</u>				
Range changing	All ranges	±0,5 %	a	6.3.4
Dead time	As specified by MANUFACTURER	±0,5 %	a	6.3.5
Temperature: – RESPONSE	+15 °C to +35 °C	±1,0 %	a	6.3.6
– ZERO DRIFT	+15 °C to +35 °C	±1,0 %	b	6.3.6
Humidity: Charge leakage	20 % to 80 % RH (< 20 g·m ⁻³)	±1,0 %	b	6.3.7
STRAY RADIATION effect	0 to 0,2 mSv/h	±1,0 %	b	6.3.8
Charge leakage	All ranges at 90 % of full scale	±0,5 %	b	6.3.9
Dose rate dependence	As specified by MANUFACTURER	±0,5 %	a	6.3.10
<u>Dose rate meters</u>				
Range changing	All ranges	±1,0 %	a	6.4.4
Temperature: – RESPONSE	+15 °C to +35 °C	±1,0 %	a	6.4.6
– ZERO DRIFT	+15 °C to +35 °C	±1,0 %	c	6.4.6
– ZERO SHIFT	+15 °C to +35 °C	±1,0 %	c	6.4.6
Humidity: – RESPONSE	20 % to 80 % RH (< 20 g·m ⁻³)	±1,0 %	a	6.4.7
– ZERO DRIFT	20 % to 80 % RH (< 20 g·m ⁻³)	±1,0 %	c	6.4.7
– ZERO SHIFT	20 % to 80 % RH (< 20 g·m ⁻³)	±1,0 %	c	6.4.7
STRAY RADIATION effect	0 mSv/h to 0,2 mSv/h	±1,0 %	c	6.4.8
<u>Battery operated MEASURING ASSEMBLIES</u>				
Battery condition	Useful life	±0,5 %	a	6.5
<u>Mains operated MEASURING ASSEMBLIES</u>				
MAINS VOLTAGE (static)	–12 % to +10 % of nominal	±0,5 %	a	6.6.1
MAINS VOLTAGE (VARIATION)	–12 % to +10 % of nominal in 10 s or less	±0,5 %	d	6.6.2
a Percentage of change of RESPONSE within the EFFECTIVE RANGE of the measured quantity. b Percentage of rate of change of INDICATED VALUE produced by minimum effective input current or dose rate. c Percentage of change of INDICATED VALUE produced by minimum effective input current or dose rate. d Percentage of minimum effective INDICATED VALUE.				

Table 7 – LIMITS OF VARIATION of PERFORMANCE CHARACTERISTICS for effects of INFLUENCE QUANTITIES and INSTRUMENT PARAMETERS – Chamber and MEASURING ASSEMBLIES combined

INFLUENCE QUANTITY or INSTRUMENT PARAMETER	MINIMUM RATED RANGE	LIMITS OF VARIATION	Note	Subclause
<u>All chamber and MEASURING ASSEMBLIES</u>				
ELECTROSTATIC DISCHARGE	As in IEC 60601-1-2	$\pm 1,0$ %	a	6.2.6.1 and 6.2.6.2
Radiated electromagnetic fields	As in IEC 60601-1-2	$\pm 1,0$ %	a	6.2.6.1
Conducted disturbances induced by fast transients/burst	As in IEC 60601-1-2	$\pm 1,0$ %	a	6.2.6.1
Conducted disturbances induced by surges	As in IEC 60601-1-2	$\pm 1,0$ %	a	6.2.6.1
Conducted disturbances induced by radio-frequencies	As in IEC 60601-1-2	$\pm 1,0$ %	a	6.2.6.1
Voltage dips/short interruptions	As in IEC 60601-1-2	$\pm 1,0$ %	a	6.2.6.1
a Percentage of minimum effective reading.				

4.6 Classification of equipment according to LIMITS OF VARIATION

4.6.1 FIELD-CLASS DOSIMETER

A RADIOTHERAPY DOSIMETER shall be classified as field-class if the performance requirements listed in Tables 1 to 3 are met.

4.6.2 REFERENCE-CLASS DOSIMETER

A RADIOTHERAPY DOSIMETER may be classified as reference-class if in addition to the performance requirements listed in Tables 1 to 3 being met, the more stringent requirements of not more than half the limits listed apply for all the following PERFORMANCE CHARACTERISTICS:

- CHAMBER ASSEMBLY:
 - long-term stability (see 5.2.2.1);
 - post-irradiation leakage (see 5.2.4).
- MEASURING ASSEMBLY:
 - long-term stability (see 6.2.4);
 - RESOLUTION (see 6.2.2);
 - repeatability (see 6.2.3);
 - ZERO DRIFT (see 6.3.1 and 6.4.1);
 - ZERO SHIFT (see 6.3.2 and 6.4.2).

NOTE Where two performance levels are specified for the effects of INFLUENCE QUANTITIES (or INSTRUMENT PARAMETERS), in phrases such as "LIMITS OF VARIATION shall be $\pm x$ % ($\pm y$ %)", the first figure, $\pm x$ %, refers to a FIELD-CLASS DOSIMETER and the second figure in parentheses, ($\pm y$ %), refers to a REFERENCE-CLASS DOSIMETER.

A reference-class chamber shall not be a SEALED CHAMBER.

4.6.3 SCANNING-CLASS DOSIMETER

A RADIOTHERAPY DOSIMETER may be classified as scanning-class if the performance requirements listed in tables 1 to 3 are met with the following modifications:

- CHAMBER ASSEMBLY:
 - long-term stability (see 5.2.2.1);
 - accumulated dose stability (see 5.2.2.2);
- MEASURING ASSEMBLY:
 - long-term stability (see 6.2.4).

5 CHAMBER ASSEMBLY performance requirements

5.1 General

The general performance requirements that apply to the air-filled IONIZATION CHAMBERS normally used for RADIOTHERAPY dosimetry are given in 5.2.

The particular performance requirements for

- thimble or SPHERICAL CHAMBERS are given in 5.3;
- PARALLEL-PLATE CHAMBERS are given in 5.4;
- VENTED CHAMBERS are given in 5.5;
- SEALED CHAMBERS are given in 5.6.

NOTE This standard does not cover those other types of chambers (e.g. extrapolation, free-air, condenser) which are only very rarely used for RADIOTHERAPY dosimetry. For these types of chambers, it is recommended that the MANUFACTURER should state the RATED RANGE of RADIATION QUALITY and dose rate, the RATED RANGES of INFLUENCE QUANTITIES, and the LIMITS OF VARIATION of RESPONSE, LEAKAGE CURRENT or induced current within these ranges.

5.2 General performance requirements for (RADIOTHERAPY) IONIZATION CHAMBERS

5.2.1 CHAMBER ASSEMBLY LEAKAGE CURRENT without IRRADIATION

The CHAMBER ASSEMBLY LEAKAGE CURRENT without IRRADIATION, but with the maximum RATED polarizing voltage applied to the CHAMBER ASSEMBLY, shall not exceed $\pm 0,5$ % of the ionization current produced by the minimum effective dose rate.

NOTE If a range of polarizing voltages is stated to be suitable for use with the chamber, the CHAMBER ASSEMBLY LEAKAGE CURRENT may be stated for various lower polarizing potentials.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to c).

- a) *Apply the maximum RATED polarizing voltage to the CHAMBER ASSEMBLY and measure the CHAMBER ASSEMBLY LEAKAGE CURRENT (without IRRADIATION) 15 min (or less), 1 h and 6 h later.*
- b) *Irradiate the IONIZATION CHAMBER under REFERENCE CONDITIONS and determine the linear relationship between ionization current and dose rate.*
- c) *Use this relationship to express the CHAMBER ASSEMBLY LEAKAGE CURRENT as a percentage of the ionization current produced by the minimum effective dose rate.*

5.2.2 Stability

5.2.2.1 Long-term stability

The LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER when irradiated in a reproducible field of cobalt-60 or caesium-137 GAMMA RADIATION shall be not greater than

- $\pm 1,0$ % over one year, for a field-class CHAMBER ASSEMBLY;
- $\pm 0,5$ % over one year, for a reference-class CHAMBER ASSEMBLY;
- $\pm 1,0$ % over one month, for a scanning-class CHAMBER ASSEMBLY.

NOTE 1 Over a number of years the RESPONSE of an IONIZATION CHAMBER can change owing to dimensional changes and to changes in the nature of the surfaces surrounding the measuring volume; the latter effect may also cause the energy dependence of the IONIZATION CHAMBER to change with time.

Compliance with this performance requirement shall be checked by retaining a representative chamber, stored under STANDARD TEST CONDITIONS, and investigating its long-term stability, by making measurements at intervals of not more than one month under REFERENCE CONDITIONS, over a period of not less than

- *six months in the case of a field-class chamber, or*
- *one year in the case of a reference-class chamber, or*
- *four months in the case of a scanning-class chamber.*

NOTE 2 If during this test period a trend in RESPONSE is indicated for any RADIATION QUALITY in the RATED RANGE of greater than $\pm 1,0$ % per year, the MANUFACTURER should inform the RESPONSIBLE ORGANIZATION of the desirability of recalibration. The MANUFACTURER should also take steps to re-design the chamber with the objective of obtaining the required long-term stability.

5.2.2.2 Accumulated dose stability

After the CHAMBER ASSEMBLY has been homogeneously irradiated with a dose of 10^4 Gy (field class and reference class) or $2 \cdot 10^3$ Gy (scanning class) using the maximum RATED field size at any RADIATION QUALITY within the RATED RANGE:

- the LIMITS OF VARIATION of RESPONSE of the IONIZATION CHAMBER due to the effect of this accumulated dose shall be not greater than $\pm 1,0$ %;
- the CHAMBER ASSEMBLY shall still meet the performance requirements for post-irradiation leakage (see 5.2.4), LEAKAGE CURRENT without IRRADIATION (see 5.2.1) and STRAY RADIATION effect (see 5.2.8).

Compliance with this performance requirement shall be checked by:

- *measuring the RESPONSE of the IONIZATION CHAMBER in a reproducible RADIATION FIELD, at both the minimum and maximum RATED RADIATION QUALITIES, before and after delivering the specified accumulated dose to the CHAMBER ASSEMBLY;*
- *repeating the tests for post-irradiation leakage, LEAKAGE CURRENT without IRRADIATION and STRAY RADIATION effect after delivering the specified accumulated dose to the CHAMBER ASSEMBLY.*

5.2.3 STABILIZATION TIME

During a period of between 15 min and 2 h after applying the polarizing voltage the LIMITS OF VARIATION of RESPONSE shall be not greater than $\pm 0,5$ % of the RESPONSE measured 1 h after applying the polarizing voltage, for the case where the IONIZATION CHAMBER is continuously irradiated from the moment the polarizing voltage is applied.

Compliance with this performance requirement shall be checked by carrying out the test described in a) and b).

- a) *Apply the polarizing voltage and irradiate the IONIZATION CHAMBER by placing it in a cobalt-60 or caesium-137 GAMMA RADIATION beam, set to the reference field size at the reference dose rate.*
- b) *Whilst keeping the IONIZATION CHAMBER continuously irradiated, measure the RESPONSE approximately 15 min, 1 h and 2 h later.*

5.2.4 Post-irradiation leakage

Within 5 s after the end of a 10 min IRRADIATION, the transient LEAKAGE CURRENT shall have decreased to $\pm 1,0$ % ($\pm 0,5$ %) of the ionization current produced in the measuring volume during the IRRADIATION.

NOTE This effect arises in that part of the stem insulator or cable irradiated in the RADIATION BEAM, and is a current that is produced by the radiation, continues after the radiation has ceased and commonly decreases exponentially with time.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to f).

- a) *Select a MEASURING ASSEMBLY with an output signal proportional to the current measured. Connect this output to a suitable recording device (e.g. a chart recorder). The combined system shall be able to measure and record current from the chamber with a time constant of 0,5 s or less.*
- b) *Position the IONIZATION CHAMBER in a cobalt-60 GAMMA RADIATION beam set to the maximum RATED field size. The chamber REFERENCE POINT should be at the centre of the field and at a distance from the source at which the dose rate is the REFERENCE VALUE.*
- c) *Irradiate the IONIZATION CHAMBER and record the ionization current produced.*
- d) *After 10 min, stop the IRRADIATION and record the LEAKAGE CURRENT for a period of 10 s.*
- e) *Read the value of the transient LEAKAGE CURRENT recorded 5 s after the IRRADIATION has ceased and calculate its magnitude as a percentage of the mean current recorded during the IRRADIATION.*
- f) *Repeat steps b) to e) inclusive, but for a dose rate near the minimum of the RATED RANGE.*

5.2.5 RATED or EFFECTIVE RANGE of dose rate (continuous radiation)

5.2.5.1 Minimum RATED or effective dose rate

The minimum RATED or effective dose rate is the lowest dose rate at which the performance requirement on the CHAMBER ASSEMBLY LEAKAGE CURRENT is met (see 5.2.1).

5.2.5.2 Maximum RATED or effective dose rate

The maximum RATED or effective dose rate is the highest dose rate at which the performance requirement on the chamber ion collection efficiency is met.

NOTE At high dose rates, the RESPONSE may vary due to the following effects:

- a) ion recombination within the measuring volume which causes the ion collection efficiency to be less than 100 %;
- b) the behaviour of LEAKAGE CURRENTS across that part of the insulator that is irradiated in the RADIATION BEAM. For the purpose of this requirement, it may be assumed that if the CHAMBER ASSEMBLY complies with the requirements of stem leakage in 5.2.2.2 and for post-irradiation leakage in 5.2.4, the influence of LEAKAGE CURRENT across the insulator on dose rate dependence will be insignificant.

The ion collection efficiency shall be not less than 99 % when the IONIZATION CHAMBER is irradiated at the maximum RATED or effective continuous dose rate with the recommended polarizing voltage applied to the CHAMBER ASSEMBLY. This requirement shall be met for both polarities of polarizing voltage.

If a range of polarizing voltages is stated to be suitable for use with the chamber, the ion collection efficiency at the maximum RATED or effective dose rate shall be stated for various polarizing voltages.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to g), separately for each polarity of polarizing voltage.

- a) *Ensure that the CHAMBER ASSEMBLY has been tested for stem leakage (see 5.2.2.2) and post-irradiation leakage (see 5.2.4) and use the results of these tests where necessary to isolate the value of the ion collection efficiency.*
- b) *Whilst keeping the continuous dose rate $\dot{D}_c$ constant at a convenient high value, measure the ionization current at five or more different polarizing voltages between 20 % and 100 % of the recommended polarizing voltage.*

- c) Plot or calculate by regression analysis $1/I_{V,c}$ against $1/V^2$ where $I_{V,c}$ is the ionization current at polarizing voltage V , when the chamber is irradiated at continuous dose rate $\dot{D}_c$.
- d) If a straight line results, perform the calculations described in paragraph e) to f), otherwise proceed with paragraph g).
- e) Read the value of the saturation ionization current, $I_{0,c}$, in amperes, from the graph, or the regression analysis, as the value on the $1/I_{V,c}$ -axis when the line is extrapolated to $(1/V^2) = 0$.
- f) For the recommended polarizing voltage V_R calculate the maximum RATED or effective dose rate $\dot{D}_{m,c}$ (in continuous radiation) for which the percentage ionization collection efficiency is 99 %

$$\dot{D}_{m,c} = \frac{0,01 \times \dot{D}_c \cdot I_{R,c}}{I_{0,c} - I_{R,c}}$$

where $I_{R,c}$ is the ionization current at recommended polarization voltage V_R , when the chamber is irradiated at continuous dose rate $\dot{D}_c$.

- g) If a straight line does not result, calculate $\dot{D}_{m,c}$ in Gy/min from the numerical value:

$$\dot{D}_{m,c} = \frac{V_R^2}{4d^4}$$

where d is the distance in millimeters of the electrodes of a PARALLEL-PLATE CHAMBER and V_R is in volts. For cylindrical chambers d is to be replaced by

$$d_{cyl} = (a-b) \left[\frac{(ab)+1 \ln(ab)}{(ab)-1} \cdot \frac{1}{2} \right]^{1/2}$$

and for SPHERICAL CHAMBERS by

$$d_{sph} = (a-b) \left[\frac{1}{3} \left(\frac{a}{b} + 1 + \frac{b}{a} \right) \right]^{1/2}$$

where a represents the radius of the outer electrode and b the radius of the inner one in millimeters.

5.2.6 Maximum RATED dose per pulse (pulsed radiation)

The maximum RATED dose per pulse is the largest dose per pulse for which the performance requirement on the chamber ion collection efficiency is met.

The ion collection efficiency shall be not less than 99 % when the IONIZATION CHAMBER is irradiated at the maximum RATED dose per pulse (swept beam excluded) with the recommended polarizing voltage applied to the CHAMBER ASSEMBLY. This requirement shall be met for both polarities of polarizing voltage.

If a range of polarizing voltages is stated to be suitable for use with the chamber, the ion collection efficiency at the maximum RATED dose per pulse shall be stated for various polarizing voltages.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to g), separately for each polarity of polarizing voltage.

- a) *Ensure that the CHAMBER ASSEMBLY complies with the requirements for stem leakage (see 5.2.2.2) and for post-irradiation leakage (see 5.2.4).*
- b) *Whilst keeping the average dose per pulse D_p constant at a convenient high value, measure the mean ionization current at each of five or more different polarizing voltages used in 5.2.5.2b).*
- c) *Plot or calculate by regression analysis $1/I_{V,p}$ against $1/V$ where $I_{V,p}$ is the mean ionization current at polarization voltage V when the chamber is irradiated at average dose per pulse D_p .*
- d) *If a straight line results, perform the calculations described in items e) to f), otherwise proceed with item g).*
- e) *Read the value of the mean saturation ionization current $I_{0,p}$, in amperes, from the graph, or the regression analysis, as the value on the $1/I_{V,p}$ -axis when the line is extrapolated to $(1/V) = 0$.*
- f) *For the recommended polarizing voltage V_R calculate the maximum RATED or effective dose per pulse $D_{m,p}$ (in pulsed radiation), for which the percentage ionization collection efficiency is 99 %*

$$D_{m,p} = \frac{0,01 \times D_p \cdot I_{R,p}}{I_{0,p} - I_{R,p}}$$

where $I_{R,p}$ is the mean ionization current at recommended polarization voltage V_R , when the chamber is irradiated at average dose per pulse D_p .

- g) *If a straight line does not result, calculate $D_{m,p}$ [mGy] from the numerical value:*

$$D_{m,p} = \frac{0,0185 \times V_R}{d^2}$$

where d is the distance in millimeters of the electrodes of a PARALLEL-PLATE CHAMBER and V_R is in volts. For cylindrical and SPHERICAL CHAMBERS d is to be replaced by d_{cyl} and d_{sph} as defined in 5.2.5.2g).

NOTE This test method is only valid when the ion collection time in the chamber is short compared with the time between pulses and long compared with the duration of the pulse.

5.2.7 RATED RANGE of field sizes

The RATED RANGE of field sizes shall not be wider than the range of field sizes over which the requirements on the LIMITS OF VARIATION of RESPONSE due to field size are met. The RATED field sizes shall be specified in terms of a circular or square field centred on the REFERENCE POINT OF THE CHAMBER.

Within the RATED RANGE the limit of VARIATION of RESPONSE with changing field size shall be $\pm 2,0$ %.

For chambers which are used in an ELECTRON beam, the MANUFACTURER shall also declare the material of the PHANTOM used to measure the field size dependence.

Compliance with this performance requirement shall be checked by comparing the chamber RESPONSE with that of a chamber whose RESPONSE is either independent of field size, or whose VARIATION of RESPONSE is accurately known, at the reference field size and the maximum and minimum RATED field sizes.

The measurement of field size dependence shall be carried out at a sufficient number of RADIATION QUALITIES so that adequate interpolation can be made for the VARIATION of this parameter with RADIATION QUALITY.

The measurements of field size dependence shall be carried out in water or in a water-equivalent PHANTOM.

5.2.8 STRAY RADIATION

When those parts of the CHAMBER ASSEMBLY and pre-amplifier that are usually outside the RADIATION BEAM (but within the radiation room), are placed in the RADIATION BEAM, the current produced from them shall not exceed 5 % for parts within 50 cm of the REFERENCE POINT OF THE CHAMBER and 25 % for parts at larger distances, of the current from the IONIZATION CHAMBER when placed at the same place in the RADIATION BEAM.

NOTE The limits given in the requirements are based on the assumption that the STRAY RADIATION dose rate will not exceed 10 % for parts within 50 cm from the REFERENCE POINT OF THE CHAMBER or 2 % for parts at larger distances, of the dose rate in the RADIATION BEAM, and the requirements will limit the effect of STRAY RADIATION to $\pm 1,0$ % of the dose rate in the RADIATION BEAM.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to c).

- a) *Position the IONIZATION CHAMBER, in free air with its build-up cap fitted, in a cobalt-60 GAMMA RADIATION beam with a field size of at least 20 cm x 20 cm, such that the REFERENCE POINT is within the RADIATION BEAM and the length of stem (or body) irradiated corresponds approximately to that irradiated with the maximum RATED field size. Irradiate the chamber and measure the ionization current.*
- b) *Keeping the REFERENCE POINT at the same point of the field, move the CHAMBER ASSEMBLY so that parts within 50 cm of the REFERENCE POINT OF THE CHAMBER are also inside the beam. Irradiate the chamber and measure the ionization current; record the change in measured current as a percentage of the current from the IONIZATION CHAMBER. This change in measured current will be the sum of:*
 - *the current induced by IRRADIATION in the parts within 50 cm of the REFERENCE POINT OF THE CHAMBER, i.e. the current due to the effect to be measured, and*
 - *the additional current generated in the measuring volume of the chamber due to the radiation scattered from the parts within 50 cm of the REFERENCE POINT OF THE CHAMBER, i.e. an unwanted current which needs to be corrected for.*
- c) *To correct for this unwanted current, measure it by repeating step b), but this time instead of using the parts within 50 cm of the REFERENCE POINT OF THE CHAMBER under test use the same parts from a suitably cut-down identical chamber (which is not connected to the measuring equipment).*
- d) *Again keeping the REFERENCE POINT at the same point of the field, move the CHAMBER ASSEMBLY so that all parts at greater distances are also inside the beam. Irradiate the chamber and measure the ionization current a fourth time. Record this second change in measured current as a percentage of the current from the IONIZATION CHAMBER. Measure again and correct for the unwanted component of current due to scattered radiation by using a method similar to that described in step c).*

5.2.9 Guard/collector insulation

The insulation resistance between the guard and collecting electrodes shall not be less than $1 \times 10^{11} \Omega$.

Compliance with this performance requirement shall be checked by measuring the resistance between the guard and collector conductors of the CHAMBER ASSEMBLY connector at a voltage of ± 1 V.

5.2.10 Cable microphony

For a sample of cable of the same make and type as fitted to the CHAMBER ASSEMBLY, the peak current induced between the collector and guard conductors when the cable is subjected to cyclical flexing shall be less than $\pm 0,1$ pA.

NOTE 1 This requirement is included to ensure that the amount of charge induced when the connecting cable of a CHAMBER ASSEMBLY is moved or flexed does not significantly increase the UNCERTAINTY OF MEASUREMENT.

NOTE 2 It is not intended that this test needs to be repeated on more than one type of CHAMBER ASSEMBLY sharing the same make and type of cable.

Compliance with this performance requirement shall be checked by carrying out the test described in a) and b).

- a) *Subject a length of 50 cm to 60 cm of the connecting cable to cyclical lateral flexing, in the test apparatus illustrated in Figure B.1, at a rate of 1 Hz with a peak-to-peak displacement of 4 cm under a tensile load of 2 kg.*
- b) *Measure the peak current induced between the collector and guard conductors under these conditions with the REFERENCE VALUE of the polarizing voltage applied to the CHAMBER ASSEMBLY.*

5.2.11 Polarity of polarizing voltage effect

The difference between INDICATED VALUES obtained within the RATED RANGE of RADIATION QUALITIES with the maximum permitted positive and negative values of polarizing voltage shall be less than 1 % or CORRECTION FACTORS shall be given with an associated OVERALL UNCERTAINTY less than ± 1 %.

Compliance with this performance requirement shall be checked by carrying out the test described in a) and b).

- a) *Irradiate the chamber in a PHANTOM under the following conditions:*
 - 1) *the field size shall be the reference field size;*
 - 2) *the REFERENCE POINT OF THE CHAMBER shall be in the centre of the field;*
 - 3) *the depth of the REFERENCE POINT OF THE CHAMBER in the PHANTOM shall be as follows:*
 - *for a CHAMBER ASSEMBLY claimed to be suitable for use in ELECTRON beams the test depths shall be: $0,1 \cdot R_p$, $0,3 \cdot R_p$, $0,5 \cdot R_p$, and $0,7 \cdot R_p$ where R_p is the practical range of the ELECTRON beam;*
 - *for other CHAMBER ASSEMBLIES the test depths shall be: the depth of the maximum dose rate and 5, 10 and 20 g/cm².*
 - 4) *the quality of the RADIATION BEAM shall be as follows:*
 - *for a CHAMBER ASSEMBLY claimed to be suitable for use in ELECTRON beams, the minimum RATED energy shall be used;*
 - *for other CHAMBER ASSEMBLIES cobalt-60 gamma-rays and the maximum RATED energy shall be used.*
- b) *Make a series of measurements of ionization current at different depths with positive polarizing voltage applied to the IONIZATION CHAMBER. Then repeat the measurements with negative polarizing voltage applied to the IONIZATION CHAMBER. Note the percentage differences. Then repeat the cycle. The results shall not differ by more than 0,3 % at each depth. If so, take the average of the two results for each depth.*

NOTE 1 It is essential to allow sufficient time for stabilization of RESPONSE after reversing polarity (see 5.2.3);

NOTE 2 The effect of VARIATION in dose rate during the measurements may be eliminated by using either

- a transmission monitor, or
- a second IONIZATION CHAMBER, preferably of the same type as the one under test, positioned next to the chamber under test at the same depth in a PHANTOM. The polarity of the polarizing voltage applied to this second chamber shall be kept constant throughout the series of measurements.

5.2.12 ELECTROMAGNETIC COMPATIBILITY

See 6.2.6.

5.3 Performance requirements particular to SHELL CHAMBERS

NOTE 1 The CHAMBER ASSEMBLIES dealt with in this subclause are characterized by the following constructional details:

- the measuring volume is bounded by:
 - in a THIMBLE CHAMBER, a cylindrical electrode on the outside and a second cylindrical electrode, coaxial with the first, on the inside. One end of the outer electrode is closed (it may be either flat, conical or hemispherical) whilst the other end is "open" to allow the inner electrode to enter the measuring volume. The boundary of the measuring volume at this "open" end is defined by the end face of the cylindrical stem insulator which separates the inner and outer electrodes;
 - in a SPHERICAL CHAMBER, a spherical electrode on the outside and a second spherical electrode, coincident with the first, on the inside. There is a small "opening" in the outer electrode to allow the inner electrode to enter the measuring volume. The boundary of the measuring volume at this "opening" is defined by the end face of the cylindrical stem insulator which separates the inner and outer electrodes;
- the inner and outer electrodes are mounted on a supporting stem to which is attached the connecting cable. The axes of the measuring volume and the stem are usually coincident;
- the measuring volume is typically between 0,1 cm³ and 1,0 cm³;
- the polarizing potential is applied between the outer electrode and the inner/guard electrodes whilst the signal charge is collected on the inner electrode.

NOTE 2 THIMBLE CHAMBERS are designed to be used with the axis of the measuring volume perpendicular to the axis of the RADIATION BEAM.

5.3.1 Dependence on RADIATION QUALITY

5.3.1.1 General

The REFERENCE VALUE and MINIMUM RATED RANGE of RADIATION QUALITIES applicable to a particular THIMBLE CHAMBER and the exact LIMITS OF VARIATION of RESPONSE allowed due to changing the RADIATION QUALITY from the REFERENCE VALUE to other qualities within the MINIMUM RATED RANGE all depend upon the use(s) for which the chamber is stated as being suitable, in particular:

- whether the chamber is suitable for use in free air or in a PHANTOM;
- the type and quality of radiation with which the chamber can be used.

Compliance with the relevant performance requirement on the dependence of RESPONSE on RADIATION QUALITY shall be checked by measuring the RESPONSE of the chamber at the reference quality and at each of the specified number of other qualities in the RATED RANGE by comparison against one of the following:

- a) *a system which is inherently energy-independent after application of the appropriate physical factors e.g. the water calorimeter or a Fricke dosimetry system;*
- b) *a dosimeter which is traceable to a NATIONAL STANDARD and which is used following a recognized international, national or regional dosimetry protocol.*

When carrying out this test to determine the VARIATION of chamber RESPONSE with changing RADIATION QUALITY, all other INFLUENCE QUANTITIES shall be at their REFERENCE VALUES, or corrections shall be applied for any deviations from these REFERENCE VALUES.

5.3.1.2 SHELL CHAMBERS used in free air to measure AIR KERMA from medium-energy X-RADIATION

The REFERENCE VALUE of RADIATION QUALITY shall be a HALF-VALUE LAYER of 1,8 mm Cu (i.e. about 200 kV X-RAY TUBE VOLTAGE).

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range of HALF-VALUE LAYERS from 0,06 mm Cu (2 mm Al) to 3 mm Cu (i.e. from approximately 70 kV to 250 kV X-RAY TUBE VOLTAGE or 30 keV to 140 keV mean energy).

Within the RATED RANGE the limit of VARIATION of RESPONSE with changing RADIATION QUALITY shall be $\pm 2,0$ %.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.2.1 using the same IRRADIATION conditions as are used for the calibration of the chamber. The test may be part of, or ancillary to, the calibration procedure. At least five RADIATION QUALITIES shall be used in the test. These should be approximately 0,06 mm, 0,16 mm, 0,42 mm, 1,8 mm and 3 mm Cu HALF-VALUE LAYER.

5.3.1.3 SHELL CHAMBERS used in free air to measure AIR KERMA from medium energy X- and GAMMA RADIATION

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from X-RADIATION of 1,8 mm Cu HALF-VALUE LAYER (i.e. about 200 kV X-RAY TUBE VOLTAGE) to cobalt-60 GAMMA RADIATION (i.e. from approximately 100 keV to 1,33 MeV mean energy).

The RESPONSE for X-RADIATION of 1,8 mm Cu HALF-VALUE LAYER shall not vary from the RESPONSE for cobalt-60 GAMMA RADIATION using the appropriate build-up cap, by more than $\pm 4,0$ %.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.2.1 using GAMMA RADIATION from a cobalt-60 beam unit (or with X-RADIATION between 1 MV and 3 MV X-RAY TUBE VOLTAGE) and with X-RADIATION of 1,8 mm Cu HALF-VALUE LAYER. A build-up cap shall be used in the test of VARIATION of chamber RESPONSE at the RADIATION QUALITIES for which the ACCOMPANYING DOCUMENTS specify a build-up cap.

5.3.1.4 SHELL CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from PHOTON radiation with medium energies at and below cobalt-60

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from X-RADIATION of 0,42 mm Cu HALF-VALUE LAYER (i.e. about 140 kV X-RAY TUBE VOLTAGE) to cobalt-60 GAMMA RADIATION (i.e. from approximately 60 keV to 1,33 MeV mean energy).

Within the RATED RANGE of RADIATION QUALITIES either

- the RESPONSE of the chamber shall not vary from the RESPONSE for cobalt-60 GAMMA RADIATION by more than $\pm 4,0$ %, or
- the RESPONSE of the chamber with changing RADIATION QUALITY shall not vary by more than $\pm 2,0$ % from the SPECIFIED ENERGY RESPONSE (normalized to cobalt-60) stated by the MANUFACTURER. If this SPECIFIED ENERGY RESPONSE was calculated, the book or journal article from which the calculation method was obtained shall be referenced.

Compliance with this performance requirement shall be checked by placing the chamber in a PHANTOM and carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three RADIATION QUALITIES with medium-energy X-RADIATION. These should be approximately 0,42 mm, 1,8 mm and 3 mm Cu HALF-VALUE LAYER.

5.3.1.5 SHELL CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from high energy PHOTON radiation

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from cobalt-60 GAMMA RADIATION to X-RADIATION of 25 MV generating potential.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER with changing RADIATION QUALITY shall not vary by more than $\pm 2,0$ % from the SPECIFIED ENERGY RESPONSE (normalized to cobalt-60) stated by the MANUFACTURER. If this SPECIFIED ENERGY RESPONSE was calculated, the book or journal article from which the calculation method was obtained shall be referenced.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three PHOTON RADIATION QUALITIES in the range 5 MV to 25 MV.

5.3.1.6 SHELL CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from high energy ELECTRON RADIATION

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION or an ELECTRON RADIATION QUALITY within the RATED RANGE used at calibration.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from 9 MeV to 25 MeV ELECTRON energy.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER with changing radiation energy shall be $\pm 2,0$ % from a SPECIFIED ENERGY RESPONSE (predicted according to the VARIATION with RADIATION QUALITY of the water/air stopping power ratio), calculated or measured for that type of chamber as a function of RADIATION QUALITY. If this specified RESPONSE was calculated, the book or journal article from which the calculation method was obtained shall be referenced.

NOTE The deviation of the actual energy RESPONSE from the SPECIFIED ENERGY RESPONSE will be due mainly to changes in the perturbation effect with RADIATION QUALITY.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three ELECTRON RADIATION QUALITIES in the range 9 MeV to 25 MeV.

5.3.1.7 SHELL CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from proton radiation

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from 50 MeV to 250 MeV proton energy.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER with changing radiation energy shall be $\pm 2,0$ % from the RESPONSE at cobalt-60 GAMMA RADIATION.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three proton RADIATION QUALITIES in the range 50 MeV to 250 MeV.

5.3.1.8 SHELL CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from heavy ion radiation

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from 100 MeV/u to 450 MeV/u heavy ion energy.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER with changing radiation energy shall be $\pm 2,0$ % from the RESPONSE at cobalt-60 GAMMA RADIATION.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three heavy ion RADIATION QUALITIES in the range 100 MeV/u to 450 MeV/u.

5.3.2 RATED RANGE of field sizes

5.3.2.1 General

The RATED RANGE of field sizes shall be not wider than the range of field sizes over which the requirements on the LIMITS OF VARIATION of RESPONSE due to stem scatter (see 5.3.2.2), stem leakage (see 5.3.2.3) and post-irradiation leakage (see 5.3.3) are all met. The RATED field sizes shall be specified in terms of a circular or square field with the REFERENCE POINT OF THE CHAMBER at the centre.

NOTE The physical effects contributing to the dependence of the RESPONSE of a THIMBLE CHAMBER on field size are:

- a) radiation scattered from the stem;
- b) ionization current arising from cavities around the connection to the collecting electrode;
- c) radiation-induced LEAKAGE CURRENT across that part of the stem insulator or cable that is irradiated, which occurs only during IRRADIATION and is related to the instantaneous dose rate;
- d) post-irradiation LEAKAGE CURRENT across that part of the stem insulator or cable which is irradiated, which continues after the radiation has ceased and is related to the preceding IRRADIATION of the stem insulator or cable.

Effect a) is treated in 5.3.2.2 under the heading stem scatter. Effects b) and c) are treated in 5.3.2.3 under the heading stem leakage. Effect d) is treated in 5.3.3 under the heading post-irradiation leakage.

5.3.2.2 Stem scatter

Over the RATED RANGE of field sizes the limit of VARIATION of RESPONSE due to stem scatter for IRRADIATION in air shall be ± 1 %.

For each condition tested where the absolute value of the VARIATION is greater than 0,5 % but not more than 1 %, the ACCOMPANYING DOCUMENTS shall state the necessary CORRECTION FACTOR with an associated OVERALL UNCERTAINTY of less than $\pm 0,5$ %.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to j).

- a) *Ensure that the CHAMBER ASSEMBLY has been tested for LEAKAGE CURRENT (see 5.2.1), STABILIZATION TIME (see 5.2.3) and post-irradiation leakage (see 5.2.4) and use the results of these tests where necessary to isolate the magnitude of the stem scatter effect when carrying out tests b) to j).*
- b) *Position the CHAMBER ASSEMBLY, with its REFERENCE POINT at the field centre, in free air with its build-up cap fitted, in a beam of the reference RADIATION QUALITY and the minimum RATED field size.*
- c) *Measure the RESPONSE of the chamber.*
- d) *Construct a dummy stem which is identical to the real stem, then place this dummy stem in the beam so that it touches the IONIZATION CHAMBER on the opposite side to the real stem.*
- e) *With the dummy stem in position measure the RESPONSE of the chamber under the same conditions as in c).*
- f) *Derive the stem scatter effect at the field size set by comparing the chamber RESPONSE measured with and without the dummy stem in position.*
- g) *Increase the field size by 1 cm on each edge and repeat steps c) to f) inclusive.*

- h) Repeat step g) until either the magnitude of the stem effect no longer increases with field size or the maximum RATED field size is reached (whichever is the sooner).*
- i) If, for the RADIATION QUALITY concerned, the magnitude of the stem scatter effect is such as to require CORRECTION FACTORS to be declared, then these CORRECTION FACTORS shall be normalized to the chamber RESPONSE for the reference field size.*
- j) Repeat test steps b) to i) at a sufficient number of RADIATION QUALITIES to allow an adequate interpolation to be made of VARIATION of stem scatter with RADIATION QUALITY.*

5.3.2.3 Stem leakage

Over the RATED RANGE of field sizes the limit of VARIATION of RESPONSE due to stem leakage for IRRADIATION in air shall be $\pm 0,5$ %.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to j) using either cobalt-60 GAMMA RADIATION or the maximum RATED RADIATION QUALITY.

- a) Ensure that the CHAMBER ASSEMBLY has been tested for stem scatter (see 5.3.2.2), and use the results of this test where necessary to isolate the value of the stem leakage effect when carrying out tests b) to f).*
- b) Apply the maximum RATED polarizing voltage to the CHAMBER ASSEMBLY.*
- c) Position the REFERENCE POINT OF THE CHAMBER in free air at the centre of a rectangular field of width equal to the minimum RATED field size and length equal to the reference field size, so that the reference field-size axis of the field is coincident with the axis of the chamber stem. Fit the build-up cap if required at the RADIATION QUALITY used for this test.*
- d) Measure the RESPONSE of the chamber.*
- e) Rotate the CHAMBER ASSEMBLY by 90° about its REFERENCE POINT so that the minimum RATED field size axis of the field is coincident with the axis of the chamber stem.*
- f) Calculate the ratio of the RESPONSE of the chamber in the two positions and correct this ratio for the effect of stem scatter to give the stem leakage effect for the minimum RATED field size.*
- g) Then position the REFERENCE POINT OF THE CHAMBER at the centre of a second rectangular field, this time of width equal to the maximum RATED field size and length equal to the reference field size, so that the reference field size axis of the field is coincident with the axis of the chamber stem.*
- h) Measure the RESPONSE of the chamber.*
- i) Rotate the CHAMBER ASSEMBLY by 90° about its REFERENCE POINT so that the maximum RATED field size axis of the field is coincident with the axis of the chamber stem.*
- j) Calculate the ratio of the RESPONSE of the chamber in the two positions and correct this ratio for the effect of stem scatter to give the stem leakage effect for the maximum RATED field size.*

NOTE 1 It would not be satisfactory to perform this test by varying the field size alone, as this would change the dose rate because of scattered radiation.

NOTE 2 The RADIATION FIELD over the measuring volume of the chamber remains unchanged during the measurements.

NOTE 3 The effect being measured is a small fraction of the RESPONSE of the chamber.

5.3.3 Chamber orientation

NOTE These requirements refer to the precision of alignment necessary when positioning the CHAMBER ASSEMBLY in the beam.

5.3.3.1 Chamber rotation

The MINIMUM RATED RANGE shall be a complete rotation of the chamber about its axis, the latter being positioned perpendicular to the axis of the RADIATION BEAM. Within this range

RANGE the LIMITS OF VARIATION of RESPONSE in air, when the REFERENCE POINT OF THE CHAMBER is 1 m from the RADIATION SOURCE, shall be $\pm 0,5$ %.

Compliance with this performance requirement shall be checked by measuring the chamber RESPONSE in air at four angles of rotation, 90° apart, using the minimum RATED PHOTON RADIATION QUALITY and the minimum RATED field size.

5.3.3.2 Chamber tilt

The MINIMUM RATED RANGE shall be a tilt of the chamber axis about the REFERENCE POINT OF THE CHAMBER of $\pm 5^\circ$ from a position with the axis perpendicular to the axis of the RADIATION BEAM. Within the RATED RANGE the LIMITS OF VARIATION of RESPONSE in air, when the REFERENCE POINT OF THE CHAMBER is 1 m from the RADIATION SOURCE, shall be $\pm 1,0$ %.

Compliance with this performance requirement shall be checked by measuring the chamber RESPONSE in air at angles of tilt 1° apart using

- *the minimum RATED RADIATION QUALITY;*
- *the smallest field size that will uniformly irradiate the chamber for all angles of tilt.*

NOTE Care should be taken to tilt the chamber about its REFERENCE POINT.

5.4 Performance requirements particular to PARALLEL-PLATE CHAMBERS

NOTE 1 The CHAMBER ASSEMBLIES dealt with in this subclause are characterized by the following constructional details:

- the air volume is a disc-shaped right circular cylinder, one flat face of which constitutes the entrance window. The inside surface of the entrance window (and sometimes, but not always, the side walls of the cylinder) are electrically conducting and form the outer electrode. The inner electrode is a conducting circular disc inset in the body insulator which forms the other flat face of the cylinder opposite to the entrance window. The measuring volume is that fraction of the total air volume through which the lines of electrical force between the inner and outer electrodes pass;
- the inner and outer electrodes are mounted in a supporting block of material (the chamber body) to which is attached the connecting cable. The cable usually exits the body in a direction parallel to the entrance window;
- the measuring volume is typically between $0,01 \text{ cm}^3$ and $0,5 \text{ cm}^3$;
- the polarizing potential is applied between the outer electrode and the inner/guard electrodes whilst the signal charge is collected from the inner electrode;
- there is usually a third electrode surface between the other two which is not connected electrically to either of them, but which is designed to be held at the same potential as the inner electrode. If the CHAMBER ASSEMBLY is guarded, this third electrode will be present in the air volume as a ring around the inner electrode; if the CHAMBER ASSEMBLY is partially guarded, the third electrode will terminate inside the body insulator just outside the air volume.

NOTE 2 PARALLEL-PLATE CHAMBERS are designed to be used with the plane of the entrance window perpendicular to the axis of the RADIATION BEAM.

NOTE 3 There are two distinct types of PARALLEL-PLATE CHAMBER:

- a) PARALLEL-PLATE CHAMBERS for soft X-RADIATION. These have an entrance window made from a thin membrane to allow low energy PHOTON radiation to enter the measuring volume without significant ATTENUATION. The dimensional stability of the measuring volume depends critically on the rigidity of this thin entrance window;
- b) PARALLEL-PLATE CHAMBERS for ELECTRON RADIATION. These have the following typical dimensions:
 - entrance window thickness up to 1 mm;
 - distance between the inner and outer electrodes up to 2 mm;
 - diameter of the inner (collecting) electrode up to 20 mm;
 - guard ring around the collecting electrode with a width of at least 1,5 times the cavity height.

5.4.1 Dependence on RADIATION QUALITY

5.4.1.1 PARALLEL-PLATE CHAMBERS used in free air to measure AIR KERMA from soft (equal to or less than 100 kV X-RAY TUBE VOLTAGE) X-RADIATION

The REFERENCE VALUE of RADIATION QUALITY shall be a HALF-VALUE LAYER of 0,36 mm Al (i.e. about 30 kV X-RAY TUBE VOLTAGE).

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range of HALF-VALUE LAYERS from 0,05 mm to 2,0 mm Al (i.e. from approximately 12 kV to 70 kV X-RAY TUBE VOLTAGE or 8 keV to 30 keV mean energy).

Within the RATED RANGE the limit of VARIATION of RESPONSE with changing RADIATION QUALITY shall be $\pm 2,0$ %.

Compliance with this performance requirement shall be checked by calibrating the chamber against a dosimeter which is traceable to a NATIONAL STANDARD and which is used following a recognized international, national or regional dosimetry protocol.

The test shall be carried out at the reference quality and at a minimum of three other qualities in the RATED RANGE:

- *one between a HALF-VALUE LAYER of 0,02 mm and 0,05 mm Al;*
- *a second between a HALF-VALUE LAYER of 0,2 mm and 0,5 mm Al, and*
- *a third between a HALF-VALUE LAYER of 1,5 mm and 2,0 mm Al.*

5.4.1.2 PARALLEL-PLATE CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from high energy ELECTRON RADIATION

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION or an ELECTRON RADIATION QUALITY within the RATED RANGE used at calibration.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from 5 MeV to 25 MeV ELECTRON energy.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of the perturbation factor of the chamber with changing radiation energy shall be $\pm 1,0$ % from unity, calculated or measured for that type of chamber as a function of RADIATION QUALITY. If the perturbation factor was calculated, the book or journal article from which the calculation method was obtained shall be referenced.

NOTE The energy dependence of an ideal PARALLEL-PLATE CHAMBER with unity perturbation factor would be due to the change in the value of the stopping power ratio (water/air) with RADIATION QUALITY.

Compliance with this performance requirement shall be checked by comparing the RESPONSE of the chamber with the RESPONSE of an IONIZATION CHAMBER with known unity perturbation factor, i.e. a PARALLEL-PLATE CHAMBER in which the ratio guard ring width:air depth is at least 2:1 and the ratio diameter:depth of the air volume is at least 8:1. Both chambers shall be irradiated in PHANTOM at the depth of maximum dose for the RADIATION QUALITY concerned.

The test shall be carried out at the reference quality (i.e. GAMMA RADIATION from a cobalt-60 beam unit) and at the maximum and minimum RATED RADIATION QUALITY and one other ELECTRON RADIATION QUALITY in the RATED RANGE.

5.4.1.3 PARALLEL-PLATE CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from proton radiation

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from 50 MeV to 250 MeV proton energy.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER with changing radiation energy shall be $\pm 2,0$ % from the RESPONSE at cobalt-60 GAMMA RADIATION.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three proton RADIATION QUALITIES in the range 50 MeV to 250 MeV.

5.4.1.4 PARALLEL-PLATE CHAMBERS used in PHANTOM to measure ABSORBED DOSE TO WATER from proton and heavy ion radiation

The REFERENCE VALUE of RADIATION QUALITY shall be cobalt-60 GAMMA RADIATION as used at calibration.

The MINIMUM RATED RANGE of RADIATION QUALITIES shall be the range from 100 MeV/u to 450 MeV/u heavy ion energy.

Within the RATED RANGE of RADIATION QUALITIES the LIMITS OF VARIATION of RESPONSE of an IONIZATION CHAMBER with changing radiation energy shall be $\pm 2,0$ % from the RESPONSE at cobalt-60 GAMMA RADIATION.

Compliance with this performance requirement shall be checked by carrying out the test described in 5.3.1 using GAMMA RADIATION from a cobalt-60 beam unit and at least three proton and heavy ion RADIATION QUALITIES in the range 100 MeV/u to 450 MeV/u.

5.4.2 Chamber orientation

NOTE These requirements refer to the precision of alignment necessary when positioning the CHAMBER ASSEMBLY in the beam.

The MINIMUM RATED RANGE shall be with the plane of the entrance window tilted by $\pm 5^\circ$ in any direction from its reference position perpendicular to the axis of the RADIATION BEAM.

Within this RATED RANGE the LIMITS OF VARIATION of RESPONSE shall be $\pm 1,0$ % when the REFERENCE POINT OF THE CHAMBER is at 1 m from the RADIATION SOURCE.

Compliance with this performance requirement shall be checked by measuring the chamber RESPONSE at angles of tilt 1° apart using

- *the minimum and the maximum RATED RADIATION QUALITIES;*
- *the smallest field size that will uniformly irradiate the chamber for all angles of tilt.*

The measurements of angle of tilt dependence shall be carried out

- *in air on soft X-RADIATION chambers;*
- *in a water equivalent PHANTOM (at a stated depth) on ELECTRON chambers.*

NOTE 1 Care should be taken to tilt the chamber about its REFERENCE POINT.

NOTE 2 If using a solid water equivalent PHANTOM, the entire PHANTOM may be tilted if the chamber cannot be tilted separately.

5.5 Performance requirements particular to VENTED CHAMBERS

NOTE The measuring volume in VENTED CHAMBERS is vented to the atmosphere in order to equilibrate rapidly with exterior ambient conditions.

5.5.1 Atmospheric pressure change

The 90 % EQUILIBRATION TIME for pressure differences between the exterior and interior of the IONIZATION CHAMBER shall be not greater than 10 s.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to c).

- a) *Position the IONIZATION CHAMBER in a field of constant dose rate. For example, this can be done by inserting the IONIZATION CHAMBER in the appropriate radioactive STABILITY CHECK DEVICE.*
- b) *Subject the IONIZATION CHAMBER to a sudden change of pressure between 5 % and 10 % in ambient pressure and measure the VARIATION in the instantaneous ionization current from the chamber with time after this pressure change.*
- c) *Record the time taken for the instantaneous ionization current to reach 90 % of the final value of the ionization current as the 90 % EQUILIBRATION TIME.*

5.5.2 Temperature

The MINIMUM RATED RANGE of ambient temperature shall be +15 °C to +35 °C.

Within the RATED RANGE the LIMITS OF VARIATION of RESPONSE with changes of ambient temperature (after correcting for changes in air density by the gas law) shall be ± 1 %.

Compliance with this performance requirement shall be checked by carrying out the test described in a) and b).

- a) *Position the IONIZATION CHAMBER in a field of constant dose rate. For example, this can be done by inserting the IONIZATION CHAMBER in the appropriate radioactive STABILITY CHECK DEVICE.*
- b) *Whilst the IONIZATION CHAMBER is being irradiated at constant dose rate, measure the RESPONSE at the lowest and highest temperature in the RATED RANGE for the IONIZATION CHAMBER, and at one other temperature at or near the reference temperature.*

Allow sufficient time between measurements at different temperatures for the IONIZATION CHAMBER to achieve temperature equilibrium. If using a STABILITY CHECK DEVICE with a RADIOACTIVE SOURCE inside a shielded container to provide the constant dose rate, allow sufficient time between tests at different temperatures for the source container to achieve temperature equilibrium.

5.5.3 Humidity

5.5.3.1 General

The MINIMUM RATED RANGE of relative air humidity shall be from 20 % to 80 % relative humidity, but only for conditions in which the absolute humidity is less than $20 \text{ g}\cdot\text{m}^{-3}$.

5.5.3.2 Effect on LEAKAGE CURRENT

Within the RATED RANGE of humidity the LEAKAGE CURRENT shall be less than ± 1 % of the ionization current produced by the minimum RATED or effective dose rate.

Compliance with this performance requirement shall be checked by carrying out the test described in a) to d).

- a) *Apply the maximum RATED polarizing voltage to the CHAMBER ASSEMBLY.*
- b) *Expose the IONIZATION CHAMBER to conditions near $20 \text{ g}\cdot\text{m}^{-3}$ for at least 12 h, then measure the chamber assembly LEAKAGE CURRENT (without IRRADIATION).*

NOTE 1 See note in 6.3.7.