BS EN 60731:2012

BSI Standards Publication

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

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National foreword

This British Standard is the UK implementation of EN 60731:2012. It is identical to IEC 60731:2011. It supersedes BS EN 60731:1997, which will be withdrawn on 14 March 2015.

The UK participation in its preparation was entrusted by Technical Committee CH/62/3, Equipment for radiotherapy, nuclear medicine and radiation dosimetry.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60731

April 2012

ICS 11.040.50

Supersedes EN 60731:1997 + A1:2002

English version

Medical electrical equipment - Dosimeters with ionization chambers as used in radiotherapy
(IEC 60731:2011)

Appareils électromédicaux - Dosimètres à chambres d'ionisation utilisés en radiothérapie (CEI 60731:2011)

Medizinische elektrische Geräte - Dosimeter mit Ionisationskammern zur Anwendung in der Strahlentherapie (IEC 60731:2011)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 62C/506/FDIS, future edition 3 of IEC 60731, prepared by SC 62C, "Equipment for radiotherapy, nuclear medicine and radiation dosimetry", of IEC TC 62, "Electrical equipment in medical practice" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60731:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2012-12-14
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-03-14

This document supersedes EN 60731:1997 + A1:2002.

EN 60731:2012 includes the following significant technical changes with respect to EN 60731:1997 + A1:2002:

The technical modifications versus EN 60731:1997 + A1:2002 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60731:2012 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 60051-1:1997 NOTE Harmonized as EN 60051-1:1998 (not modified).

Annex ZA
(normative)
Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60417	data base	Graphical symbols for use on equipment	-	-
IEC 60601-1 + corr. December + corr. December	2005 2006 2007	Medical electrical equipment - Part 1: General requirements for basic safety and essential performance	EN 60601-1 + corr. March + A11	2006 2010 2011
IEC 60601-1-2 (mod)	2007	Medical electrical equipment - Part 1-2: General requirements for basic safety and essential performance - Collateral standard: Electromagnetic compatibility - Requirements and tests	EN 60601-1-2 + corr. March	2007 2010
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	EN 60601-1-3 + corr. March	2008 2010
IEC 60601-2-8	2010	Medical electrical equipment - Part 2-8: Particular requirements for basic safety and essential performance of therapeutic X-ray equipment operating in the range 10 kV to 1 MV	EN 60601-2-8	201X[1)]
IEC/TR 60788	2004	Medical electrical equipment - Glossary of defined terms	-	-
IEC 60976	2007	Medical electrical equipment - Medical electron accelerators - Functional performance characteristics	EN 60976	2007
IEC 61010-1 + corr. May	2010 2011	Safety requirements for electrical equipment for measurement, control and laboratory use - Part 1: General requirements	EN 61010-1	2010
IEC 61187	-	Electrical and electronic measuring equipment - Documentation	EN 61187	-
IEC 61267	2005	Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics	EN 61267	2006
IEC 61676	2002	Medical electrical equipment - Dosimetric instruments used for non-invasive measurement of X-ray tube voltage in diagnostic radiology	EN 61676	2002
ISO/IEC Guide 98-3	2008	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-

[1)] To be published.

Publication	Year	Title	EN/HD	Year
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	-	-

CONTENTS

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 ore 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 cm^3 and 1,0 cm^3 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 cm^3 and 0,5 cm^3 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

[ISO/IEC GUIDE 98-3:2008, 2.3.5]

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
<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 $\mathrm{d}\overline{\varepsilon}$ by $\mathrm{d}m$ where $\mathrm{d}\overline{\varepsilon}$ is the mean energy imparted by IONIZING RADIATION to water of mass $\mathrm{d}m$

NOTE 1 The unit of ABSORBED DOSE TO WATER is Gy (where 1 Gy = 1 J·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 $\mathrm{d}D$ by $\mathrm{d}t$, where $\mathrm{d}D$ is the increment of ABSORBED DOSE TO WATER in the time interval $\mathrm{d}t$

NOTE 1 The unit of ABSORBED DOSE RATE TO WATER is Gy·s^{-1} (Gy·min^{-1}; Gy·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 $\mathrm{d}E_{\mathrm{tr}}$ by $\mathrm{d}m$ where $\mathrm{d}E_{\mathrm{tr}}$ is the sum of the initial kinetic energies of all the charged ionizing particles liberated by uncharged ionizing particles in air of mass $\mathrm{d}m$

NOTE 1 The unit of AIR KERMA is Gy (where 1 Gy = 1 J·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 $\mathrm{d}K$ by $\mathrm{d}t$, where $\mathrm{d}K$ is the increment of AIR KERMA in the time interval $\mathrm{d}t$

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

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

3.32
EXPOSURE
X
quotient of $\mathrm{d}Q$ by $\mathrm{d}m$ where $\mathrm{d}Q$ 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 $\mathrm{d}m$ 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 cov(y,z) [also denoted by $v(y,z)$] may be estimated by $s(y_i,z_i)$ obtained from n independent pairs of simulanous observations y_i and z_i of y and z,

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

where $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ 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 -∞ to x gives the DISTRIBUTION FUNCTION evaluated at x of a CONTINUOUS DISTRIBUTION

NOTE $f(x)\mathrm{d}x$ is the "probability element" , $f(x)\mathrm{d}x = P_r(x<X<x+\mathrm{d}x)$.

[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 ±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
All IONIZATION CHAMBERS		
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
SHELL CHAMBERS		
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
PARALLEL-PLATE CHAMBERS		
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	±0,5 % [a]	6.2.2
Repeatability	±0,5 % [b]	6.2.3
Long-term stability	±1,0 % [c]	6.2.4
ZERO DRIFT – dosimeter	±1,0 % [d]	6.3.1
ZERO DRIFT – dose rate meter	±1,0 % [e]	6.4.1
ZERO SHIFT – dosimeter	±1,0 % [f]	6.3.2
ZERO SHIFT – dose rate meter	±1,0 % [e]	6.4.2
NON-LINEARITY – dosimeter	±0,5 % [g]	6.3.3
NON-LINEARITY – dose rate meter	±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
All IONIZATION CHAMBERS				
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]	≥ 1 x 10^{11} Ω	–	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
SHELL CHAMBERS				
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 PHANTOM	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 PHANTOM	^{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
PARALLEL-PLATE CHAMBERS				
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
VENTED CHAMBERS				
Atmospheric pressure change	±5 % to ±10 % [k]	< 10 s	[j]	5.5.1
Temperature	+15 °C to +35 °C	±1,0 %	[a]	5.5.2
Humidity:	–	–	–	–
– LEAKAGE CURRENT	20 % to 80 % RH (< 20 g·m^{-3})	±1,0 %	[c]	5.5.3.2
– RESPONSE	20 % to 80 % RH (< 20 g·m^{-3})	±0,5 %	[a]	5.5.3.3
SEALED CHAMBERS	–	–	–	–
Atmospheric pressure change	±10 % [k]	±1,0 %	[a]	5.6.1
Temperature	+10 °C to +40 °C	±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
All MEASURING ASSEMBLIES				
STABILIZATION TIME	15 min to 6 h	±0,5 %	a	6.2.5
Dosimeters				
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
Dose rate meters				
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
Battery operated MEASURING ASSEMBLIES				
Battery condition	Useful life	±0,5 %	a	6.5
Mains operated MEASURING ASSEMBLIES				
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
All chamber and MEASURING ASSEMBLIES				
ELECTROSTATIC DISCHARGE	As in IEC 60601-1-2	±1,0 %	[a]	6.2.6.1 and 6.2.6.2
Radiated electromagnetic fields	As in IEC 60601-1-2	±1,0 %	[a]	6.2.6.1
Conducted disturbances induced by fast transients/burst	As in IEC 60601-1-2	±1,0 %	[a]	6.2.6.1
Conducted disturbances induced by surges	As in IEC 60601-1-2	±1,0 %	[a]	6.2.6.1
Conducted disturbances induced by radio-frequencies	As in IEC 60601-1-2	±1,0 %	[a]	6.2.6.1
Voltage dips/short interruptions	As in IEC 60601-1-2	±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 ±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

– ±1,0 % over one year, for a field-class CHAMBER ASSEMBLY;
– ±0,5 % over one year, for a reference-class CHAMBER ASSEMBLY;
– ±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 ±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 ±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 ±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 ±1,0 % (±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

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

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 ±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 ±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 ±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/cm^2.*

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 cm^3 and 1,0 cm^3;
– 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 ±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 ±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 ±4,0 %, or
– the RESPONSE of the chamber with changing RADIATION QUALITY shall not vary by more than ±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 ±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 ±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 ±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 ±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 ±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 (see5.2.1), 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 ±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 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 ±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 ±5° 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 ±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 cm^3 and 0,5 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 ±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 ±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 ±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 ±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 ±5° 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 ±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 $g \cdot m^{-3}$.

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 $g \cdot m^{-3}$ for at least 12 h, then measure the chamber assembly LEAKAGE CURRENT (without IRRADIATION).

NOTE 1 See note in 6.3.7.

c) Irradiate the IONIZATION CHAMBER under REFERENCE CONDITIONS and determine the linear relationship between ionization current and dose rate.

NOTE 2 This is the same as test b) of 5.2.1 and if done already need not be repeated.

d) Use this relationship to express the chamber assembly LEAKAGE CURRENT at the maximum RATED humidity as a percentage of the minimum effective dose rate.

5.5.3.3 Effect on RESPONSE

Within the RATED RANGE the limit of VARIATION of RESPONSE with changing humidity shall be ±0,5 %.

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

a) Store the chamber under conditions of 20 % RH or less for one month.

b) Remove the chamber from store and measure its RESPONSE under REFERENCE CONDITIONS.

c) Store the chamber under conditions of 80 % RH or more for one month.

d) Remove the chamber from store and re-measure its RESPONSE under REFERENCE CONDITIONS.

e) Calculate the percentage change in the two values of RESPONSE measured.

5.6 Performance requirements particular to SEALED CHAMBERS

5.6.1 Atmospheric pressure change

For a chamber claimed to be sealed, the limit of VARIATION of RESPONSE for at least 1 h after a ±10 % change in external air pressure, shall be ±1,0 %.

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

a) Before carrying out this test ensure that the chamber has been checked for the effects of post-irradiation leakage (see 5.2.4), and if necessary apply a correction for this. Also apply corrections for changes in ambient temperature if necessary (see 5.6.2).

b) Position the IONIZATION CHAMBER in a field of constant dose rate. This can most conveniently be done by inserting the IONIZATION CHAMBER in the appropriate radioactive STABILITY CHECK DEVICE.

c) Stop the IRRADIATION (if convenient to do so) and subject the chamber to a change in ambient pressure of –10 %. Maintain this new pressure for the remainder of the test.

d) Wait for 1 h, then irradiate the IONIZATION CHAMBER at the same constant dose rate and again measure the ionization current.

e) Calculate the change in ionization current from the chamber over the 1 h period and express it as a percentage of the original current.

f) Repeat steps c) to e) for a change in ambient pressure of +10 %.

5.6.2 Temperature

NOTE Experimental evidence indicates that SEALED CHAMBERS may show temperature dependence.

The MINIMUM RATED RANGE shall be +10 °C to +40 °C.

Within the RATED RANGE either

– the limit of VARIATION of RESPONSE due to changes in ambient temperature shall be ±1,0 %, or

– if this VARIATION is greater than 1,0 %, the RESPONSE shall be specified in the ACCOMPANYING DOCUMENTS as a set of CORRECTION FACTORS (one for each of the test

temperatures) applicable to the particular type of IONIZATION CHAMBER. The OVERALL UNCERTAINTY on the value of these CORRECTION FACTORS shall be not greater than 1,0 %.

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.

6 MEASURING ASSEMBLY performance requirements

6.1 General

The general performance requirements that apply to the MEASURING ASSEMBLIES normally used for RADIOTHERAPY dosimetry are given in 6.2.

The particular requirements for

– MEASURING ASSEMBLIES which can work as dosimeters are given in 6.3;
– MEASURING ASSEMBLIES which can work as dose rate meters are given in 6.4;
– battery powered MEASURING ASSEMBLIES are given in 6.5;
– mains powered MEASURING ASSEMBLIES are given in 6.6.

NOTE 1 Dosimeters – these instruments measure integrated charge and display their readings in one or more of the following units: C, Gy or C/kg.

NOTE 2 Dose rate meters – these instruments measure instantaneous current and display their readings in one or more of the following units: A, Gy/s, Gy/min, Gy/h, (C/kg)/s, (C/kg)/min or (C/kg)/h.

6.2 General performance requirements for RADIOTHERAPY DOSIMETERS

6.2.1 EFFECTIVE RANGES

6.2.1.1 EFFECTIVE RANGE of readings

The minimum effective reading on each measurement range shall be the lowest reading for which the requirements of the relevant subclauses RESOLUTION (see 6.2.2) and NON-LINEARITY (see 6.3.3 or 6.4.3) are stated to be satisfied. The maximum effective reading on each measurement range shall be the highest reading for which the requirements of NON-LINEARITY (see 6.3.3 or 6.4.3) are stated to be satisfied.

6.2.1.2 EFFECTIVE RANGE OF INDICATED VALUES

The minimum effective INDICATED VALUE shall be the lowest INDICATED VALUE for which the requirements on the relevant performance parameters input current (see 6.2.1.3), RESOLUTION (see 6.2.2), repeatability (see 6.2.3), NON-LINEARITY (see 6.3.3 or 6.4.3) and MAINS VOLTAGE VARIATION (see 6.6) are stated to be satisfied.

The maximum effective INDICATED VALUE shall be the maximum effective reading on the least sensitive measurement range unless otherwise stated in the ACCOMPANYING DOCUMENTS.

In addition:

– the ratio of the maximum effective INDICATED VALUE to the minimum effective INDICATED VALUE shall be not less than 10:1;

– for multi-range instruments the EFFECTIVE RANGE OF INDICATED VALUES shall be covered without gaps.

NOTE When tests are carried out on a complete dosimeter the EFFECTIVE RANGE OF INDICATED VALUES cannot be wider than the RATED RANGE of dose rate for the CHAMBER ASSEMBLY.

6.2.1.3 RATED or EFFECTIVE RANGE of input currents

NOTE The requirements of subclauses 6.3.5, 6.3.9 and 6.3.10 apply only to dosimeters.

The minimum RATED or effective input current shall be the lowest input current for which the requirements on the relevant performance parameters ZERO DRIFT (see 6.3.1 or 6.4.1), ZERO SHIFT (see 6.3.2 or 6.4.2), charge leakage (see 6.3.9), NON-LINEARITY (see 6.3.3 or 6.4.3), temperature (see 6.3.6 or 6.4.6), humidity (see 6.4.7 or 6.3.7) and STRAY RADIATION (see 6.3.8 or 6.4.8) are stated to be satisfied.

The maximum RATED or effective input current shall be the highest input current for which the requirements on the relevant performance parameters NON-LINEARITY (see 6.3.3 or 6.4.3), dose rate dependence (see 6.3.10) and dead time (see 6.3.5) are stated to be satisfied.

6.2.2 RESOLUTION of the display or data output terminal

The RESOLUTION of the display or data output terminal shall be equal to or better than 0,5 % (0,25 %) of the minimum effective reading for any range.

Compliance with this performance requirement shall be checked by inspection.

NOTE The UNCERTAINTY of reading of the display is numerically equal to the RESOLUTION. Making the assumptions for an analogue panel meter that visual discrimination is 0,2 mm and that the minimum effective reading is half scale, this means that to meet this requirement the full scale length of an analogue panel meter (see 8.2.2.3) would have to be 8 cm. For a digital display, compliance is achieved when the minimum effective reading is 199. For decade ranging, this would require a full scale display capability of at least 1999.

6.2.3 Repeatability

At the minimum effective INDICATED VALUE the repeatability shall be such that the relative STANDARD DEVIATION derived from successive measurements shall not exceed ±0,5 % (±0,25 %) of that INDICATED VALUE.

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

a) Set the MEASURING ASSEMBLY to the most sensitive dose (dose rate) range. Ensure that the MEASURING ASSEMBLY has been switched on for at least the STABILIZATION TIME (see 6.2.5) before beginning test b).

b) Inject a charge [current] sufficient to give a reading at or near the minimum effective INDICATED VALUE. Note this reading.

c) Repeat b) nine times, each time injecting the same charge [current].

d) Calculate the relative STANDARD DEVIATION of the ten successive readings, expressed as a percentage of the mean INDICATED VALUE.

NOTE Differences between the INDICATED VALUES in successive measurements under constant conditions may result from short- and long-term fluctuations or drift phenomena. For the stated requirements only short-term fluctuations and drift are considered.

6.2.4 Long-term stability

The LIMITS OF VARIATION of RESPONSE of a MEASURING ASSEMBLY shall not be greater than

– ±1,0 % over 1 year, for a field-class MEASURING ASSEMBLY;

– ±0,5 % over 1 year, for a reference-class MEASURING ASSEMBLY;

– ±1,0 % over 1 month, for a scanning-class MEASURING ASSEMBLY.

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

a) Retain a representative MEASURING ASSEMBLY.

b) Measure its RESPONSE to a constant known charge [current] in the RATED RANGE injected repeatedly at intervals of not more than one month over a total period of not less than six months (four months in the case of a scanning-class MEASURING ASSEMBLY).

c) Draw a graph of RESPONSE against time in months. From this graph obtain, by extrapolation if necessary, a value for the change in RESPONSE over one year (one month in the case of a scanning-class MEASURING ASSEMBLY).

NOTE 1 Over a number of years the RESPONSE of a MEASURING ASSEMBLY to a given input charge or current can change. The method of construction and choice of components should be such that the change in RESPONSE would not be expected to exceed the required limit. If, in order to achieve a specific performance, components have to be used which are known to have poor stability, one or more STABILITY CHECK DEVICES should be incorporated in or provided with the MEASURING ASSEMBLY in order that the RESPONSE can be checked, and controls may be provided in order to correct the RESPONSE.

NOTE 2 If during this test period, a trend in RESPONSE is indicated of greater than ±1,0 % per year the MANUFACTURER should inform the RESPONSIBLE ORGANIZATION of the desirability of recalibration (field-class and reference-class only). The MANUFACTURER should also take steps to re-design the MEASURING ASSEMBLY with the objective of obtaining the required long-term stability.

6.2.5 STABILIZATION TIME

During a period between 15 min and 6 h after switching on, the LIMITS OF VARIATION of RESPONSE shall be within ±0,5 % of the RESPONSE 1 h after switching on.

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

a) Ensure that the MEASURING ASSEMBLY has been switched off for at least 2 h before beginning test b).

b) Switch the MEASURING ASSEMBLY on and measure its RESPONSE in the dose [dose rate] mode at 15 min, 1 h and 6 h later by injecting a constant known charge [current] approximately equal to that customarily given during the calibration of the MEASURING ASSEMBLY.

6.2.6 ELECTROMAGNETIC COMPATIBILITY

6.2.6.1 IMMUNITY and EMISSIONS

Dosimeters covered by this standard shall comply with the requirements for IMMUNITY and EMISSIONS, except for the exemptions listed in the following subclauses.

Compliance shall be checked using the complete equipment. The LIMITS OF VARIATIONS stated in Table 7) shall not be exceeded during the measurements.

NOTE 1 The "complete equipment" means the MEASURING ASSEMBLY connected to a CHAMBER ASSEMBLY of a type customarily supplied with the MEASURING ASSEMBLY.

NOTE 2 A suitable overall STABILITY CHECK DEVICE can be fitted to the CHAMBER ASSEMBLY to produce a signal current during these measurements, provided that IMMUNITY and EMISSIONS are not affected by the STABILITY CHECK DEVICE.

NOTE 3 It is allowed to perform the measurements without an input signal, but with the MEASURING ASSEMBLY switched to the "measure" condition.

6.2.6.2 ELECTROSTATIC DISCHARGE

The maximum spurious indications (both transient and permanent) of the display or data output terminal due to ELECTROSTATIC DISCHARGE shall be less than the limits given in Table 7).

The test according to IEC 60601-1-2:2007, subclause 6.2.2 (ELECTROSTATIC DISCHARGE), is not to be performed on parts of the chamber and MEASURING ASSEMBLY that are normally exposed in the RADIATION BEAM. Compliance with this performance requirement shall be checked by discharging a suitable test generator and by observing and recording the indications of the display and any data output terminals while measurements are performed on all ranges (if the ranges are selectable).

6.2.6.3 Surges

The maximum spurious indications (both transient and permanent) of the display or data output due to surges shall be less than the limits given in Table 7).

The test according to IEC 60601-1-2:2007, subclause 6.2.5 (surges), is not to be performed on the connection lines between the IONIZATION CHAMBER and the MEASURING ASSEMBLY. For mains-operated instruments compliance shall be checked by observing and recording the indications of the display and any data output terminals while measurements are performed on the most sensitive range (if the ranges are selectable), both with and without the presence of disturbances induced by surges.

6.3 Performance requirements particular to dosimeters

6.3.1 ZERO DRIFT

The ZERO DRIFT of the MEASURING ASSEMBLY shall not exceed ±1,0 % (±0,5 %) of the rate of change of INDICATED VALUE produced by the minimum effective input current or dose rate.

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

a) If there is a threshold input current below which the MEASURING ASSEMBLY will not measure, set this threshold to zero (see 8.2.4).

b) Disconnect the IONIZATION CHAMBER from the input connector and shield this connector with a conducting grounded screen. When fitted to the input connector, a metal dust cap makes a convenient shield.

c) Ensure that the STRAY RADIATION level at the MEASURING ASSEMBLY is less than 7,5 μSv/h and that the MEASURING ASSEMBLY has been switched off for at least 1 h before beginning the test.

d) Switch the MEASURING ASSEMBLY on, if ranges are selectable, select the most sensitive dose range, and proceed to test e) within 15 min.

e) Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc. Place the MEASURING ASSEMBLY in the "measure" mode and note the dose reading on the display in this "measure" condition. Record the value of charge equivalent to this reading as Q_1[C]. (If the display is scaled in dose units, e.g. Gy, the value of equivalent charge can be obtained by dividing the reading on the display by the RESPONSE value measured in 6.2.5).

f) Keeping the MEASURING ASSEMBLY in the "measure" condition, wait for a measuring period T[s], then again note the charge equivalent to the reading on the display. Record this value as Q_2[C]. The period T[s] shall be not less than the time it would take for the minimum RATED input current to give the minimum effective INDICATED VALUE.

g) Calculate D_m[A], the ZERO DRIFT in the "measure" condition using the equation:

$$D_m = (Q_2 - Q_1)/T$$

h) Express this ZERO DRIFT as a percentage of the minimum RATED input current on the range selected.

i) Repeat tests e) to h) 1 h and 6 h after the MEASURING ASSEMBLY was switched on, thereby obtaining two more values for the ZERO DRIFT. The value of ZERO DRIFT quoted in the ACCOMPANYING DOCUMENTS shall be the maximum of the three values obtained.

j) After the above tests a) to i), apply an input current corresponding to the minimum RATED input current for a period T. T shall be the time it would take for the minimum RATED input current to give the minimum effective INDICATED VALUE. At the end of the measuring period note the charge Q_1[C] equivalent to the reading on the display. Leave the MEASURING ASSEMBLY in the "measure" position without performing a zeroing or reset.

k) Repeat the above measurement j) six times, waiting x seconds between the end of a measurement and the start of the next one (x = 2, 3, 5, 10, 30, 60) and noting the results as Q_2, Q_4, …, Q_7.

NOTE This test makes sure that interruption periods of the input signal as encountered e.g. in step-and-shoot INTENSITY MODULATED RADIATION THERAPY (IMRT) beams do not affect the measurements in cases where the MEASURING ASSEMBLY detects and corrects ZERO DRIFT in the "measure" position.

l) Calculate D_i[A]

$D_1 = Q_1/T$

$D_i = (Q_i - Q_{i-l})/T$ (i = 2, …, 7)

and express each D_i as a percentage of the minimum RATED input current on the range selected. None of these values shall deviate from 100 % by more than ±1,0 % (±0,5 %).

6.3.2 ZERO SHIFT

The ZERO SHIFT of the MEASURING ASSEMBLY shall not exceed ±1,0 % (±0,5 %) of the minimum effective INDICATED VALUE for any range when it is switched

– from the "set zero" or "reset" condition to the "measure" condition (applies to all dosimeters);
– from the "measure" condition to the "read" condition (only applies to dosimeters with a "read" position).

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

a) If there is a threshold input current below which the MEASURING ASSEMBLY will not measure, set this threshold to zero (see 8.2.4).

b) Disconnect the IONIZATION CHAMBER from the input connector and shield this connector with a conducting grounded screen. When fitted to the input connector, a metal dust cap makes a convenient shield.

c) Switch the MEASURING ASSEMBLY off for at least 1h before beginning the test.

d) Switch the MEASURING ASSEMBLY on, and if the ranges are selectable select the most sensitive dose range and proceed to test e) within 15 min.

e) Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc. Note the dose reading on the display in the "set zero" (or "reset") condition. Record the value of charge equivalent to this reading as Q_1[C]. If the "set zero" or "reset" condition is a momentary state, assume Q_1[C] to be zero. (If the display is scaled in dose units, e.g. Gy, the value of equivalent charge can be obtained by dividing the reading on the display by the RESPONSE value measured in 6.2.5).

f) Switch the MEASURING ASSEMBLY to the "measure" condition then again note the charge equivalent to the reading on the display. Record this value as Q_2[C].

g) If the MEASURING ASSEMBLY has a "read" position, switch it to this condition then again note the charge equivalent to the reading on the display. Record this value as Q_3[C].

h) Calculate $S_{sz,m}$[C], the ZERO SHIFT caused by switching from the "set zero" to the "measure" conditions using the equation:

$$S_{sz,m} = Q_2 - Q_1$$

i) If the MEASURING ASSEMBLY has a "read" position calculate $S_{m,r}$[C], the ZERO SHIFT caused by switching from the "measure" to the "read" conditions using the equation:

$$S_{m,r} = Q_3 - Q_2$$

j) Express the ZERO SHIFT(S) as a percentage of the minimum effective INDICATED VALUE, expressed in [C], on the range selected.

k) Repeat tests e) to j) 1 h and 6 h after the MEASURING ASSEMBLY was switched on, thereby obtaining two more values for the ZERO SHIFT(S). The value of each type of ZERO SHIFT quoted in the ACCOMPANYING DOCUMENTS shall be the maximum of the three values obtained.

6.3.3 NON-LINEARITY

NON-LINEARITY is 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:

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

NOTE 1 For a MEASURING ASSEMBLY set to the "dose" mode; the input signal is electric charge;

NOTE 2 For a MEASURING ASSEMBLY set to the "dose rate" mode, the input signal is electric current.

Within the EFFECTIVE RANGE of readings on each dose range, the LIMITS OF VARIATION of RESPONSE due to NON-LINEARITY of the MEASURING ASSEMBLY shall be ±0,5 %.

NOTE 3 NON-LINEARITY of the MEASURING ASSEMBLY should be distinguished from NON-LINEARITY caused by an IONIZATION CHAMBER.

The method of checking compliance with this performance requirement depends upon how the MEASURING ASSEMBLY operates:

- *If the ranges are selectable the NON-LINEARITY shall be measured at*
  - *five equally spaced points on each dose range;*
  - *the minimum effective reading on the most sensitive dose range;*
  - *the maximum effective reading on the least sensitive dose range.*
- *For auto ranging or single range instruments, the NON-LINEARITY shall be measured at*
  - *five equally spaced points per decade;*
  - *the minimum and maximum effective readings.*

The relevant NON-LINEARITY values shall be measured by carrying out the test described in a) to i):

a) Switch the polarizing voltage to zero and connect a calibrated highly linear variable charge source to the input connector. If the ranges are selectable, select the most sensitive dose range.

b) Switch on the MEASURING ASSEMBLY and wait for at least the STABILIZATION TIME before proceeding to test c).

c) Follow the MANUFACTURER'S instructions for making a measurement such as adjusting the zero, etc.

d) Switch the MEASURING ASSEMBLY to the "measure" condition then inject an accurately known charge $q_{0,5}$[C] sufficient to give a reading at or near 0,5 of the full reading of the range set. Note this reading as $m_{0,5}$[dose units]. Return the MEASURING ASSEMBLY to the "set zero" condition.

NOTE $(q_{0,5}/m_{0,5})$ is the CALIBRATION FACTOR for this range.

e) Switch the MEASURING ASSEMBLY to the "measure" condition then inject an accurately known charge q_1[C] sufficient to give a reading at or near the first scale point to be checked. Note this reading as m_1[dose units]. Return the MEASURING ASSEMBLY to the "set zero" condition.

f) Calculate and record d_1, the percentage deviation from linearity at the first scale point to be checked, using the equation

$$d_1 = 100 \times \{(m_1 \times q_{0,5})/(m_{0,5} \times q_1) - 1\}$$

g) Repeat e) and f) for readings at each of the other scale points to be checked, to obtain values for d_2, d_3, etc.

h) For instruments with selectable dose ranges repeat c) to g) for each of the other dose ranges provided on the MEASURING ASSEMBLY.

i) The value of NON-LINEARITY for the MEASURING ASSEMBLY shall be the maximum of the values of d_1, d_2, d_3, etc.

6.3.4 Range changing

NOTE 1 This requirement applies to a MEASURING ASSEMBLY incorporating a range switch which alters the scale factor of the instrument by stated ratios and/or switches between dose and dose rate ranges. In the case of a MEASURING ASSEMBLY provided with more than one IONIZATION CHAMBER and which incorporates a selector switch to alter the scale factor of the instrument according to the chamber used, the range changing requirement does not apply to changing between chamber selections if the instrument is given a radiation calibration using each chamber with the selector switch in the appropriate position for that chamber.

Either:

– the LIMITS OF VARIATION of RESPONSE due to changing from a reading of 0,5 full scale on the dose range on which the dosimeter is calibrated to a reading of 0,5 full scale on each of the other dose ranges provided on the MEASURING ASSEMBLY shall be ±0,5 %, or

– if the VARIATION of RESPONSE due to range changing exceeds 0,5 % for any dose range, the ACCOMPANYING DOCUMENTS shall state a CORRECTION FACTOR to correct the dosimeter RESPONSE at 0,5 of full scale on that range. The OVERALL UNCERTAINTY in the value of this CORRECTION FACTOR shall not exceed 0,5 %.

Compliance with this performance requirement in respect of range changing between the dose ranges shall be checked by carrying out the calculations described in a) to c) below, using the results of the NON-LINEARITY test (6.3.3).

a) The range CORRECTION FACTOR for the dose range on which the MEASURING ASSEMBLY is calibrated shall be unity.

b) Calculate the range CORRECTION FACTORS for the other dose ranges using the relationship:

$$R_A = (q_{0,5,A} \times m_{0,5,B})/(q_{0,5,B} \times m_{0,5,A})$$

where

R_A *is the range CORRECTION FACTOR for dose range A; the range CORRECTION FACTOR for dose range B is 1,000, i.e. range B is the dose range on which the MEASURING ASSEMBLY is calibrated;*

$q_{0,5,A}$ *is the value of $q_{0,5}$ for range A obtained following 6.3.3;*

$q_{0,5,B}$ *is the value of $q_{0,5}$ for range B obtained following 6.3.3;*

$m_{0,5,A}$ *is the value of $m_{0,5}$ for range A obtained following 6.3.3;*

$m_{0,5,B}$ *is the value of $m_{0,5}$ for range B obtained following 6.3.3.*

NOTE 2 Because a typical dosimeter may have four ranges, each a factor of 10 apart, the charge source used will need to be highly linear over a dynamic range of 10 000 if the required UNCERTAINTY in the values of the range CORRECTION FACTORS is to be achieved.

c) For each dose range calculate the VARIATION of RESPONSE in percent using the relationship:

$$V_A = 100 \times (1 - R_A)$$

where

V_A *is the VARIATION of RESPONSE due to changing from a reading of 0,5 full scale on the calibrated dose range to a reading of 0,5 full scale on dose range A.*

6.3.5 Dead time

NOTE This requirement applies to a MEASURING ASSEMBLY which measures charge by using a trigger circuit to charge and discharge a capacitor. The "dead time" is the interval at the end of each cycle during which this integrating capacitor is being discharged. If one (or more) complete cycle(s) is(are) included in a measurement, the dead time will affect the RESPONSE of the instrument.

Within the RATED RANGE of input currents or dose rates either:

– the limit of VARIATION of RESPONSE due to dead time influence shall be ±0,5 %, or

– if the VARIATION of RESPONSE exceeds 0,5 % the ACCOMPANYING DOCUMENTS shall state a set of CORRECTION FACTORS to correct the RESPONSE for the effect of dead time. The OVERALL UNCERTAINTY of the CORRECTION FACTORS shall not exceed 0,5 %.

Compliance with this performance requirement shall be checked by measuring the average RESPONSE over at least five cycles at not fewer than five input currents evenly spaced over the RATED RANGE of input currents. In order to eliminate the effect of chamber RESPONSE NON-LINEARITY, the input current shall be provided by a variable current source of known accuracy.

6.3.6 Temperature

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

Within the RATED RANGE:

– the LIMITS OF VARIATION of RESPONSE shall be ±1,0 %;

– the ZERO DRIFT shall not vary from the value at the reference temperature +20 °C by more than ±1,0 % of the rate of change of INDICATED VALUE produced by the minimum effective input current or dose rate.

Compliance with this performance requirement shall be checked by measuring the following PERFORMANCE CHARACTERISTICS at the lowest and highest temperatures in the RATED RANGE, and at least at one other temperature at or near the reference temperature:

a) the RESPONSE to a constant input charge which gives approximately the REFERENCE INDICATED VALUE, on each dose range provided;

b) the ZERO DRIFT.

During the temperature tests the humidity shall be maintained within the range of STANDARD TEST VALUES.

6.3.7 Humidity

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

Within this RATED RANGE the charge leakage shall be less than ±1 % of the minimum effective input current.

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

a) Expose the MEASURING ASSEMBLY to conditions near 20 g·m^{-3} for at least 12 h before proceeding to test b).

NOTE An absolute humidity of near 20 g·m^{-3} can be attained under any of the following conditions:

Relative humidity %	Air temperature °C
80	+26,5
75	+25
60	+30
50	+35

b) Set the MEASURING ASSEMBLY to output the highest RATED polarizing voltage and select the lowest (most sensitive) charge range.

c) Carry out the charge leakage test detailed in 6.3.9 steps a) to g).

6.3.8 STRAY RADIATION effect

NOTE This requirement applies to those parts of the MEASURING ASSEMBLY that are normally outside the radiation room, i.e. that are situated in a level of radiation sufficiently low for occupation by personnel during the measurement.

The MINIMUM RATED RANGE of STRAY RADIATION dose equivalent rate shall be from zero to 0,2 mSv/h.

Within this RATED RANGE the ZERO DRIFT of a dosimeter shall not vary from the value measured with the STRAY RADIATION less than 7,5 μSv/h by more than ±1,0 % of the rate of change of INDICATED VALUE produced by the minimum RATED input current or dose rate.

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

a) Position the MEASURING ASSEMBLY in a uniform field of PHOTON radiation of known dose equivalent rate [μSv/h] equal to or greater than the maximum RATED STRAY RADIATION dose equivalent rate. For a MEASURING ASSEMBLY supplied for use with unknown IONIZATION CHAMBERS, the energy of the STRAY RADIATION shall be that of cobalt-60 GAMMA RADIATION, otherwise it shall be the highest RATED radiation energy or cobalt-60 GAMMA RADIATION, whichever has the lower energy.

NOTE This test may be carried out at higher dose equivalent rates, e.g. 1 mSv/h to 10 mSv/h, and the results may be linearly extrapolated, if necessary, down to the maximum RATED dose equivalent rate.

b) Carry out the ZERO DRIFT test detailed in 6.3.1 steps a) to h).

c) Subtract the value of ZERO DRIFT measured in test 6.3.1 (performed under STANDARD TEST CONDITIONS with zero STRAY RADIATION) from the value measured following a) and b) above to give the VARIATION in ZERO DRIFT caused by increasing the STRAY RADIATION dose equivalent rate from its REFERENCE VALUE to its maximum RATED VALUE.

6.3.9 Charge leakage

NOTE This requirement only applies to dosimeters which rely on the storage of charge on a capacitor and may therefore be prone to the effect of capacitor self-discharge.

The rate of loss of charge shall not exceed ±0,5 % of the minimum effective input current.

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

a) If there is a threshold input current below which the MEASURING ASSEMBLY will not measure, set this threshold to zero (see 8.2.4). Furthermore, if the MEASURING ASSEMBLY automatically terminates the measurement it shall be set so that it remains in the "measure" condition (see 8.2.5).

b) Ensure that the MEASURING ASSEMBLY has been switched on for at least the STABILIZATION TIME (see 6.2.5) before beginning test d).

c) If ranges are selectable, set the MEASURING ASSEMBLY to its most sensitive dose range.

d) If ranges are selectable, inject a charge sufficient to give a reading of at least 90 % of the full reading of the dose range set. If ranges are not selectable, inject a charge sufficient to achieve 90 % of the maximum voltage that can be placed on the storage capacitor prior to achieving either full scale or reset of the capacitor.

e) Keeping the MEASURING ASSEMBLY in the measurement mode disconnect the signal and any other external leakage paths from the input connector. Shield this connector with a conducting grounded screen.

f) Wait 5 min, then observe the change in dose reading on the display over a known period of not less than 5 min.

g) Calculate the rate of charge loss in amperes, and then express it as a percentage of the minimum RATED input current.

h) Repeat steps d) to g) inclusive for each dose range in turn.

6.3.10 Dose rate dependence of dosimeters

The limit of VARIATION of RESPONSE of the MEASURING ASSEMBLY due to VARIATIONS in dose rate shall not exceed ±0,5 % within the RATED RANGE of input currents or dose rates.

Compliance with this performance requirement shall be checked by using a charge source connected to the input. This circuit shall be of the type described in 4.4.7 c) 1) aa) or 4.4.7 c) 1) bb) except that it shall be possible to vary the value of the input current as follows:

– *if using a capacitive discharge circuit, two different values of limiting resistor shall be available:*
  - *one resistor to give a peak current equal to or just greater than 1,5 times the maximum RATED or effective input current;*
  - *the other resistor to give a peak current equal to or just less than 0,15 times the maximum RATED or effective input current.*
– *if using a constant current circuit it shall be capable of generating two different currents:*
  - *a constant current equal to or just greater than the maximum RATED or effective input current;*
  - *a constant current equal to or just less than 0,1 times the maximum RATED or effective input current.*

NOTE In the context of this test, the phrases "just less than" and "just greater than" are used to allow for component tolerances in the charge source, but shall be within 10 %.

Using this charge source, carry out the test described in a) to g).

a) Switch the polarizing voltage to zero; connect a calibrated charge source to the input connector. If ranges are selectable, select the most sensitive dose range.

b) Switch on the MEASURING ASSEMBLY and wait for at least the STABILIZATION TIME before proceeding to step c).

c) Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc.

d) Depending upon whether the charge source is a constant current or capacitive discharge device, set the charge source to output either

– *a constant current equal to or just greater than the maximum RATED or effective input current, or*

– *a peak current equal to or just greater than 1,5 times the maximum RATED or effective input current.*

Inject an accurately known charge q_1[C] sufficient to give a reading at or near 0,5 of the full reading. Note this reading as m_1[dose units].

e) *Depending upon whether the charge source is a constant current or capacitive discharge device, set the charge source to output either*

– *a constant current equal to or just less than 0,1 times the maximum RATED or effective input current, or*

– *a peak current equal to or just less than 0,15 times the maximum RATED or effective input current.*

Inject an accurately known charge q_2[C] sufficient to give a reading at or near 0,5 of the full reading. Note this reading as m_2[dose units].

f) *Calculate and record $d_{1,2}$, the percentage deviation due to dose rate, using the equation*

$$d_{1,2} = 100 \times \{[(m_1 \times q_2)/(m_2 \times q_1)] - 1\}$$

g) *If ranges are selectable, repeat c) to f) for each of the other dose ranges provided on the MEASURING ASSEMBLY.*

6.4 Performance requirements particular to dose rate meters

6.4.1 ZERO DRIFT

The ZERO DRIFT of the MEASURING ASSEMBLY over 10 min shall not exceed ±1,0 % (±0,5 %) of the INDICATED VALUE produced by the minimum effective input current or dose rate.

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

a) *If there is a threshold input current below which the MEASURING ASSEMBLY will not measure, set this threshold to zero (see 8.2.4).*

b) *Disconnect the IONIZATION CHAMBER from the input connector and shield this connector with a conducting grounded screen. When fitted to the input connector, a metal dust cap makes a convenient shield.*

c) *Switch the MEASURING ASSEMBLY off for at least 1 h before beginning the test.*

d) *Switch the MEASURING ASSEMBLY on, if ranges are selectable select the lowest dose rate range and proceed to test e) within 15 min.*

e) *Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc. Note the dose rate reading on the display in the "measure" condition.*

f) *Keeping the MEASURING ASSEMBLY in the "measure" condition, wait for 10 min, then again note the dose rate reading on the display.*

g) *Calculate the ZERO DRIFT by first subtracting the INDICATED VALUE of dose rate recorded in e) from that recorded in f).*

h) *Apply the exact relationship determined in 6.2.5 between the value of current injected and the value of dose rate displayed, to calculate (for the dose rate range selected) the INDICATED VALUE produced by the minimum RATED input current.*

i) *Using the quantities calculated in g) and h) express the ZERO DRIFT as a percentage of the INDICATED VALUE produced by the minimum effective input current or dose rate on the range selected.*

j) *Repeat steps e) to i) 1 h and 6 h after the MEASURING ASSEMBLY was switched on, thereby obtaining two more values for the ZERO DRIFT. The value of ZERO DRIFT quoted in the ACCOMPANYING DOCUMENTS shall be the maximum of the three values obtained.*

k) After the above test a) to j), apply an input current corresponding to the minimum effective input current for a period of several seconds. During the measuring period note the reading of the display. Leave the MEASURING ASSEMBLY in the "measure" position without performing a zeroing or reset.

l) Repeat the above measurement k) six times, waiting x seconds between the end of a measurement and a start of the next one (x = 2, 3, 5, 10, 30, 60) and noting the results as I_2, I_4, …, I_7.

NOTE This test makes sure that interruption periods of the input signal as encountered e.g. in step-and-shoot INTENSITY MODULATED RADIATION THERAPY (IMRT) beams do not affect the measurements in cases where the MEASURING ASSEMBLY detects and corrects ZERO DRIFT in the "measure" position.

m) Express each measuring result as a percentage of the minimum effective input current on the range selected. None of these values shall deviate from 100 % by more than ±1,0 % (±0,5 %).

6.4.2 ZERO SHIFT

The ZERO SHIFT of the MEASURING ASSEMBLY shall not exceed ±1,0 % (±0,5 %) of the INDICATED VALUE produced by the minimum effective input current or dose rate when it is switched from the "reset" or "set zero" condition to the "measure" condition with the input disconnected from an IONIZATION CHAMBER and shielded.

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

a) If there is a threshold input current below which the MEASURING ASSEMBLY will not measure, set this threshold to zero (see 8.2.4).

b) Disconnect the IONIZATION CHAMBER from the input connector and shield this connector with a conducting grounded screen. When fitted to the input connector, a metal dust cap makes a convenient shield.

c) Switch the MEASURING ASSEMBLY off for at least 1 h before beginning the test.

d) Switch the MEASURING ASSEMBLY on, if ranges are selectable select the most sensitive dose rate range and proceed to test e) within 15 min.

e) Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc. Note the dose rate reading on the display in the "set zero" (or "reset") condition. Record the value of current equivalent to this reading as I_1[A]. If the "set zero" or "reset" condition is a momentary state, assume I_1[A] to be zero. (If the display is scaled in dose rate units, e.g. Gy/min, the value of equivalent current can be obtained by first converting the reading on the display into units of dose·s^{-1} and then dividing this rate by the RESPONSE value measured in 6.2.5).

f) Switch the MEASURING ASSEMBLY to the "measure" condition, wait five times the RESPONSE TIME, then again note the current equivalent to the reading on the display. Record this value as I_2[A].

g) Calculate $S_{sz,m}$[A], the ZERO SHIFT caused by switching from the "set zero" to the "measure" conditions using the equation:

$$S_{sz,m} = I_2 - I_1$$

h) Express the ZERO SHIFT as a percentage of the minimum effective INDICATED VALUE, expressed in [A], on the range selected.

i) Repeat tests e) to h) 1 h and 6 h after the MEASURING ASSEMBLY was switched on, thereby obtaining two more values for the ZERO SHIFT. The value of ZERO SHIFT quoted in the ACCOMPANYING DOCUMENTS shall be the maximum of the three values obtained.

6.4.3 NON-LINEARITY

NON-LINEARITY is 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:

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

NOTE 1 For a MEASURING ASSEMBLY set to the "dose" mode; the input signal is electric charge;

NOTE 2 For a MEASURING ASSEMBLY set to the "dose rate" mode, the input signal is electric current.

Within the EFFECTIVE RANGE of readings on each dose rate range the limit of VARIATION of RESPONSE due to NON-LINEARITY of the MEASURING ASSEMBLY shall be ±1 %.

NOTE 3 NON-LINEARITY of the MEASURING ASSEMBLY should be distinguished from NON-LINEARITY caused by an IONIZATION CHAMBER.

The method of checking compliance with this performance requirement depends upon how the MEASURING ASSEMBLY operates:

- *If the ranges are selectable the NON-LINEARITY shall be measured at*
  - *five equally spaced points on each dose rate range;*
  - *the minimum effective reading on the most sensitive dose rate range;*
  - *the maximum effective reading on the least sensitive dose rate range.*
- *For auto ranging or single range instruments the NON-LINEARITY shall be measured at*
  - *five equally spaced points per decade;*
  - *the minimum and maximum effective readings.*

The relevant NON-LINEARITY values shall be measured by carrying out the test described in a) to i).

a) Switch the polarizing voltage to zero, connect a calibrated highly linear variable current source to the input connector then select the most sensitive dose rate range.

b) Switch on the MEASURING ASSEMBLY and wait for at least the STABILIZATION TIME before proceeding to test c).

c) Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc.

d) Switch the MEASURING ASSEMBLY to the "measure" condition then inject an accurately known current $i_{0,5}$[A] sufficient to give a reading at or near 0,5 of the full reading. Note this reading as $m_{0,5}$[dose rate units].

e) Then inject an accurately known current i_1[A] sufficient to give a reading at or near the first scale point to be checked. Note this reading as m_1[dose rate units]. Return the MEASURING ASSEMBLY to the "set zero" condition.

f) Calculate and record d_1, the percentage deviation from linearity at the first scale point to be checked, using the equation

$$d_1 = 100 \times \{(m_1 \times i_{0,5})/(m_{0,5} \times i_1) - 1\}$$

g) Repeat e) and f) for readings at each of the scale points to be checked, to obtain values for d_2, d_3, etc.

h) For instruments with selectable dose rate ranges repeat c) to g) for each of the other dose rate ranges provided on the MEASURING ASSEMBLY.

i) The value of NON-LINEARITY for the MEASURING ASSEMBLY shall be the maximum of the values of d_1, d_2, d_3, etc.

6.4.4 Range changing

NOTE 1 This requirement applies to a MEASURING ASSEMBLY incorporating a range switch which alters the scale factor of the instrument by stated ratios and/or switches between dose and dose rate ranges. In the case of a

MEASURING ASSEMBLY provided with more than one IONIZATION CHAMBER and which incorporates a selector switch to alter the scale factor of the instrument according to the chamber used, the range changing requirement does not apply to changing between chamber selections if the instrument is given a radiation calibration using each chamber with the selector switch in the appropriate position for that chamber.

Either:

– the LIMITS OF VARIATION of RESPONSE due to changing from a reading of 0,5 full scale on the dose rate range on which the MEASURING ASSEMBLY is calibrated to a reading of 0,5 full scale on each of the other dose rate ranges provided on the MEASURING ASSEMBLY shall be ±1,0 %, or

– if the VARIATION of RESPONSE due to range changing exceeds 1 % for any dose rate range, the ACCOMPANYING DOCUMENTS shall state a CORRECTION FACTOR to correct the dose rate meter RESPONSE at 0,5 of full scale on that range. The OVERALL UNCERTAINTY in the value of this CORRECTION FACTOR shall not exceed 1 %.

In addition, the LIMITS OF VARIATION of RESPONSE due to changing from a reading of 0,5 full scale on the dose rate range on which the MEASURING ASSEMBLY is calibrated to a reading of 0,5 full scale on the dose range on which the MEASURING ASSEMBLY is calibrated shall be ±1,0 %.

Compliance with the statement of performance in the ACCOMPANYING DOCUMENTS in respect of range changing between the calibrated dose range and the calibrated dose rate range shall be checked by carrying out the test described in a) to f).

Compliance with the statement of performance in respect of range changing between the dose rate ranges in the ACCOMPANYING DOCUMENTS shall be checked by carrying out the calculations described in g) to i) following on the results of the NON-LINEARITY test (see 6.4.3).

a) Ensure that the MEASURING ASSEMBLY has been switched on for at least the STABILIZATION TIME before proceeding to test b).

b) Inject into the input of the MEASURING ASSEMBLY a constant current of sufficient magnitude to give a reading of about 0,5 full scale on the calibrated dose rate range. Make a measurement and note the INDICATED VALUE of instantaneous dose rate after five exponential time constants have passed.

c) Keeping the injected current constant at the same value as in b), switch to the calibrated dose range. Make a measurement, integrating for a sufficient time to obtain a reading of about 0,5 full scale. Note both the INDICATED VALUE of dose and the integration time used. From these two values calculate the mean dose rate.

d) Convert the value of mean dose rate measured in c) into the same units as apply to the instantaneous dose rate measured in b).

e) Calculate the range CORRECTION FACTOR for the calibrated dose rate range using the relationship:

$$R_C = D_m/D_i$$

where

R_C *is the range CORRECTION FACTOR for dose rate range C;*

D_i *is the instantaneous dose rate measured on dose rate range C;*

D_m *is the mean dose rate measured on the calibrated dose range, expressed in the same units as* D_i.

f) For the calibrated dose rate range calculate the VARIATION of RESPONSE in percent using the relationship:

$$V_C = 100 \times (1 - R_C)$$

where

V_C *is the* VARIATION *of* RESPONSE *due to changing from a reading of 0,5 full scale on the calibrated dose range to a reading of 0,5 full scale on dose rate range C.*

g) *In the calculations detailed in h) to i) take the value of* R_C*, the range* CORRECTION FACTOR *for the calibrated dose rate range to be either:*

- *1 000 if the* MEASURING ASSEMBLY *has no calibrated dose range, or*
- *the value calculated in 6.4.4 e) if the* MEASURING ASSEMBLY *has a calibrated dose range.*

h) *Calculate the range* CORRECTION FACTORS *for the other dose rate ranges using the relationship:*

$$R_A/R_C = (i_{0,5,A}\, m_{0,5,C})/(i_{0,5,C}\, m_{0,5,A})$$

where

R_A *is the range* CORRECTION FACTOR *for dose rate range A;*

R_C *is the range* CORRECTION FACTOR *for dose rate range C, as determined in 6.4.4g);*

$i_{0,5,A}$ *is the value of* $i_{0,5}$ *for range A obtained following 6.4.3;*

$i_{0,5,C}$ *is the value of* $i_{0,5}$ *for range C obtained following 6.4.3;*

$m_{0,5,A}$ *is the value of* $m_{0,5}$ *for range A obtained following 6.4.3;*

$m_{0,5,C}$ *is the value of* $m_{0,5}$ *for range C obtained following 6.4.3.*

NOTE 2 Because a typical dose rate meter may have four ranges, each a factor of 10 apart, the current source used will need to be highly linear over a dynamic range of 10 000 if the required UNCERTAINTY in the values of the range CORRECTION FACTORS is to be achieved.

i) *For each dose rate range calculate the* VARIATION *of* RESPONSE *in percent using the relationship:*

$$V_A = 100 \times (1 - R_A)$$

where

V_A *is the* VARIATION *of* RESPONSE *due to changing from a reading of 0,5 full scale on the calibrated dose rate range to a reading of 0,5 full scale on dose rate range A.*

6.4.5 RESPONSE TIME

The 90 % RESPONSE TIME shall not exceed 3 s for any range using any associated CHAMBER ASSEMBLY. If the time constant is adjustable, this requirement shall apply to the shortest available time constant.

NOTE A MEASURING ASSEMBLY which uses an input circuit with a high-value resistor to measure current may have a significant RESPONSE TIME on the most sensitive dose rate ranges.

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

a) *Switch the polarizing voltage to zero, connect a stable variable current source to the input connector. This current source shall be fitted with a switch which can instantaneously isolate the current generated from the input of the* MEASURING ASSEMBLY.

b) Switch on the MEASURING ASSEMBLY and wait for at least the STABILIZATION TIME before proceeding the test c).

c) If ranges are selectable, select the most sensitive dose rate range.

d) Follow the MANUFACTURER'S instructions for making a measurement, such as adjusting the zero etc. Set the current source to output a current equivalent to approximately 0,5 of the full reading on the dose rate range set.

e) Switch the MEASURING ASSEMBLY to the "measure" condition and wait for the reading on the display to stabilize. Record reading, the final steady value on the display, as $m_{100\%}$ [dose rate units]. Calculate the readings $m_{10\%}$ and $m_{90\%}$ corresponding to 10 % and 90 %, respectively, of this final steady value.

f) Isolate the output of the current source, and at the same instant start an elapsed timer running. Observe the display, stopping the timer at the instant when the reading has decreased to $m_{10\%}$. Note the elapsed time as $t_{100,10}$[s].

g) Wait for the reading on the display to stabilize (at around zero), then switch on the output of the current source, and at the same instant start the elapsed timer running. Observe the display, stopping the timer at the instant when the reading has increased to $m_{90\%}$. Note the elapsed time as $t_{0,90}$[s].

h) The value for the 90 % RESPONSE TIME quoted in the ACCOMPANYING DOCUMENTS shall be the mean of the values obtained for $t_{100,10}$ and $t_{0,90}$.

6.4.6 Temperature

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

Within the RATED RANGE

– the LIMITS OF VARIATION of RESPONSE shall be ±1,0 %;

– the ZERO DRIFT over 10 min and the ZERO SHIFT shall not vary from their values at the reference temperature +20 °C by more than ±1,0 % of the INDICATED VALUE produced by the minimum effective input current or dose rate.

Compliance with this performance requirement shall be checked by measuring the following PERFORMANCE CHARACTERISTICS at the lowest and highest temperatures in the RATED RANGE, and at least at one other temperature at or near the reference temperature:

a) the RESPONSE to a constant input current which gives approximately the REFERENCE INDICATED VALUE, on each dose range provided;

b) the ZERO DRIFT and ZERO SHIFT.

During the temperature tests the humidity shall be maintained within the range of STANDARD TEST VALUES.

6.4.7 Humidity

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

Within this RATED RANGE

– the LIMITS OF VARIATION of RESPONSE shall be ±1,0 %;

– the ZERO DRIFT over 10 min and the ZERO SHIFT shall not vary from their values at the reference humidity 50 % RH by more than ±1,0 % of the INDICATED VALUE produced by the minimum effective input current or dose rate.

Compliance with this performance requirement shall be checked by measuring the following PERFORMANCE CHARACTERISTICS at the lowest and highest relative humidities in the RATED RANGE, and at least at one other relative humidity at or near the reference humidity:

a) the RESPONSE to a constant input current which gives approximately the REFERENCE INDICATED VALUE, on each dose range provided;

b) the ZERO DRIFT and ZERO SHIFT on the most sensitive dose rate range (see 6.4.1 and 6.4.2).

Before taking any measurements at each of the relative humidities the MEASURING ASSEMBLY shall be exposed to that relative humidity for at least 12 h.

NOTE An absolute humidity of near 20 $g \cdot m^{-3}$ can be attained under any of the following conditions:

Relative humidity %	Air temperature °C
80	+26,5
75	+25
60	+30
50	+35

6.4.8 STRAY RADIATION effect

NOTE This requirement applies to those parts of the MEASURING ASSEMBLY that are normally outside the radiation room, i.e. that are situated in a level of radiation sufficiently low for occupation by personnel during the measurement.

The MINIMUM RATED RANGE of STRAY RADIATION dose equivalent rate shall be from zero to 0,2 mSv/h.

Within this RATED RANGE the ZERO DRIFT and ZERO SHIFT of a dose rate meter, shall not vary from the value measured with the STRAY RADIATION less than 7,5 μSv/h by more than ±1,0 % of the INDICATED VALUE produced by the minimum effective input current or dose rate.

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

a) Position the MEASURING ASSEMBLY in a uniform field of PHOTON radiation of known dose equivalent rate [μSv/h] equal to or greater than the maximum RATED STRAY RADIATION dose equivalent rate. For a MEASURING ASSEMBLY supplied for use with unknown IONIZATION CHAMBERS, the energy of the STRAY RADIATION shall be that of cobalt-60 GAMMA RADIATION, otherwise it shall be the highest RATED radiation energy or cobalt-60 GAMMA RADIATION, whichever has the lower energy.

NOTE This test may be carried out at higher dose equivalent rates, for example 1 to 10 mSv/h, and the results may be linearly extrapolated, if necessary, down to the maximum RATED dose equivalent rate.

b) Carry out the ZERO DRIFT test detailed in 6.4.1 steps a) to i).

c) Subtract the value of ZERO DRIFT measured in test 6.4.1 (performed under STANDARD TEST CONDITIONS with zero STRAY RADIATION) from the value measured following a) and b) above to give the VARIATION in ZERO DRIFT caused by increasing the STRAY RADIATION dose equivalent rate from its REFERENCE VALUE to its maximum RATED VALUE.

d) Carry out the ZERO SHIFT test detailed in 6.4.2 steps a) to h).

e) Subtract the value of ZERO SHIFT measured in test 6.4.2 (performed under STANDARD TEST CONDITIONS with zero STRAY RADIATION) from the value measured following a) and b) above to give the VARIATION in ZERO SHIFT caused by increasing the STRAY RADIATION dose equivalent rate from its REFERENCE VALUE to its maximum RATED VALUE.

6.5 Performance requirements particular to battery-operated MEASURING ASSEMBLIES

During the "useful life" of a set of operating batteries the LIMITS OF VARIATION of RESPONSE shall be ±0,5 %.

Compliance with this performance requirement shall be checked by measuring (on each dose range provided) the RESPONSE of the MEASURING ASSEMBLY (to that constant input charge which gives approximately the REFERENCE INDICATED VALUE) under two different conditions:

a) with a set of fresh batteries installed;

b) with a set of used batteries that are sufficiently low to cause a low battery condition to be displayed.

6.6 Performance requirements particular to supply mains-operated MEASURING ASSEMBLIES

6.6.1 MAINS VOLTAGE – static

The MINIMUM RATED RANGE shall be from –12 % to +10 % of a stated nominal value.

Within the RATED RANGE the LIMITS OF VARIATION of RESPONSE shall be ±0,5 %.

Compliance with this performance requirement shall be checked by measuring on each dose range provided, at the minimum and maximum RATED MAINS VOLTAGES, the VARIATION of RESPONSE to that constant input charge which gives approximately the REFERENCE INDICATED VALUE.

6.6.2 MAINS VOLTAGE – VARIATION during a measurement

The LIMITS OF VARIATION of the INDICATED VALUE caused by varying the mains supply voltage over the RATED RANGE in 10 s or less when the MEASURING ASSEMBLY is in the "measure" condition shall be ±0,5 % of the minimum effective INDICATED VALUE.

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

a) Connect the CHAMBER ASSEMBLY having the highest collector to polarizing electrode capacitance of those normally supplied for use with the MEASURING ASSEMBLY to the input of the MEASURING ASSEMBLY. Select the most sensitive dose range.

b) Using a suitable RADIATION SOURCE, for example a radioactive STABILITY CHECK DEVICE, irradiate the IONIZATION CHAMBER at a constant dose rate.

c) With the MAINS VOLTAGE set to its REFERENCE VALUE make three repeat measurements of dose using a 10 s integration time and record the mean INDICATED VALUE as M_0.

d) Make three more repeat measurements of dose integrated over 10 s, but this time during each 10 s period whilst the dosimeter is in the "measure" condition ramp the a.c. voltage supplied to the MEASURING ASSEMBLY from its maximum to its minimum RATED VALUE. Record the mean INDICATED VALUE as M_1. Calculate V_1, the VARIATION of INDICATED VALUE due to decreasing the mains supply voltage during the measurement, using the equation:

$$V_1 = 100 \times (M_1 - M_0)/M_0$$

e) Make three more repeat measurements of dose integrated over 10 s, but this time during each 10 s period whilst the dosimeter is in the "measure" condition ramp the a.c. voltage supplied to the MEASURING ASSEMBLY from its minimum to its maximum RATED VALUE. Record the mean INDICATED VALUE as M_2. Calculate V_2, the VARIATION of INDICATED VALUE due to increasing the mains supply voltage during the measurement, using the equation:

$$V_2 = 100 \times (M_2 - M_0)/M_0$$

f) The value of the limit of VARIATION of the INDICATED VALUE quoted in the ACCOMPANYING DOCUMENTS shall be the maximum of the values of V_1 and V_2 obtained.

7 STABILITY CHECK DEVICE performance requirements

7.1 General

There are two types of STABILITY CHECK DEVICE normally used in RADIOTHERAPY dosimetry:

a) An instrument STABILITY CHECK DEVICE to check the stability of RESPONSE of the MEASURING ASSEMBLY only. This uses either:
   1) an electrical circuit to generate a constant current, charge or potential difference which can be injected into the input of the MEASURING ASSEMBLY, or
   2) a RADIOACTIVE SOURCE with an IONIZATION CHAMBER. Such a device shall apply to the input of the MEASURING ASSEMBLY either a reproducible current produced by a RADIOACTIVE SOURCE in a sealed ionization volume or a current proportional to air density produced by a RADIOACTIVE SOURCE in an unsealed ionization volume.

b) An overall STABILITY CHECK DEVICE to check the stability of the combined RESPONSE of the IONIZATION CHAMBER and MEASURING ASSEMBLY. This uses a RADIOACTIVE SOURCE for irradiating the IONIZATION CHAMBER in a reproducible constant RADIATION FIELD.

7.2 General performance requirements for STABILITY CHECK DEVICES

7.2.1 Long-term stability

The limit of VARIATION of the current, charge or potential difference output by the STABILITY CHECK DEVICE shall be not greater than ±0,5 % over one year (after correction for source decay in the case of a radioactive STABILITY CHECK DEVICE).

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

a) Retain a representative STABILITY CHECK DEVICE.

b) Using the same reference MEASURING ASSEMBLY (the display of which has been set to read in the appropriate "check" or "measure" mode) and, if required, the same reference CHAMBER ASSEMBLY measure its output at intervals of not more than one month over a total period of not less than six months. On each occasion, the reference MEASURING ASSEMBLY shall first have been calibrated by injecting a charge, the value of which is traceable to the relevant NATIONAL STANDARD of charge, to enable a correction to be made for changes in the RESPONSE of the reference MEASURING ASSEMBLY.

c) Draw a graph of RESPONSE against time in months. From this graph obtain, by extrapolation if necessary, a value for the change in output over one year.

7.2.2 Repeatability

The STANDARD DEVIATION of a single measurement with the STABILITY CHECK DEVICE as determined from repeated measurements shall not exceed 0,3 % of the mean output value.

Compliance with this performance requirement shall be checked by taking 10 measurements in the manner specified in the INSTRUCTIONS FOR USE and calculating the STANDARD DEVIATION.

When testing the repeatability of an overall STABILITY CHECK DEVICE the reference CHAMBER ASSEMBLY shall be completely removed from the STABILITY CHECK DEVICE and replaced between successive measurements.

During the test the overall STABILITY CHECK DEVICE and the reference IONIZATION CHAMBER shall be kept as nearly at temperature equilibrium as possible, but corrections may be made for changes in air density if necessary.

8 Constructional requirements as related to PERFORMANCE CHARACTERISTICS

8.1 Constructional requirements on CHAMBER ASSEMBLIES

For SEALED CHAMBERS, the MANUFACTURER shall provide an overall STABILITY CHECK DEVICE.

8.2 Constructional requirements on MEASURING ASSEMBLIES

8.2.1 Adjustment of RESPONSE

If the RESPONSE of the MEASURING ASSEMBLY can be adjusted either:

a) to correct for one or more of the following:
   - long term changes in the RESPONSE of the dosimeter;
   - the effect of temperature and pressure on the RESPONSE of the IONIZATION CHAMBER, or

b) to apply a CALIBRATION FACTOR,

then the MEASURING ASSEMBLY shall be designed such that it is not possible for the OPERATOR to unintentionally change any of the adjustment factors.

Specifically the design shall be such that:

- control switches and scaling potentiometers are either inside the MEASURING ASSEMBLY and inaccessible from the outside without the use of a TOOL, or they shall be clearly marked and scaled so that they can be set with a precision corresponding to the RESOLUTION of the instrument and then locked to avoid accidental alterations to the setting;
- it is not possible for digitally stored calibration and/or CORRECTION FACTORS to be changed until after the OPERATOR has either entered a security code (or password) or changed the position of a locked or inaccessible switch.

Compliance with this constructional requirement shall be checked by inspection.

8.2.2 Display device

8.2.2.1 General

A display device shall be provided for the visual presentation of data from which the value of the dose or dose rate can be derived. For scanning-type dosimeters the display may be replaced by a data output terminal and software to display or print MEASURED VALUES.

8.2.2.2 Scale marking

For MEASURING ASSEMBLIES supplied with disconnectable CHAMBER ASSEMBLIES, suitable means shall be incorporated so that the correct relationship between the reading and the INDICATED VALUE can be easily and unambiguously established by the OPERATOR for each CHAMBER ASSEMBLY.

8.2.2.3 Display by analogue panel meter

The meter shall have a precision not worse than class index 0,5 as specified in 4.1 of IEC 60051:1997.

The maximum range of movement of the pointer shall be at least 3 % greater than the maximum reading and the meter shall not be damaged when an input to the MEASURING ASSEMBLY corresponding to full reading on the least sensitive range is applied with the instrument switched to the most sensitive range.

The pointer shall remain above the maximum reading at least as long as this input is applied.

8.2.2.4 Display by digital panel meter

A warning indication shall show if the input corresponds to a reading greater than the maximum display reading.

A device shall be incorporated to test the correct operation of an electronic display if the numerals are made up of segments.

Mechanical registers shall be capable of responding correctly to input currents or pulse rates at least 10 % greater than the maximum RATED input current, or pulse rate.

8.2.2.5 Display by combination of digital and analogue panel meter

If the fraction of the last digit displayed is indicated by an analogue panel meter, the requirements of 8.2.2.4 shall be met.

8.2.2.6 Other methods of display

Methods of display other than those specified in 8.2.2.3 to 8.2.2.5 may be used. Such other methods shall not be inferior to the specified methods in readability, linearity and RESOLUTION.

Compliance with the constructional requirements of 8.2.2 shall be checked by inspection.

8.2.3 Battery indication and compensation

An external indication of battery power shall be provided by indication of on-load battery voltages or by other indication when the batteries have reached the end of their useful life. If necessary for the instrument to comply with the requirement in 6.4.1, a control may be provided to compensate for changes in battery voltage.

Compliance with this constructional requirement shall be checked by inspection.

8.2.4 Input current threshold

If there is a threshold input current below which the MEASURING ASSEMBLY will not measure, the MANUFACTURER shall provide a means for the RESPONSIBLE ORGANIZATION to remove this threshold if required.

Compliance with this constructional requirement shall be checked by inspection.

8.2.5 Automatic termination of measurement in the dose mode

If the MEASURING ASSEMBLY automatically terminates the measurement of dose the MANUFACTURER shall provide a means for the RESPONSIBLE ORGANIZATION to disable this function if required.

Compliance with this constructional requirement shall be checked by inspection.

8.3 Constructional requirements on STABILITY CHECK DEVICES

8.3.1 Output of the STABILITY CHECK DEVICES

The output of the STABILITY CHECK DEVICE shall be such that

– for a dosimeter the time taken to achieve the check indication is not significantly longer than the time taken to achieve this indication at the minimum RATED dose rate;

– for a dose rate meter, the check indication is greater than the minimum effective INDICATED VALUE.

8.3.2 Constructional requirements particular to a radioactive type STABILITY CHECK DEVICE

The following requirements apply:

a) The half-life of the RADIONUCLIDE shall be as long as practicable and shall be not less than five years.

b) The purity of the radioactive material shall be adequate to ensure that the true ACTIVITY after a period of three years is not different by more than ±1,5 % from that expected from the decay data stated by the MANUFACTURER for that radioactive STABILITY CHECK DEVICE.

8.3.3 Constructional requirements particular to an overall STABILITY CHECK DEVICE

The following requirements apply:

a) Such a device shall apply a constant (after correction for radioactive decay) RADIATION FIELD to the IONIZATION CHAMBER.

b) The geometrical relationship between the RADIOACTIVE SOURCE and the IONIZATION CHAMBER shall be accurately repeatable and such as to minimize the effect of small changes in chamber position.

c) The construction shall be such as to allow the assessment of the temperature at the position of the IONIZATION CHAMBER.

d) A device shall be provided to close the aperture when the IONIZATION CHAMBER is removed, in order to prevent the accidental entry of small objects which could damage the IONIZATION CHAMBER when it is re-inserted.

Compliance with the constructional requirements on STABILITY CHECK DEVICES shall be checked by inspection.

8.4 Constructional requirements on PHANTOMS and build-up caps

When a solid or liquid-filled PHANTOM is intended to locate the measuring volume of an IONIZATION CHAMBER at a specified depth (or depths) in a medium and in a specified position relative to the axis of the RADIATION BEAM, the following requirements apply:

– the tolerance of the depth of the REFERENCE POINT of the IONIZATION CHAMBER (measured along the axis of the RADIATION BEAM from the surface of the PHANTOM nearest to the RADIATION SOURCE) from each nominal value specified for the PHANTOM shall be ±0,5 mm or ±1,0 % of the nominal value, whichever is the greater (see Figure 1);

– the tolerance of the lateral position of the REFERENCE POINT of the IONIZATION CHAMBER relative to the intended position of the axis of the RADIATION BEAM (which is marked on the PHANTOM, see Clause 10) shall be ±1,0 mm (see Figure 2).

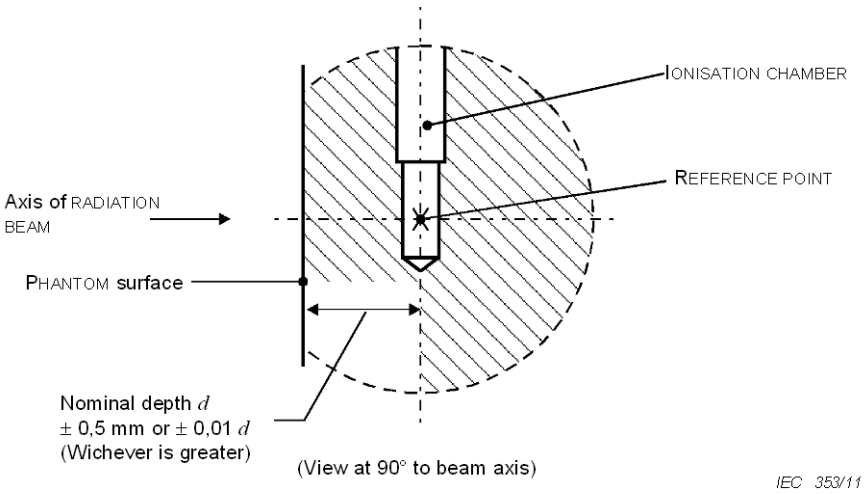


Figure 1 – Tolerance of depth in PHANTOM

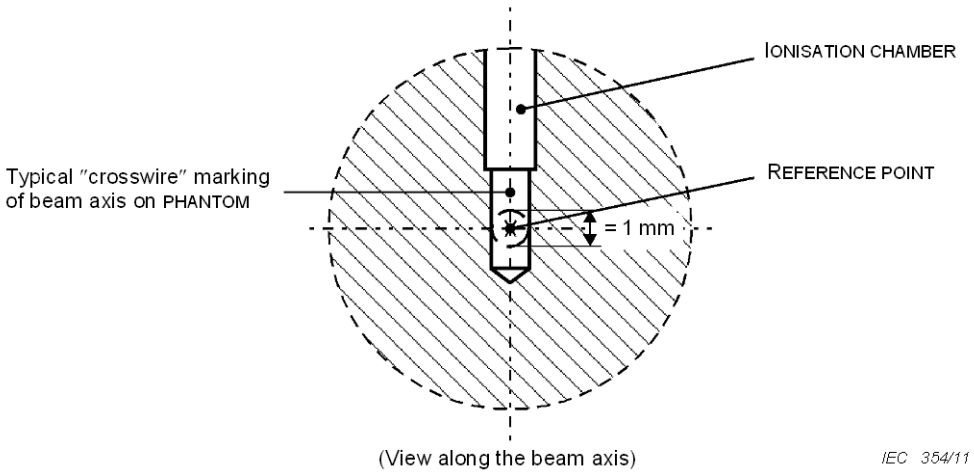


Figure 2 – Tolerance of lateral position in PHANTOM

If the PHANTOM is designed to accept two or more IONIZATION CHAMBERS simultaneously the above requirements shall apply equally to each chamber position. The requirements shall also apply if removable adaptors are provided in order to fit a number of different types of IONIZATION CHAMBER into the PHANTOM.

Compliance with this constructional requirement shall be checked by measurement.

9 Marking

9.1 Marking required on CHAMBER ASSEMBLY

9.1.1 Information required in IEC 60601-1

The following information shall be clearly and permanently marked by the MANUFACTURER on the CHAMBER ASSEMBLY or on a firmly attached label:

a) the information required by 7.2 of IEC 60601-1:2005;

b) for a CHAMBER ASSEMBLY which does not meet the requirements of TYPE B, BF or CF APPLIED PART, as defined in IEC 60601-1:2005, a warning that the CHAMBER ASSEMBLY shall not be used in contact with a PATIENT.

NOTE The warning symbol (No. 14 of IEC 61010-1) may be used to indicate non-compliance with requirements for TYPE B, BF or CF APPLIED PART.

9.1.2 Other information

The following information shall be clearly marked by the MANUFACTURER either on a label firmly attached to the CHAMBER ASSEMBLY or on a data sheet included with the packing of the CHAMBER ASSEMBLY:

a) the position of the REFERENCE POINT of the IONIZATION CHAMBER;

NOTE This is to enable the IONIZATION CHAMBER to be accurately positioned during calibration.

b) the nominal full reading when the chamber is supplied specifically for use with one MEASURING ASSEMBLY;

c) the RATED RANGE of RADIATION QUALITIES.

9.1.3 Compliance check

Compliance with the requirements of 9.1 shall be checked by inspection of the CHAMBER ASSEMBLY and its packaging.

9.2 Marking required on MEASURING ASSEMBLY

9.2.1 CHAMBER ASSEMBLY in contact with the PATIENT

The following information shall be clearly and permanently marked by the MANUFACTURER on those MEASURING ASSEMBLIES that are intended for use with a CHAMBER ASSEMBLY which is in contact with a PATIENT, i.e. on a MEASURING ASSEMBLY which is designed to meet the requirements of TYPE B, BF or CF APPLIED PART as defined in IEC 60601-1:

– the information required by 7.2 of IEC 60601-1:2005.

9.2.2 CHAMBER ASSEMBLY not in contact with the PATIENT

The following information shall be clearly and permanently marked by the MANUFACTURER on those MEASURING ASSEMBLIES that are not intended for use with a CHAMBER ASSEMBLY which is in contact with a PATIENT, i.e. on a MEASURING ASSEMBLY which is not designed to meet the requirements of TYPE B, BF or CF APPLIED PART, as defined in IEC 60601-1:

a) the information required by IEC 61010-1;

b) a warning that the MEASURING ASSEMBLY shall not be connected to a CHAMBER ASSEMBLY which is to be used in contact with a PATIENT.

NOTE The warning symbol (No. 14 of IEC 61010-1) may be used to indicate non-compliance with requirements for TYPE B, BF or CF APPLIED PART.

9.2.3 Each MEASURING ASSEMBLY

On each MEASURING ASSEMBLY the MANUFACTURER shall:

a) clearly and permanently mark the function of all electrical connections, operating controls and display devices;

b) provide, either by means of clear permanent marking or easily understood instructions on the display, sufficient information to enable a qualified OPERATOR to use the MEASURING ASSEMBLY without frequent reference to the INSTRUCTIONS FOR USE.

9.2.4 MEASURING ASSEMBLY with a display scaled in dose

On a MEASURING ASSEMBLY with a display scaled in dose (dose rate) units the MANUFACTURER shall provide:

a) a clear legend on or adjacent to the display to indicate whether the reading is "uncorrected" or "corrected";

b) in cases where the reading is "corrected", a simple means for the OPERATOR to call-up on the display the value of each and every CORRECTION FACTOR that has been applied to that reading.

9.2.5 Multi-range MEASURING ASSEMBLY

On a multi-range MEASURING ASSEMBLY with an analogue display, the MANUFACTURER shall mark the range changing controls with the INDICATED VALUE at full scale for each position. Range changing controls shall not be marked with scale multiplying factors.

9.2.6 MEASURING ASSEMBLY with more than one chamber

If the MEASURING ASSEMBLY is supplied with more than one chamber, the chambers may be identified by markings on the MEASURING ASSEMBLY.

9.2.7 Graphical symbols

Any graphical symbols used shall be in accordance with IEC 60417.

9.2.8 Compliance check

Compliance with the requirements of 9.2 shall be checked by inspection of the MEASURING ASSEMBLY.

9.3 Marking required on STABILITY CHECK DEVICE

9.3.1 General

The STABILITY CHECK DEVICE shall be marked in accordance with the requirements of Clause 5 of IEC 61010-1 and additionally with the serial number of the device.

9.3.2 STABILITY CHECK DEVICE containing a RADIOACTIVE SOURCE

For a STABILITY CHECK DEVICE containing a RADIOACTIVE SOURCE, a permanent label shall be affixed to the surface of the shielded container and, if the device is structurally part of the MEASURING ASSEMBLY, on the surface of the CONTROL PANEL, and on the surface of the carrying case, if one is supplied. This label shall include the international trefoil symbol and the name of the RADIONUCLIDE, the ACTIVITY of the RADIONUCLIDE and the date for which the stated ACTIVITY is applicable.

9.3.3 Device which contributes to protection against IONIZING RADIATION

If any part of the device which contributes to protection against IONIZING RADIATION has to be detached in order to insert the chamber, this part shall bear a warning about the loss of protection and the necessity for replacing it after the reading.

9.3.4 Compliance check

Compliance with the requirements of 9.3 shall be checked by inspection of the STABILITY CHECK DEVICE.

9.4 Marking required on PHANTOM or build-up cap

The PHANTOM shall be marked to identify:

a) which surface is intended to be nearest the RADIATION SOURCE;

b) the intended position of the axis of the beam of radiation on the radiation entry and exit faces of the PHANTOM;

c) the intended position of the REFERENCE POINT of the IONIZATION CHAMBER (or chambers) if different from b) also on the radiation entry and exit faces of the PHANTOM.

The PHANTOM and any additional sheets, caps or blocks of build-up material shall be marked to indicate the intended method of assembly.

Compliance with the requirements of this subclause shall be checked by inspection.

10 ACCOMPANYING DOCUMENTS

10.1 ACCOMPANYING DOCUMENTS for CHAMBER ASSEMBLY

10.1.1 INSTRUCTIONS FOR USE of CHAMBER ASSEMBLY

10.1.1.1 General

The following requirements apply:

a) The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include manual giving INSTRUCTIONS FOR USE of the CHAMBER ASSEMBLY.

b) The instruction manual shall comply with the requirements contained in IEC 61187.

c) Sufficient information shall be given in the INSTRUCTIONS FOR USE to ensure unambiguous identification of the instrument to which they apply.

d) For equipment which does not meet the requirements of TYPE B, BF or CF APPLIED PART as defined in IEC 60601-1 a warning shall be given in the INSTRUCTIONS FOR USE that the instrument shall not be used in contact with a PATIENT.

e) For equipment which does not fulfil all the requirements given in Clause 5 of this standard, information shall be provided about those subclauses with which it does not comply.

Compliance with the requirements of 10.1.1 shall be checked by inspection of the instruction manual part of the ACCOMPANYING DOCUMENTS.

10.1.1.2 Information on the RATED RANGES

The following information on the RATED RANGES for the CHAMBER ASSEMBLY shall be supplied:

– RADIATION QUALITIES (type of radiation and energy);

– field size (dependent upon RADIATION QUALITY).

10.1.1.3 Information on the method of operation

The following information on the method of operation of the CHAMBER ASSEMBLY shall be provided:

a) for a CHAMBER ASSEMBLY supplied independently of a MEASURING ASSEMBLY, guidance about the type of MEASURING ASSEMBLY for which it is suitable and about the method of connection, and a warning if a current-limiting resistor is necessary;

b) appropriate methods of supporting the CHAMBER ASSEMBLY, and warning about inappropriate methods;

c) whether the chamber is suitable for use in a PHANTOM;

d) the recommended orientation in the RADIATION BEAM and information about the dependence of RESPONSE on orientation in the RADIATION BEAM;

e) the RATED RANGE of polarizing voltages;

f) the maximum polarizing voltage that may be applied without damage and without charge multiplication;

g) guidance about the time to be allowed before making a measurement after the chamber has been subjected to the following:

- switching-on of polarizing voltage;
- connection of electrical fittings;
- movement of cable;
- sudden change of pressure or temperature;
- effects of transport;

h) recommended methods of measuring the signal from the IONIZATION CHAMBER without STRAY RADIATION or external fields;

i) a warning that frequent checking with a STABILITY CHECK DEVICE is advisable especially for a sealed IONIZATION CHAMBER;

j) a warning where applicable that long EXPOSURE to high humidity may have an adverse effect and recommended methods of treatment of the chamber after such an EXPOSURE;

k) recommended methods of correcting the INDICATED VALUE of VENTED CHAMBERS for changes in air density;

l) permissible methods of cleaning the CHAMBER ASSEMBLY;

m) a warning against damaging fragile parts, for example the window of thin-window chambers;

n) the type of radioactive STABILITY CHECK DEVICE (if any) to be used with the dosimeter;

o) a warning that LEAKAGE CURRENT should be checked;

p) the collection time for both positive ions and ELECTRONS at the recommended polarizing voltage(s).

q) the dose rate (continuous radiation) and ABSORBED DOSE per pulse (pulsed radiation) for which the ion collection efficiency is 99 % if the nominal polarizing voltage is applied.

10.1.1.4 Values derived from TYPE TESTS

The INSTRUCTIONS FOR USE shall include the values derived from TYPE TESTS of the following performance data:

a) limits at STANDARD TEST CONDITIONS of the PERFORMANCE CHARACTERISTICS listed in Table 3);

b) RATED RANGES of the INFLUENCE QUANTITIES and the associated VARIATIONS of the PERFORMANCE CHARACTERISTICS listed in Table 5);

c) the EFFECTIVE RANGES of dose and dose rate over which the performance data declared is valid.

10.1.1.5 Information on the construction of the chamber

The INSTRUCTIONS FOR USE shall include the following information on the construction of the chamber:

a) the size and shape of the IONIZATION CHAMBER, both internal and external;

b) the elemental composition by mass, dimensions and density of the IONIZATION CHAMBER walls, collector electrode and insulator and the elemental composition by mass and thickness of all conductive coatings;

c) the electrical connections between the terminals/body of the cable connector and

- each external conducting part of the CHAMBER ASSEMBLY;
- each electrode within the IONIZATION CHAMBER.

d) the elemental composition by mass and dimensions of the build-up cap, if any;

e) the position of the REFERENCE POINT of the IONIZATION CHAMBER in relation to a recognizable point (e.g. the tip of a THIMBLE CHAMBER) or a mark;

f) whether the IONIZATION CHAMBER is unguarded, partially guarded or guarded;

g) whether the IONIZATION CHAMBER is vented to the atmosphere (i.e. "unsealed");

NOTE 1 This is because it is essential for the OPERATOR to correct the RESPONSE of a VENTED CHAMBER for the effects of ambient pressure and temperature on the air density within the measuring volume.

h) whether the IONIZATION CHAMBER is sealed.

NOTE 2 This is because it is essential for the OPERATOR to check the RESPONSE of a SEALED CHAMBER with a radioactive STABILITY CHECK DEVICE immediately before and after use.

10.1.2 Test sheet for CHAMBER ASSEMBLY

The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include a test sheet giving the results of the ROUTINE TESTS carried out on the individual CHAMBER ASSEMBLY as part of the MANUFACTURER'S quality assurance programme.

As a minimum, the test sheet shall state the following:

a) the type number and serial number of the CHAMBER ASSEMBLY;

b) the value measured for the CHAMBER ASSEMBLY LEAKAGE CURRENT without IRRADIATION;

c) CORRECTION FACTORS for the effects of the following INFLUENCE QUANTITIES shall be provided, if the performance of the IONIZATION CHAMBER does not meet the requirements laid down in the relevant subclause without such a CORRECTION FACTOR:

1) polarity of polarizing voltage (5.2.11);
2) field size (5.3.2 or 5.2.7);
3) temperature (5.5.2 or 5.6.2).

d) CORRECTION FACTORS for any other INFLUENCE QUANTITY known to affect the RESPONSE of the IONIZATION CHAMBER by more than ±1,0 %;

e) The REFERENCE VALUE of the INFLUENCE QUANTITIES to which the CORRECTION FACTORS correct the RESPONSE of the IONIZATION CHAMBER. Normally these will be the REFERENCE VALUES for which the radiation calibration applies.

Compliance with the requirements of this subclause shall be checked by inspection of the test sheet part of the ACCOMPANYING DOCUMENTS.

10.1.3 Calibration certificate for CHAMBER ASSEMBLY

If the CHAMBER ASSEMBLY is supplied with a calibration then the MANUFACTURER shall provide a calibration certificate giving the calibration and CORRECTION FACTORS by which the RESPONSE of the IONIZATION CHAMBER may be corrected to give the dose or dose rate at the REFERENCE POINT OF THE CHAMBER (see 5.3.1 and 5.4.1).

The calibration certificate shall state the following:

a) the type number and serial number of the CHAMBER ASSEMBLY;

b) the calibration conditions, in particular:

1) the reference RADIATION QUALITY and REFERENCE INDICATED VALUE at which the CALIBRATION FACTOR applies;
2) the individual RADIATION QUALITIES within the RATED RANGE at which each of the CORRECTION FACTORS applies;

3) the instrument settings and the operating conditions under which the calibrations were carried out;

4) for each INFLUENCE QUANTITY the REFERENCE VALUE to which the INDICATED VALUES were corrected, for example "corrected to an ambient pressure of 101,3 kPa".

c) the name and address of the calibration laboratory, signature of the person performing the calibration and traceability to the NATIONAL STANDARD.

If the calibration has been performed at a laboratory that is not a member of a national or international accreditation scheme, then the calibration certificate may include the following statement: "This calibration is provided to indicate the VARIATION of the chamber RESPONSE with RADIATION QUALITY. It should not be used directly or indirectly to calibrate the dose to PATIENTS".

Compliance with the requirements of this subclause shall be checked by inspection of the calibration certificate part of the ACCOMPANYING DOCUMENTS.

10.2 ACCOMPANYING DOCUMENTS for MEASURING ASSEMBLY

10.2.1 INSTRUCTIONS FOR USE of MEASURING ASSEMBLY

10.2.1.1 General

The following requirements apply:

a) The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include manual giving INSTRUCTIONS FOR USE of the MEASURING ASSEMBLY.

b) The instruction manual shall comply with the requirements contained in IEC 61187.

c) Sufficient information shall be given in the INSTRUCTIONS FOR USE to ensure unambiguous identification of the MEASURING ASSEMBLY to which they apply.

d) For equipment which does not meet the requirements of TYPE B, BF or CF APPLIED PART as defined in IEC 60601-1, a warning shall be given in the INSTRUCTIONS FOR USE that the MEASURING ASSEMBLY shall not be connected to a CHAMBER ASSEMBLY which is used in contact with a PATIENT.

e) For equipment which does not fulfil all the requirements given in Clause 6 of this standard, information shall be provided about those subclauses with which it does not comply.

Compliance with the requirements of 10.2.1 shall be checked by inspection of the instruction manual part of the ACCOMPANYING DOCUMENTS.

10.2.1.2 Information on the method of operation

The following minimum information on the method of operation of the MEASURING ASSEMBLY shall be provided:

a) for a mains-powered instrument:

1) the RATED RANGE of MAINS VOLTAGES and frequencies;

2) the means of adjusting the instrument (if necessary) to accept the MAINS VOLTAGE available.

b) for a battery-powered instrument:

1) the "useful life" of a set of operating batteries;

2) the method of testing whether the batteries need replacing;

3) the method for replacing the batteries.

c) the function and method of operation of each control, the purpose of each socket and the meaning of each indication;

d) the correct operating position of the MEASURING ASSEMBLY and if necessary, the method of levelling;

e) guidance on the time to be allowed, before making a measurement after the MEASURING ASSEMBLY has been subjected to the following:
   – switching on (STABILIZATION TIME),
   – connection of electrical fittings,
   – sudden changes of temperature or humidity,
   – effects of transport;
f) in case of SCANNING-CLASS DOSIMETERS guidance on the minimum dwell time at a position, or maximum scanning speed, allowing hysteresis-free scans;
g) recommended methods of checking that the RESPONSE is not being affected by high humidity, STRAY RADIATION or external fields;
h) guidance about suitable types of associated IONIZATION CHAMBERS, and types of plugs required;
i) the maximum value of the current available from the polarizing voltage supply;
j) clear instructions on how to apply the CALIBRATION FACTOR and CORRECTION FACTORS to the INDICATED VALUE to obtain the TRUE VALUE of ABSORBED DOSE [dose rate] or KERMA [KERMA rate] at the REFERENCE POINT of the IONIZATION CHAMBER under REFERENCE CONDITIONS;
k) for a MEASURING ASSEMBLY having a built-in facility for correcting the IONIZATION CHAMBER reading, the algorithms used to make this correction;
l) for a MEASURING ASSEMBLY having a built-in facility for carrying out some form of analysis on the INDICATED VALUES, for example calculating the mean and STANDARD DEVIATION of a set of repeat readings, the algorithms used to make this analysis.

10.2.1.3 Values derived from TYPE TESTS

The INSTRUCTIONS FOR USE shall include the values derived from TYPE TESTS of the following data:

a) limits at STANDARD TEST CONDITIONS of the PERFORMANCE CHARACTERISTICS listed in Table 4);
b) RATED RANGES of the INFLUENCE QUANTITIES and the associated VARIATIONS of the PERFORMANCE CHARACTERISTICS listed in Tables 5) and 6);
c) the EFFECTIVE RANGES of those quantities listed below over which the performance data declared is valid:
   – readings,
   – INDICATED VALUES,
   – input currents.

10.2.1.4 Information where relevant on the construction

The INSTRUCTIONS FOR USE shall include the following information where relevant on the construction of the MEASURING ASSEMBLY:

a) number and types of batteries required;
b) type and rating of fuses required;
c) potential differences from earth of the polarizing supply and the guard terminal;
d) if access to the inside is permitted, a circuit diagram with layout or a detailed block diagram, and the means of access;
e) if access to the inside is not permitted, a warning to this effect;
f) whether the MEASURING ASSEMBLY is sealed against the effect of high humidity;
g) method of maintaining the desiccator, if one is required.

10.2.2 Test sheet for MEASURING ASSEMBLY

The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include a test sheet giving the results of the ROUTINE TESTS carried out on the individual MEASURING ASSEMBLY as part of the MANUFACTURER'S quality assurance programme.

As a minimum, the test sheet shall state the following:

a) the type number and serial number of the MEASURING ASSEMBLY;

b) the value measured for the ZERO DRIFT of the MEASURING ASSEMBLY when in the "measure" condition (6.3.1 and/or 6.4.1);

c) CORRECTION FACTORS for the effects of the following INFLUENCE QUANTITIES shall be provided, if the performance of the instrument does not meet the requirements laid down in the relevant subclause without such a CORRECTION FACTOR:

   1) NON-LINEARITY of MEASURING ASSEMBLY (6.3.3 and/or 6.4.3);

   2) range change (6.3.4 and/or 6.4.4);

   3) dead time (6.3.5);

   4) temperature (6.3.6 and/or 6.4.6).

d) CORRECTION FACTORS for any other INFLUENCE QUANTITY known to affect the RESPONSE of the MEASURING ASSEMBLY by more than ±1,0 %;

e) the REFERENCE VALUE of the INFLUENCE QUANTITIES to which the CORRECTION FACTORS correct the RESPONSE of the MEASURING ASSEMBLY.

Compliance with the requirements of this subclause shall be checked by inspection of the test sheet part of the ACCOMPANYING DOCUMENTS.

10.2.3 Calibration certificate for MEASURING ASSEMBLY

If the MEASURING ASSEMBLY is supplied with an IONIZATION CHAMBER with a calibration, then the MANUFACTURER shall provide a calibration certificate giving the calibration and CORRECTION FACTORS by which the INDICATED VALUE of the MEASURING ASSEMBLY may be corrected to give the dose or dose rate at the REFERENCE POINT of this IONIZATION CHAMBER (see 5.3.1 and 5.4.1).

The calibration certificate shall state the following:

a) the type number and serial number of the MEASURING ASSEMBLY;

b) the type number and serial number of the CHAMBER ASSEMBLY;

c) the calibration conditions, in particular:

   1) the reference RADIATION QUALITY and REFERENCE INDICATED VALUE at which the CALIBRATION FACTOR applies;

   2) the individual RADIATION QUALITIES within the RATED RANGE at which each of the CORRECTION FACTORS applies;

   3) the instrument settings and the operating conditions under which the calibrations were carried out;

   4) for each INFLUENCE QUANTITY the REFERENCE VALUE to which the INDICATED VALUES were corrected, for example "corrected to an ambient pressure of 101,3 kPa".

d) the name and address of the calibration laboratory, signature of the person performing the calibration and traceability to the NATIONAL STANDARD.

If the calibration has been performed by a laboratory which is not a member of a national or international accreditation scheme, the calibration certificate may include the following statement: "This calibration is provided to indicate the VARIATION of the chamber RESPONSE with RADIATION QUALITY. It should not be used directly or indirectly to calibrate the dose to PATIENTS".

Compliance with the requirements of this subclause shall be checked by inspection of the calibration certificate part of the ACCOMPANYING DOCUMENTS.

10.3 ACCOMPANYING DOCUMENTS for STABILITY CHECK DEVICE

10.3.1 INSTRUCTIONS FOR USE of STABILITY CHECK DEVICE

The following requirements apply:

a) The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include manual giving INSTRUCTIONS FOR USE of the STABILITY CHECK DEVICE.

b) For instrument STABILITY CHECK DEVICES the manual shall give guidance as to how often and in what manner the MEASURING ASSEMBLY should be checked, and what precautions have to be taken in order to achieve the specified repeatability.

c) For overall STABILITY CHECK DEVICES the manual shall give guidance as to how often and in what manner the chamber and MEASURING ASSEMBLIES should be checked, and what precautions have to be taken in order to achieve the specified repeatability.

d) For radioactive STABILITY CHECK DEVICES the manual shall include instructions on the correct positioning of the IONIZATION CHAMBER and the method of assessing the temperature at the position of the IONIZATION CHAMBER. The manual shall include a warning not to leave the CHAMBER ASSEMBLY in the radioactive STABILITY CHECK DEVICE for unnecessarily long periods of time, if this is likely to have an adverse effect on the performance of the CHAMBER ASSEMBLY.

e) The INSTRUCTIONS FOR USE shall include the value of repeatability derived from TYPE TESTS.

f) The INSTRUCTIONS FOR USE shall include information about the construction of the device and if a RADIOACTIVE SOURCE is used, the name and ACTIVITY of the RADIONUCLIDE, and the dose rate at 2 cm or 10 cm from the surface of the housing so that suitable precautions can be taken for storage and in case of mechanical damage or fire.

Compliance with the requirements of this subclause shall be checked by inspection of the instruction manual part of the ACCOMPANYING DOCUMENTS.

10.3.2 Test sheet for STABILITY CHECK DEVICE

The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include a test sheet giving the results of ROUTINE TESTS carried out on the individual STABILITY CHECK DEVICE (identified uniquely by the type and serial number) as part of the MANUFACTURER'S quality assurance programme.

For radioactive STABILITY CHECK DEVICE the test sheet shall state the following in addition to type and serial number of the device:

a) the name, half-life and ACTIVITY of the RADIONUCLIDE together with the date on which the stated ACTIVITY is applicable;

b) the method used and the results of the tests to demonstrate freedom from radioactive contamination;

c) the results of any measurements made to determine the LEAKAGE RADIATION through the source housing.

Compliance with the requirements of this subclause shall be checked by inspection of the test sheet part of the ACCOMPANYING DOCUMENTS.

10.3.3 Measurement certificate for STABILITY CHECK DEVICE

10.3.3.1 General

If required to be supplied by 10.3.3.2 or 10.3.3.3 the measurement certificate shall state the following:

a) the type number and serial number of the STABILITY CHECK DEVICE;

b) the type number(s) and serial number(s) of the CHAMBER ASSEMBLY and/or MEASURING ASSEMBLY supplied with the STABILITY CHECK DEVICE;

c) the measurement conditions, in particular:

   1) the instrument settings and operating conditions under which the calibration was carried out;

   2) for each INFLUENCE QUANTITY the REFERENCE VALUE to which the check indication was corrected, for example for radioactive STABILITY CHECK DEVICES and vented IONIZATION CHAMBERS the statement "corrected to an ambient pressure of 101,3 kPa".

Compliance with the requirements of 10.3.3 shall be checked by inspection of the calibration certificate part of the ACCOMPANYING DOCUMENTS.

10.3.3.2 Instrument STABILITY CHECK DEVICE

If an instrument STABILITY CHECK DEVICE is supplied with a MEASURING ASSEMBLY the MANUFACTURER shall provide a measurement certificate giving the current reading obtained using the MEASURING ASSEMBLY with the STABILITY CHECK DEVICE before despatch of equipment.

If the STABILITY CHECK DEVICE uses a RADIOACTIVE SOURCE the measurement certificate shall include the date on which the measurement was made and information on how to correct the check indication for radioactive decay.

10.3.3.3 Overall STABILITY CHECK DEVICES

There are two cases:

a) if an overall radioactive STABILITY CHECK DEVICE is supplied with an IONIZATION CHAMBER and MEASURING ASSEMBLY, the MANUFACTURER shall provide a measurement certificate giving the reading obtained using the STABILITY CHECK DEVICE, IONIZATION CHAMBER and MEASURING ASSEMBLY before despatch of the equipment;

b) if an overall radioactive STABILITY CHECK DEVICE is supplied with an IONIZATION CHAMBER only, the MANUFACTURER shall provide a measurement certificate giving the current output by the IONIZATION CHAMBER when used with the STABILITY CHECK DEVICE before despatch of the equipment.

In both cases the measurement certificate shall include the date on which the measurement was made and information on the correction of the check indication for radioactive decay.

10.4 ACCOMPANYING DOCUMENTS for PHANTOMS and build-up caps

The following requirements apply:

a) The ACCOMPANYING DOCUMENTS provided by the MANUFACTURER shall include a manual giving instructions on how to use the PHANTOM or build-up cap and any special instructions necessary, for example how to avoid charge storage effects during ELECTRON dosimetry measurements. This manual may be that of the IONIZATION CHAMBER with which the PHANTOM or build-up cap is supplied or it may be a separate document.

b) If a PHANTOM or build-up cap is provided for calibration of or routine use with an IONIZATION CHAMBER, the INSTRUCTIONS FOR USE shall include information on the dimensions, chemical composition, density and MANUFACTURER of the material from which the PHANTOM or build-up cap is made. This information shall also be given for any additional sheets, caps or blocks of build-up material provided.

c) For a solid- or liquid-filled PHANTOM which is intended to locate the measuring volume of an IONIZATION CHAMBER at a specified depth (or depths) in a medium and in a specified position relative to the axis of the RADIATION BEAM, the ACCOMPANYING DOCUMENTS shall also state:

1) the nominal depth of the REFERENCE POINT of the IONIZATION CHAMBER (measured along the axis of the RADIATION BEAM from the surface of the PHANTOM nearest to the source of radiation), together with the tolerance on this depth expressed either in millimeters or as a percentage of the nominal value;

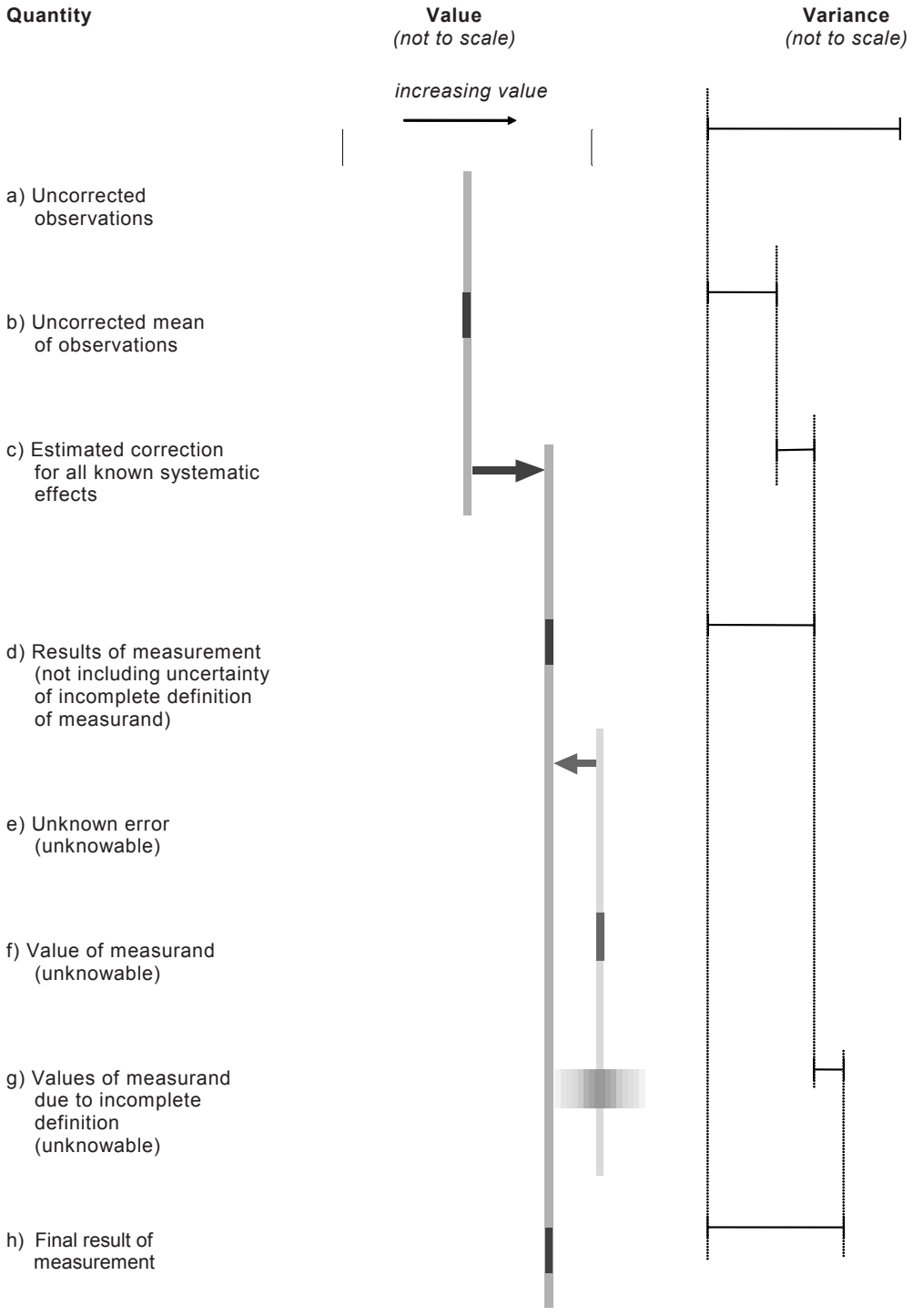
2) the tolerance, expressed in millimeters, of the lateral position of the REFERENCE POINT of the IONIZATION CHAMBER relative to the intended position of the axis of the RADIATION BEAM as marked on the radiation entry and exit faces of the PHANTOM.

Compliance with the requirements of this subclause shall be checked by inspection of the instruction manual part of the ACCOMPANYING DOCUMENTS.

Annex A
(informative)

Values, error and UNCERTAINTY

Figure A.1 shows the relationship between values, error and UNCERTAINTY (ISO/IEC Guide 98-3:2008).



Annex B
(normative)

Test equipment for cable microphony

Figure B.1 shows the test equipment for cable microphony as required in 5.2.10.

The cable is fixed at points A and B. It goes through a guide at point C. The distance between B and C is 55 cm. At point D the cable hangs over a wheel. The whole stands on a table and at point E a weight of about 2 kg is fixed to the cable.

At end F the cable is connected to an electrometer and at the other end G it is connected to an IONIZATION CHAMBER which is inserted partly into a radioactive STABILITY CHECK DEVICE so that a current corresponding to the lower end of the RATED RANGE of dose rate for this IONIZATION CHAMBER is produced.

At point H the cable passes between two wheels. The wheels have a diameter of 8 cm. This pair of wheels is fixed to an excentre which goes up and down with a frequency of 1 Hz and an amplitude of 4 cm from peak to peak.

NOTE 1 The source is not required if the electrometer is bipolar.

NOTE 2 The electrometer should have an adequately fast RESPONSE.

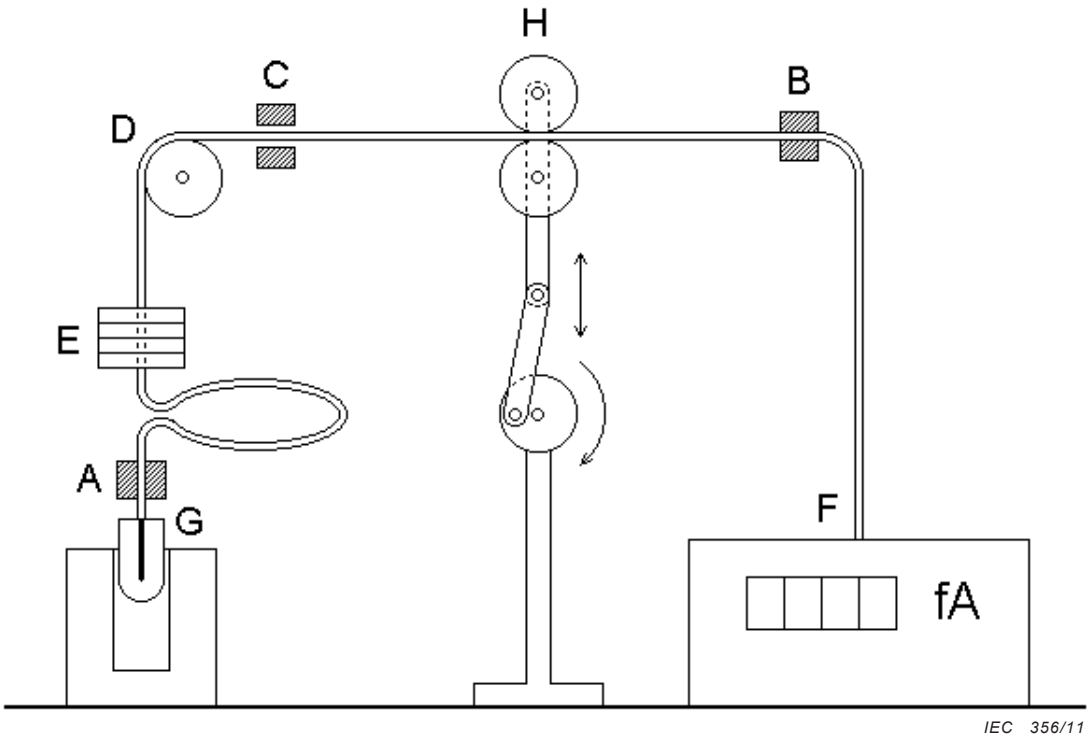


Figure B.1 – Test equipment for cable microphony

Annex C
(normative)

UNCERTAINTY OF MEASUREMENT

C.1 Introduction

For RADIOTHERAPY DOSIMETERS designed to meet the PERFORMANCE CHARACTERISTICS in this standard, one is interested in the question "What is the COMBINED STANDARD UNCERTAINTY in measurements made with these dosimeters?" Until recently, there has been a lack of international consensus on the expression of UNCERTAINTY in measurements. In 1992, the International Standards Organization (ISO) issued a "Guide to the Expression of uncertainty in Measurements" (see ISO/IEC Guide 98-3:2008) which gives recommended procedures for combining the various UNCERTAINTY components into a COMBINED STANDARD UNCERTAINTY.

C.2 Categories of UNCERTAINTIES for dosimeters

The UNCERTAINTIES that affect a dosimeter can be grouped into three categories, as follows:

a) Calibration: In RADIOTHERAPY, it is common practice for the FIELD-CLASS DOSIMETER to be calibrated against a secondary STANDARD dosimeter which, in turn, has been calibrated directly against a NATIONAL STANDARD. At each stage of calibration, UNCERTAINTIES will arise, and the estimated UNCERTAINTY on the CALIBRATION FACTORS should be stated on the calibration certificates.

b) Performance of dosimeter: Regardless of how well a dosimeter was calibrated, its CALIBRATION FACTORS will be accurate only at the time and for the conditions under which it was calibrated. If it is, say, dose rate dependent, the readings will be in error whenever it is used at a dose rate different from the dose rate used at its calibration. The better the performance of the dosimeter, the smaller will be the UNCERTAINTIES due to the dosimeter PERFORMANCE CHARACTERISTICS.

c) Measurement procedure: UNCERTAINTIES can arise in the measurement of dose, which are not caused by the dosimeter. Some examples of this are timer UNCERTAINTIES in a beam shutter mechanism, inaccurate setting up of distance, scattered radiation from chamber-supporting devices, etc. The dosimeter is reading the correct dose at the position of the IONIZATION CHAMBER, but it is not the correct dose at the time, place and under the conditions of irradiating a PATIENT.

C.3 Summary of recommendations

The ISO Guide to the expression of UNCERTAINTY in measurement provides general rules for evaluating and expressing UNCERTAINTY and should be referred to for a more comprehensive discussion on this topic. The objective of this annex is to provide the RESPONSIBLE ORGANIZATION with examples of how this procedure can be used to estimate the OVERALL UNCERTAINTY in the measured dose made with a dosimeter which meets the specifications of this standard.

In the ISO Guide approach, the estimated VARIANCE, u^2, characterizing each UNCERTAINTY component affecting the measurements is obtained from one of two methods. Both methods of evaluation are based on PROBABILITY DISTRIBUTIONS and the UNCERTAINTY components resulting from each type are quantified by a STANDARD DEVIATION or a VARIANCE. The type A (evaluation of) STANDARD UNCERTAINTY is a calculation from a series of repeated observations and is the familiar VARIANCE estimated by statistical procedures. For an UNCERTAINTY component obtained from a type B (evaluation of) STANDARD UNCERTAINTY, the estimated VARIANCE is evaluated using other available knowledge.

In brief, the ISO Guide recommends the following sequential process:

(1) Define the mathematical expression for the relationship between a MEASURAND Y and input quantities, X_i, given by the model of the measurement procedure,

$$Y = f(X_i)$$

The input quantities may include variables or UNCERTAINTY components that may not be explicitly needed in the mathematical expression used to calculate the estimated MEASURAND, y,

$$y = f(x_i)$$

i.e. the model includes input estimates x_i with fixed values (often unity) but having UNCERTAINTIES influencing the magnitude of the COMBINED STANDARD UNCERTAINTY.

(2) Determine the value of input estimate quantities x_i, and STANDARD UNCERTAINTIES, $u(x_i)$, where the latter are expressed in terms of experimental STANDARD DEVIATIONS (or STANDARD DEVIATIONS of the mean where appropriate) or UNCERTAINTY quantities assumed to correspond to STANDARD DEVIATIONS, irrespective of the method used to evaluate their magnitude. Often it is more convenient to use the relative STANDARD UNCERTAINTY, $u(y)/(y)$.

(3) Evaluate COVARIANCES, $u(x_i,x_j)$ (or the correlation coefficients) for correlated input estimate quantities x_i and x_j by appropriate methods. (In practice, this step is often overlooked but it can have an important impact on the overall estimate of the COMBINED STANDARD UNCERTAINTY estimate).

(4) Calculate the estimated y, and the COMBINED STANDARD UNCERTAINTY, $u_c(y)$, where the latter is equal to the positive square root of the total VARIANCE obtained by summing all VARIANCE and COVARIANCE components using the law of propagation of UNCERTAINTY for the specific mathematical function given by the measurement model. Often it is more convenient to use the relative COMBINED STANDARD UNCERTAINTY, $u_c(y)/y$.

(5) When required to give an EXPANDED UNCERTAINTY to provide a higher level of confidence, multiply the COMBINED STANDARD UNCERTAINTY by an appropriate COVERAGE FACTOR, k, typically 2 or 3.

(6) Report the results of the measurement, y, with its COMBINED STANDARD UNCERTAINTY, $u_c(y)$, or EXPANDED UNCERTAINTY, $ku_c(y)$, with a specification (including assumptions) for the value of k used. For results of primary importance, a complete specification of all the separate UNCERTAINTY components $u(x_i)$ and $u(x_i,x_j)$ should be reported with their corresponding DEGREES OF FREEDOM.

C.4 Recommended COVERAGE FACTOR

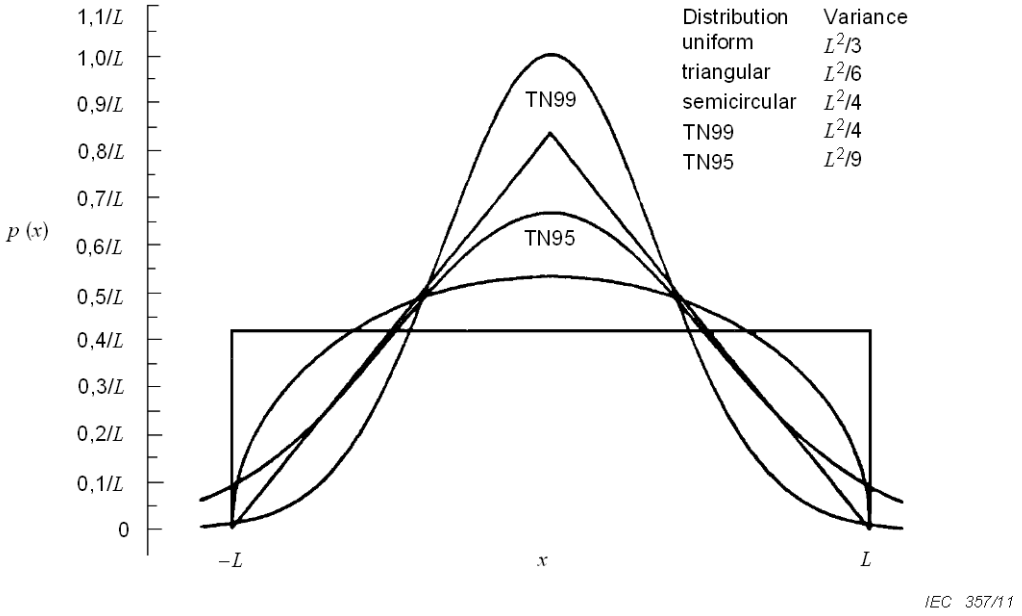
If one wants to report an EXPANDED UNCERTAINTY to correspond to a higher confidence interval rather than report the COMBINED STANDARD UNCERTAINTY, then use a COVERAGE FACTOR as the multiplier of the COMBINED STANDARD UNCERTAINTY. As there is UNCERTAINTY on the value of the UNCERTAINTY, using a COVERAGE FACTOR of 2 or 3 will provide an UNCERTAINTY interval having a higher level of confidence.

For measurements with RADIOTHERAPY DOSIMETERS, a COVERAGE FACTOR of 2 is recommended. This corresponds to a 95 % confidence interval if all the INFLUENCE QUANTITIES were normally distributed.

C.5 Formalism

It is desired to estimate the COMBINED STANDARD UNCERTAINTY OF MEASUREMENTS made with dosimeters meeting or exceeding the PERFORMANCE CHARACTERISTIC requirements given in this standard. The PERFORMANCE CHARACTERISTIC criteria are written in terms of allowed ranges either having symmetric LIMITS OF VARIATION, for example $\pm L$ or $L_- = -L$ and $L_+ = +L$, or asymmetric limits, for example 0 to L or $L_- = 0$, and $L_+ = +L$.

Unless the RESPONSIBLE ORGANIZATION is provided with additional information, some assumption on the PROBABILITY DISTRIBUTION of the PERFORMANCE CHARACTERISTICS within these limits shall be made.



NOTE See text for discussion of the normal distribution case.

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

Figure C.1 shows several PROBABILITY DISTRIBUTIONS between symmetric limits $\pm L$. The VARIANCE for the finite PROBABILITY DISTRIBUTIONS can be expressed directly in terms of the limit L, i.e. see Figure C.1. If the PERFORMANCE CHARACTERISTIC has a normal PROBABILITY DISTRIBUTION within LIMITS OF VARIATION, then some procedure shall be adopted to handle the fact that there is a finite probability of the measured PERFORMANCE CHARACTERISTIC being outside the limit of VARIATION. The method adopted in Figure A.1 was to assume that the VARIANCE of the normal PROBABILITY DISTRIBUTION is such that either the "2σ" or "3σ" point occurred at the limit L. These two cases are referred to as TN95 and TN99 in Figure A.1 to represent a truncated normal distribution. For the asymmetric case with limits 0 to L, the VARIANCE will be one quarter of the value listed in Figure C.1.

As shown in the ISO Guide to the expression of UNCERTAINTY in measurement in the practical case it makes little difference which distribution is used in estimating of the COMBINED STANDARD UNCERTAINTY. The example in the next section assumes a uniform PROBABILITY DISTRIBUTION for each PERFORMANCE CHARACTERISTIC within the tolerance limit. If the PERFORMANCE CHARACTERISTIC has some other PROBABILITY DISTRIBUTION, then multiply the listed value of the STANDARD DEVIATION for the uniform case by the STANDARD DEVIATION for the new distribution divided by 0,577.

A measurement model for estimating the UNCERTAINTY for the PERFORMANCE CHARACTERISTIC ranges given in this standard is

$$\dot{K} = C \cdot (I - R_1 - R_2) \cdot \prod_{i=3} R_i \cdot \prod_{j=22} R_j$$

where

$\dot{K}$ is the dose rate;

C is a CALIBRATION FACTOR converting IONIZATION CHAMBER current to dose;

I is the measured ionization current, and

R represents the PERFORMANCE CHARACTERISTIC requirement.

The equation contains products of the chamber PERFORMANCE CHARACTERISTIC (denoted by the subscript i which takes on values between 3 and 21) and the MEASURING ASSEMBLY PERFORMANCE CHARACTERISTIC (denoted by the subscript j which takes on values between 22 and 43). The chamber PERFORMANCE CHARACTERISTICS R_1 and R_2 (which account for leakage) are additive and all of the others are multiplicational. R_1 and R_2 values are small and all of the other R_i and R_j values are near unity. Depending on the type of dosimeter and dose rate to be measured, i and j can take on only certain combinations of values due the fact that there are many pairs of mutually exclusive combinations, for example dose/dose rate, thimble/parallel-plate IONIZATION CHAMBER, sealed/vented IONIZATION CHAMBER, low/high dose rate measurements, battery/mains operated MEASURING ASSEMBLY, etc.

Table C.1 summarizes the PERFORMANCE CHARACTERISTIC limits which IONIZATION CHAMBERS and MEASURING ASSEMBLIES shall meet to achieve the requirements of this standard. Depending on the particular type of dosimeter being calibrated, the relative COMBINED STANDARD UNCERTAINTY can be estimated by: assuming or measuring a PROBABILITY DISTRIBUTION for each PERFORMANCE CHARACTERISTIC parameter, calculating corresponding relative STANDARD UNCERTAINTY and VARIANCE for each parameter, determining any COVARIANCES, determining all weighting factors (i.e. partial derivatives in the expression for COMBINED STANDARD UNCERTAINTY) for the measurement model used, summing the appropriately weighted VARIANCES and COVARIANCES, and taking the positive square root of the resulting sum.

As an example consider a cable-connected battery operated FIELD-CLASS DOSIMETER using an unsealed thimble IONIZATION CHAMBER for measuring dose rate for RADIATION QUALITIES around HVL of 8 mm Al. Then the appropriate indices are i = 1, 2, 3, 5, 8, 9, 10, 11, 12, 14, 18 and 19 and j = 23, 24, 26, 28, 30, 31, 32, 33, 38, 39, 40 and 41. For terms with the above equation appearing in products, the partial derivative in the expression for the COMBINED STANDARD UNCERTAINTY is 1. For the leakage terms this term is $R_1/(I - R_1 - R_2) \approx R_1/I$, i.e., the value of the performance limit. Assume that the UNCERTAINTY in the leakage measurement is 50 % and is uniformly distributed. Ignoring COVARIANCES, the combined UNCERTAINTY for a dosimeter designed to operate within the extremes of all the allowed PERFORMANCE CHARACTERISTIC ranges is 2,7 %.

If the RESPONSIBLE ORGANIZATION takes care in setting up the dosimeters, makes additional measurements to verify the VARIATION range of a PERFORMANCE CHARACTERISTIC for a specific dosimeter in the RESPONSIBLE ORGANIZATION facility, or by implementing a quality control program for a specific PERFORMANCE CHARACTERISTIC verifies that there is less VARIATION for actual dosimeter use condition than allowed by the LIMITS OF VARIATION given in this standard, then the assumed PERFORMANCE CHARACTERISTIC range will be modified. Incorporating the procedures indicated in the "remarks" column, Table C.1 also shows how the combined UNCERTAINTY estimate can be reduced to 0,9 %, again assuming a uniform PROBABILITY DISTRIBUTION for all the PERFORMANCE CHARACTERISTIC parameters.

Table C.1 – Estimate of COMBINED STANDARD UNCERTAINTY for performance of a hypothetical dosimeter

Sub-script	PERFORMANCE CHARACTERISTIC	Subclause	Relative UNCERTAINTY [a] %	Remarks	Relative UNCERTAINTY [b] %
			CHAMBER ASSEMBLY		
1	CHAMBER ASSEMBLY LEAKAGE CURRENT [c,d]	5.2.1	±0,29 [e]	The RESPONSIBLE ORGANIZATION is making measurements at dose rates where the measured leakage corresponds to 0,1 % to 0,2 %	±0,06
2	Post-irradiation leakage [c,d]	5.2.4	±0,58 [e]	Coefficient of VARIATION of 9 post-irradiation measurements is ±0,4	0,13
3	Long-term stability [c]	5.2.2.1	±0,58 [e]	Use of control chart shows 99 % control limit is ± 0,6 %	±0,2
4	Accumulated dose stability	5.2.2.2	±0,58		
5	STABILIZATION TIME	5.2.3	±0,29 [e]	Left the dosimeter on overnight before measurement	±0,1
6	Dose rate [f]	5.2.5.1 5.2.5.2	±0,58		
7	ABSORBED DOSE per pulse [f]	5.2.6	±0,58		
8	STRAY RADIATION effect [g]	5.2.8	±0,29 [e]	No change	±0,29
9	Polarity of polarizing voltage	5.2.11	±0,29 [e]	Measured polarity effect over dose rate used varied by 0,2 %	±0,06
			SHELL CHAMBERS		
10	RADIATION QUALITY [h]	5.3.1.2	±1,15 [e]	THIMBLE CHAMBER is used only in beams where it was calibrated. Based on published energy RESPONSE of the chamber and an estimate of the difference in beam qualities between calibration and use, the STANDARD DEVIATION is estimated to be 0,04 % [h]	±0,04
11	Field size – Stem scatter	5.3.2.2	±0,58 [e]	The STANDARD DEVIATION of 9 replicate measurements of stem scatter using a dummy IONIZATION CHAMBER in the most common field size used at the facility was ±0,45 %	±0,15
12	Field size – Leakage	5.3.2.3	±0,29 [e]	The range of measured stem leakage in different field sizes was ±0,5 %	±0,29
13	Rotation	5.3.3.1	±0,29 [e]	The MANUFACTURER of the IONIZATION CHAMBER states that the UNCERTAINTY due to rotation is ±0,2 %	±0,2
14	Tilt	5.3.3.2	±0,58 [e]	The RESPONSIBLE ORGANIZATION is very careful in positioning the IONIZATION CHAMBER and estimates the UNCERTAINTY due this effect is ±0,1 %	±0,1

Sub-script	PERFORMANCE CHARACTERISTIC	Subclause	Relative UNCERTAINTY [a] %	Remarks	Relative UNCERTAINTY [b] %
			PARALLEL-PLATE CHAMBERS		
15	RADIATION QUALITY	5.4.1.1	±1,15		
16	Field size	5.2.7	±1,15		
17	Tilt	5.4.2	±0,58		
			VENTED CHAMBERS		
18	Temperature	5.5.2	±0,58 [e]	The IONIZATION CHAMBER will be in a well-controlled environment (±2 °C). Assume that the limit varies linearly with the range, for example ±0,4 %.	±0,23
19	Humidity	5.5.3	±0,58 [e]	The IONIZATION CHAMBER will be in a well-controlled environment (±15 % RH). Assume that the limit varies linearly with the range, for example ±0,66 %	±0,38
			SEALED CHAMBERS		
20	Pressure change	5.6.1	±0,58		
21	Temperature	5.6.2	±0,58		
	COMBINED STANDARD UNCERTAINTY for CHAMBER ASSEMBLY		±1,96		±0,72
			MEASURING ASSEMBLY		
22	EM fields				
23	RESOLUTION [c]	6.2.2	±0,29 [e]	The measurement will be made at a dose rate where the UNCERTAINTY due to RESOLUTION is ±0,2	±0,11
24	Repeatability	6.2.3	±0,06 [e]	As reported by the MANUFACTURER	±0,06
25	ZERO DRIFT [c] – dosimeter	6.3.1	±0,58		
26	ZERO DRIFT [c] – Dose rate meter	6.4.1	±0,58 [e]	The MANUFACTURER states that the limits on the ZERO DRIFT are ±0,2 %	±0,11
27	ZERO SHIFT – Dosimeter	6.4.2	±0,58		
28	ZERO SHIFT – Dose rate meter	6.4.2	±0,58 [e]	The MANUFACTURER states that the limits on the ZERO SHIFT are ±0,4 %	±0,23
29	NON-LINEARITY – Dosimeter	6.3.3	±0,29		
30	NON-LINEARITY – Dose rate meter	6.4.3	±0,58 [e]	The MEASURING ASSEMBLY and chamber were calibrated as a unit. The measured dose rate is near the calibration dose rate so u is estimated to be ±0,1	±0,1
31	Long-term stability[c]	6.2.4	±0,29 [e]	Use of control chart shows 99 % control limit is ±0,3 %	±0,1
32	STABILIZATION TIME	6.2.5	±0,29 [e]	The RESPONSIBLE ORGANIZATION plans to leave the unit on overnight	±0,1
33	STRAY RADIATION effect	6.3.8 6.4.8	±0,58 [e]	Based on measurements in the IRRADIATION room, the range of STRAY RADIATION effects are estimated to be ±0,2	±0,11

Sub-script	PERFORMANCE CHARACTERISTIC	Subclause	Relative UNCERTAINTY [a] %	Remarks	Relative UNCERTAINTY [b] %
			Dosimeters		
34	Range changing	6.3.4	±0,29		
35	Dead time	6.3.5	±0,29		
36	Temperature RESPONSE ZERO DRIFT	 6.3.6 6.3.6	 ±0,58 ±0,58		
37	Humidity RESPONSE ZERO DRIFT	 6.3.7 6.3.7	 ±0,58 ±0,58		
			Dose rate meters		
38	Range changing	6.4.4	±0,58 [e]	The RESPONSIBLE ORGANIZATION plans to only use a single range	±0,0
39	Temperature RESPONSE ZERO DRIFT	 6.4.6 6.4.6	 ±0,58 [e] ±0,58 [e]	The MEASURING ASSEMBLY will be in well controlled environment (±2 °C). Assume that the limit varies linearly with the range, for example ±0,4 %	±0,23
40	Humidity RESPONSE ZERO DRIFT	 6.4.7 6.4.7	 ±0,58 [e] ±0,58 [e]	The MEASURING ASSEMBLY will be in well controlled environment (±15 % RH). Assume that the limit varies linearly with the range, for example 0,66 %	±0,38
			Battery operated		
41	Battery condition	6.5	±0,29 [e]	Fresh batteries are installed just before the measurements are made	±0,1
			Mains operated		
42	MAINS VOLTAGE (static)	6.6.1	±0,29		
43	MAINS VOLTAGE (VARIATION)	6.6.2	±0,29		
	COMBINED STANDARD UNCERTAINTY for measurement assembly		±1,84		±0,57
	COMBINED STANDARD UNCERTAINTY		±2,7		±0,9

[a] Relative STANDARD UNCERTAINTY assuming that there is no additional information about the PROBABILITY DISTRIBUTION of the PERFORMANCE CHARACTERISTIC within the allowed interval other than it has an uniform distribution, i.e. 0,577 L for symmetric limits and 0,288 L for limits ranging from 0 to L.

[b] Relative STANDARD UNCERTAINTY assuming that the RESPONSIBLE ORGANIZATION makes use of additional information which limits the range of the allowed interval but assumes that the PROBABILITY DISTRIBUTION of the PERFORMANCE CHARACTERISTIC within the reduced interval still has uniform distribution, i.e. 0,577 L for symmetric limits and 0,288 L for limits ranging from 0 to L.

[c] For field-class IONIZATION CHAMBER, limit for reference-class IONIZATION CHAMBER half this amount.

[d] Important at low dose rates.

[e] Included in combined UNCERTAINTY total.

[f] Ion recommendation at high dose rates.

[g] If the effects of STRAY RADIATION have been measured, then an explicit correction should be made. In this case it is the UNCERTAINTY in the correction that should be estimated.

[h] See text for comment.

If the beam RADIATION QUALITY is not the same for both use and calibration of the IONIZATION CHAMBER, then it is necessary to account for additional UNCERTAINTY in the CALIBRATION FACTOR, C, for the functional dependence on beam quality, $f(BQ)$. This standard places limits on the VARIATION of $f(BQ)$, not C. There are two ways to estimate the effect of RADIATION QUALITY on the CALIBRATION FACTOR. The simplest is to assume that the UNCERTAINTY corresponds to the maximum and minimum VARIATION in IONIZATION CHAMBER RESPONSE with RADIATION QUALITY as reported by the MANUFACTURER. The second method is to have a calibration laboratory calibrate the IONIZATION CHAMBER at selected RADIATION QUALITIES and assume some smooth curve between the MEASURED VALUES. If a curve is fit through multiple calibration points, the UNCERTAINTY on the measurements at the RESPONSIBLE ORGANIZATION'S facility is

$$u_{\mathrm{q}}^2 = \left(\frac{\partial f}{\partial BQ}\right)^2 u_{\mathrm{BQ}}^2 + u_{\mathrm{f(BQ)}}^2$$

where the first term accounts for the UNCERTAINTY in measuring the beam quality between the RESPONSIBLE ORGANIZATION facility and the calibration facility and the last term is the UNCERTAINTY in the functional relationship. If the chamber is calibrated only for one beam quality, BQ_0, then the UNCERTAINTY in the measurement is $f(BQ)/f(BQ_0) - 1$. As an example, consider a dosimeter whose RESPONSE varies linearly with beam quality from 1,02 at BQ to 0,98 at 11 BQ. Then $\partial f/\partial BQ$ = 0,04/10 BQ. If the fractional UNCERTAINTY in the beam quality is ±10 % and the fit is ±0,5 %, then

$u^2 = (0{,}004)^2\ (0{,}1)^2 + (0{,}005)^2$, or $u \approx \pm 0{,}5$

Now consider COVARIANCE. In the examples so far, there are some obvious COVARIANCE terms that have been ignored. First, the air density in unsealed IONIZATION CHAMBERS was corrected to REFERENCE CONDITIONS. The allowed range for temperature effect for the IONIZATION CHAMBER and MEASURING ASSEMBLY is for temperature effects other than the gas law. However, if the temperature is measured incorrect, it will cause changes in both the air density correction and these other temperature effects, i.e. these results are correlated. A more subtle temperature effect is that of the change in air density between the X-RAY TUBE and IONIZATION CHAMBER with environmental conditions. This can affect the spectrum which in turn affects the RADIATION QUALITY which in turn affects the CALIBRATION FACTOR.

There are several other UNCERTAINTY components of using a dosimeter which are not directly addressed in this standard. Examples of the unrestricted (case 1) and limited (case 2) PERFORMANCE CHARACTERISTICS are summarized in table C.2. The table includes the COMBINED STANDARD UNCERTAINTY for the CHAMBER ASSEMBLY, for the MEASURING ASSEMBLY, and for their combined result.

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

Origin of UNCERTAINTY	*u* %	Remarks
Primary STANDARD		
Comparison of primary with secondary	±1,0	Calibration certificate from primary standardizing laboratory stating that the EXPANDED UNCERTAINTY with a COVERAGE FACTOR of ±2 %
Comparison of FIELD-CLASS DOSIMETER with secondary	±1,0	Based on secondary standardizing laboratory assessment of its calibration UNCERTAINTIES
,FIELD-CLASS DOSIMETER performance		
Case 1 [a]	±2,7	From Table C.1 for dosimeter just meeting PERFORMANCE CHARACTERISTIC requirements of this standard
Case 2 [b]	±0,9	From Table C.1 where RESPONSIBLE ORGANIZATION makes additional measurements
Measurement procedure		
Shutter UNCERTAINTY	±0,3	STANDARD error of mean of shutter UNCERTAINTY measurements
Distance setting	±0,2	Based on analysis by RESPONSIBLE ORGANIZATION on how well he can position the FIELD-CLASS DOSIMETER at the desired measurement point
Beam uniformity	±0,2	Based on previous measurements of density of radiograph of RADIATION BEAM
Stability of FIELD-CLASS DOSIMETER	±0,8	Based on quality control procedure of secondary standardizing laboratory
COMBINED STANDARD UNCERTAINTY		
Case 1 [a]	±3,2	
Case 2 [b]	±1,9	

[a] No additional information available on the PERFORMANCE CHARACTERISTIC, column 4 in Table C.1.

[b] Additional information available on the PERFORMANCE CHARACTERISTIC, column 6 in Table C.1.

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[1] ICRU Report 33, *Radiations quantities and units.* International commission on radiation units and measurements, Washington, 1980

[2] IAEA TRS-398:2000, *Absorbed dose determination in external beam radiotherapy. An international code of practice for dosimetry based on standards of absorbed dose to water*

[3] IEC 60051-1:1997, *Direct acting indicating analogue electrical measuring instruments and their accessories – Part 1: Definitions and general requirements common to all parts*

Index of defined terms used in this standard

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