BS IEC 62463:2010

BSI Standards Publication

Radiation protection instrumentation – X-ray systems for the screening of persons for security and the carrying of illicit items

National foreword

This British Standard is the UK implementation of IEC 62463:2010.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

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.

ISBN 978 0 580 56616 5

ICS 13.280

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 July 2010.

Amendments issued since publication

Amd. No.	Date	Text affected

IEC 62463

Edition 1.0 2010-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – X-ray systems for the screening of persons for security and the carrying of illicit items

Instrumentation pour la radioprotection – Systèmes radiographiques aux rayons X pour le contrôle des individus dans le cadre de la sécurité et du transport d'objets illicites

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE
CODE PRIX

U

ICS 13.280

ISBN 978-2-88912-024-6

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIATION PROTECTION INSTRUMENTATION – X-RAY SYSTEMS FOR THE SCREENING OF PERSONS FOR SECURITY AND THE CARRYING OF ILLICIT ITEMS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62463 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation.

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

FDIS	Report on voting
45B/642/FDIS	45B/658/RVD

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

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

INTRODUCTION

The existence of this standard does not indicate approval of the use of the relevant equipments. However these equipments exist and are used in some countries and are likely to be used to scan persons of all nationalities including nationals of those countries which ban their use. If other international organisations ban their use, this standard could be withdrawn. Meanwhile it is considered valuable to have this standard to reduce the radiation doses to members of the public and others likely to have to use the equipments. Personnel X-ray screening assemblies are used to examine persons in order to detect objects such as: weapons, explosives, smuggled or stolen items such as drugs or diamonds. The screening devices can be divided into three types: one type using the Compton backscattered X-rays (Backscatter system) for the image creation, one using the transmitted X-rays (Transmission system) for the image creation, and a third type as a combination of the two types (Backscatter + Transmission).

All three types consist of an X-ray unit and a detector unit, and take about 10 s to perform a scan.

The systems are operated by and the image is viewed on an external computer. Sophisticated software is used to evaluate the complex images and to enable the detection of hidden objects.

The main difference between the system types is the position of the detectors. Usually, they also differ in the tube voltage range used.

Backscatter X-ray systems, (B), use a narrow pencil shaped beam that scans the subject at high speed in a horizontal and vertical direction. Large detectors are installed on the same side of the subject as the X-ray source. The person stands in front of the enclosure and is scanned by the X-ray beam having a typical cross-sectional area of approximately 25 mm^2; this of course is the quantity limiting the spatial resolution of the system. Usually the person is scanned twice, once from the front and then from the back. Sometimes lateral scans are also performed. Typical systems use fixed peak voltage (kV) and current (mA) settings for the X-ray source. These are typically 50 kV and 5 mA. The total aluminium equivalent filtration is in the range of 1 mm to 7 mm.

Transmission X-ray systems, (T), often use a vertical fan–shaped beam of X-rays and a linear array of detectors. The person stands between the X-ray tube and the detector array and is scanned by the X-ray beam having a typical width of approximately 2 mm. The limiting quantity for the spatial resolution is the size of the detector elements. Typical systems use a fixed peak voltage (kV) and current (mA). Settings are in the range of about 140 kV to 220 kV and 0,1 mA to about 4 mA. The total aluminium equivalent thickness is in the range of about 1 mm to about 16 mm. The systems are capable of detecting objects within the body.

Backscatter plus transmission X-ray systems, (BT), are systems that use both backscattered and transmitted X-rays, during the same scan procedure.

RADIATION PROTECTION INSTRUMENTATION – X-RAY SYSTEMS FOR THE SCREENING OF PERSONS FOR SECURITY AND THE CARRYING OF ILLICIT ITEMS

1 Scope and object

This International Standard is applicable to X-ray systems designed for screening people to detect if they are carrying objects that could be used for criminal purposes, e.g., terrorist use, drug smuggling and theft. These objects include weapons, explosives, chemical and biological agents and other concealed items.

Three types of X-ray screening systems are currently in use. These are backscatter systems, transmission systems and combination backscatter/transmission systems. With backscatter systems the X-rays are used to detect objects hidden under or within the person's clothing. With transmission systems objects swallowed or hidden in body cavities may be detected. Combined devices can be used to get both pieces of information simultaneously.

The object of this standard is to lay down standard requirements and also to specify general characteristics, general test procedures, radiation characteristics, electrical characteristics, environmental influences, mechanical characteristics, safety requirements and to provide examples of acceptable methods in terms of dose to the whole or part of the body for each screening procedure and the time taken for each screening procedure.

In particular the standard addresses the design requirements as they relate to the radiation protection of the people being screened, people who are in the vicinity of the equipment and the operators. The standard does not address the performance requirements for the quality of the object detection.

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 60038:2009, *IEC standard voltages*

IEC 60050-393:2003, *International Electrotechnical Vocabulary (IEV) – Part 393: Nuclear instrumentation – Physical phenomena and basic concepts*

IEC 60050-394:2007, *International Electrotechnical Vocabulary (IEV) – Part 394: Nuclear instrumentation – Instruments, systems, equipments and detectors*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-75:1997*, Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electric fast transient/burst immunity test*

IEC 61000-4-5, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

IEC 61000-4-6, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-12, *Electromagnetic compatibility (EMC) – Part 4-12: Testing and measurement techniques – Ring wave immunity test*

IEC 61187, *Electrical and electronic equipment – Documentation*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety related systems*

ISO 4037 (all parts), *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*

ISO 4037-1:1996, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. The general terminology concerning X-ray screening systems is given in IEC 60050-393:2003 and IEC 60050-394:2007.

3.1
ambient dose equivalent, Hx(d)
the ambient dose equivalent at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded and aligned field, in the ICRU sphere at a depth, d, on the radius opposing the direction of the aligned field

[ICRU 51]

NOTE 1 The recommended depth, d, for strongly penetrating radiation is 10 mm, and ambient dose equivalent at this depth may be written as $H_x^*(10)$.

NOTE 2 Soft tissue means ICRU 4-element, see ICRU 39.

3.2
constant potential X-ray unit
unit in which the ripple of the high voltage does not exceed ±10 %

3.3
exposure beam location
that part of the external surface of the system enclosure through which the collimated X-ray beam passes

3.4
half value layer (air kerma), HVL or HVLx
the thickness of the specified material which attenuates the beam of radiation to an extent such that the air kerma rate is reduced to one half of its original value. In this definition, the contribution of all scattered radiation, other than any which might be present initially in the beam concerned, is deemed to be excluded.

[ICRU 17]

3.5
filtration
the total filtration is made up of the fixed filtration and any additional filtration used by the manufacturer.

The fixed filtration comprises the inherent filtration of the tube, plus that due to the monitor ionisation chamber.

The inherent filtration of the tube is due to the various constituent elements (glass of the bulb, oil, window, etc.) and is expressed, for a given high voltage, as the thickness of an aluminium filter which, in the absence of the constituent elements of the tube, would supply a radiation having the same first HVL.

3.6
monitor instrument
instrument with an alarm used to monitor the stability of the ambient dose equivalent rate during an irradiation or to compare the ambient dose equivalent rate during a screening with the reference dose equivalent rate determined during the type testing

3.7
mode of operation
backscatter, transmission or backscatter and transmission system and scanning technique

3.8
operator
person authorised and fully trained to operate the system

3.9
reference instrument
instrument whose calibration is traceable either directly or indirectly to primary standards held by a national primary laboratory or to an acknowledged reference laboratory which holds appropriate standards

3.10
reference point
the point within the space that may be occupied by the person being screened receiving the maximum dose and at which for the purpose of the testing requirements of this standard the X-ray spectra (or HVL) and reference ambient dose equivalent per screening procedure is measured

3.11
safety interlocks
devices which are intended to prevent or interrupt the generation of X-radiation whenever safety is compromised by access to the interior of the system, operational irregularity or equipment failure

3.12
scan
the scanning cycle consisting of the operation necessary to produce one view (e.g., front view)

3.13
scanning system
the whole equipment used to produce a scan, including the X-ray generator and collimator

3.14
screening procedure
the sum of all scans necessary to examine one person

3.15
enclosure
the containment within which the X-ray unit and its scanning system are enclosed

3.16
ripple
ratio, expressed as a percentage, defined for a given current by the formula:

$$(U_{max} - U_{min}) \times 100/U_{max}$$

where U_{max} is the maximum value and U_{min} the minimum value of the voltage.

3.17
user
the person being screened by the equipment

3.18
X-ray unit
assembly comprising a high voltage supply, an X-ray tube with its protective housing, and high voltage electrical connections

3.19
X-ray tube
vacuum tube designed to produce X-rays by bombardment of the anode by a beam of electrons accelerated through a potential difference

4 Units

In this standard, the units are the multiples and sub-multiples of units of the International System of Units (SI)[1]. The following non-SI units are also used:

Time: years, days, hours (h), minutes (min).

For energy: electron-volt (eV), (1 eV = 1,602 $\times$ 10^{-19} J).

NOTE Definitions of the radiation quantities and dosimetric terms are given in IEC 60050-393 and IEC 60050-394.

5 Classification of systems

Systems are classified according to whether they are backscatter X-ray systems, (B) or transmission X-ray systems, (T), or combined backscatter and transmission systems, (BT).

6 General test procedures

6.1 Nature of tests

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

1 (SI International Bureau of Weights and Measures: The International System of Units, 8th edition 2006).

6.2 Reference conditions and standard test conditions

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

6.3 Tests performed under standard test conditions

Tests performed under standard test conditions are listed in Table 2, which indicates, for each characteristic under test, requirements according to the subclause where the corresponding test method is described.

6.4 Tests performed with variation of influence quantities

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

7 Safety considerations

7.1 General

The manufacturer shall provide a description of the radiation safety systems that are designed to prevent, during normal operation of the X-ray screening system, accidental exposure to the operator and public and for ensuring that the person being screened is not exposed above manufacturers stated maximum dose per screening procedure (see Clause 9). The accompanying manual provided by the manufacturer shall include details of the fail-safe features of the radiation safety exposure circuit. These details shall also include functional test instructions.

The manufacturer shall reference the radiological and electrical safety considerations used for the system by quoting applicable IEC and ISO publications, see 7.4.1.

7.2 Shielding

7.2.1 Requirements

When a person is being screened and the X-ray beam is emanating, shutter or beam stop open, the ambient dose equivalent rate to any area where other members of the public or the operator have access should not exceed 2,5 $\mu Sv \cdot h^{-1}$ taken over several scans. Where the doserate could exceed this value at a distance in excess of 30 cm from any external surface the manufacturer shall provide an isodose contour at this value. National regulations may stipulate lower limits.

7.2.2 Method of test

The direction in which the highest dose per screening procedure is emitted shall be identified by measurement. (Technical drawings and further physical aspects may assist in determining this but should not be relied upon.) Careful consideration should be given to control stations, fissures around doors, ventilation openings, shielding joints and any other vulnerable areas based on technical drawings. If there are outer doors or removable panels that are not locked or interlocked, the radiation survey shall be repeated with the doors open and panels removed. At the distance specified in 7.2.1, from the surface of the device the ambient dose equivalent per screening procedure (that means the sum of all scans necessary to examine a person) shall be measured. The X-ray scanner shall be operated in the mode with the greatest high voltage, greatest tube current and the smallest total filtration allowed to be used in operation. This shall be done for at least five subsequent screening procedures following each other as fast as the device is able to perform. The total dose over all these screening

procedures shall be divided by the time all these screening procedures took. This value plus the overall uncertainty (k = 2) shall not exceed the ambient dose equivalent rate requirement listed in 7.2.1.

This dose equivalent rate shall be determined by a reference instrument having a response that is within 20 % of the true value over the energy range from 25 keV to the maximum energy in keV corresponding to the maximum operating voltage of the X-ray tube.

7.3 System controls and normal operation indications

7.3.1 Requirements

The operating conditions, namely the tube voltage and tube current, for each mode of operation shall be pre-set by the manufacturer and shall not be alterable by the system operator. If there is more than one mode, prior to each scan a mode indicator shall be clearly visible to the operator.

The operators control panel shall show the following:

- Electrical power to the system is on. Only the operator is permitted to switch on the power and this should require the use of a key.
- When the X-rays are being produced an “X-rays on” illuminated sign shall operate.
- The voltage and current for the operating mode shall be displayed when required by an engineer or maintenance staff.
- Indication shall be made for both when the shutter or beam stop is open and/or for when the scan is taking place, “scan on”.
- The production of x-rays shall only start if the illuminated sign “X-rays” is ready to operate.

Sufficient diagnostics shall be designed into the system to facilitate fault finding and to provide local and remote information on the status of the system. A self-test device shall be provided to perform self-testing continuously. Operation of the equipment after fault detection must be prevented until the fault is cleared. The manufacturer shall produce a test plan which shall demonstrate the normal operation of the system. This test plan shall contain all normal operational features, diagnostics, self-test facilities and safety features of the system.

If the moveable parts, e.g., the platform, X-ray unit or chopper, do not work properly the system shall shut down automatically.

7.3.2 Method of test

Using the manufacturer’s test plan verify that the operator’s control panel displays the information as required in 7.3.1.

Testing is done automatically by the software and related electronics. Interlocks, indications and alarms shall be independent of the system’s normal controls and operation indicators.

7.4 Safety indicators and interlocks

7.4.1 Safety standards

Appropriate requirements shall apply concerning specification, design, manufacturing, installation and operation of the equipment, with respect to the necessary hardware and software. The requirements shall be agreed between manufacturer and purchaser. In particular the purchaser (operator) shall decide the appropriate safety standard applicable to the site in which the system will be placed. The basic safety standard IEC 61508 Functional Safety of Electrical/ Electronic/Programmable electronic systems shall apply, as appropriate according to the required Safety Integrity Level (SIL) specified for the system.

7.4.2 Requirements

Operational interlocks shall terminate the production of X-rays in the event of any operational problem that could result in abnormal or unintended radiation emission. Either through redundancy or special design, a malfunction of any operational interlock or any system monitoring an operational interlock shall also terminate X-ray production regardless of the actual radiation emission. This shall include, but is not limited to: unintended stopping or slowing of the scanning motion, abnormal or unintended X-ray source output, computer safety system malfunction, termination malfunction, and when applicable, X-ray shutter or beam stop mechanism malfunction.

7.4.3 Method of test

The manufacturer shall produce a test plan in accordance with IEC 61508 which shall demonstrate the operation of the safety alarms and interlocks for the SIL level specified.

The system shall be switched on and allowed to run its start up and self-test routines. A fault condition in each one of the monitored parameters shall be simulated and the warning or fault description recorded.

8 Conditions and methods for producing the X-ray screening spectra

8.1 General

In practice the spectra of the radiation produced depends primarily on:

– the high-voltage across the X-ray tube;

– the thickness and nature of the total filtration;

– the type and nature of the target.

8.2 Tube potential characteristics of the X-ray unit

8.2.1 Requirements

The conventionally true value of the potential shall be known to within ±5 %.

8.2.2 Method of test

Calibrate, at several points close to their stated operating tube potential, and under normal operating conditions, the equipment used to indicate the tube potential. The best methods employ a calibrated resistor chain or involve the measurement of the maximum photon energy by spectrometry. If the calibration is determined by spectrometry, the tube potential shall be found from the intersection of the extrapolated linear high energy part of the spectrum with the energy axis. Advice on methods of accomplishing this are described in ISO 4037-1.

9 Ambient dose equivalent at the position of the person being screened

9.1 Requirements

The ambient dose equivalent, Hx(10), at the reference point shall not exceed 0,4 μSv per screening procedure (that means the sum of all scans necessary to examine a person) for backscatter systems, (B) and 5 μSv per screening procedure (that means the sum of all scans necessary to examine a person) for transmission systems (T) and backscatter and transmission systems, (BT). Other values may be specified as required by national regulations.

9.2 Method of test

The method used to determine the reference point of maximum dose and the dose at that point for each screening procedure shall be as described in Annex A. Measurements shall be made with a reference instrument. Calculation is not sufficient.

With the X-ray scanner operating in the mode with greatest high voltage, the greatest tube current, and the smallest total filtration, the ambient dose equivalent per scan procedure (that means the sum of all scans necessary to examine a person) shall be measured at the reference point applying the methods described in Annex A. This value plus the overall uncertainty (k = 2) shall not exceed the ambient dose equivalent requirements listed in 9.1.

10 Electrical characteristics

10.1 Supply voltage

The system shall be designed to operate from a single-phase a.c. supply voltage in one of the following categories in accordance with IEC 60038:

– Series I: 230 V.

– Series II: 120 V and/or 240 V.

NOTE Nominal single phase power supplies of 100 V, 50 Hz or 60 Hz and of 117 V and/or 234 V, 60 Hz are used in some countries and a nominal single-phase power of 110 V, 50 Hz is also used as an alternative supply in other countries.

10.2 Requirements

The system shall be capable of operating from mains supply voltage tolerance from –10 % to +10 % and supply frequencies of 47 Hz to 51 Hz (57 Hz to 61 Hz in countries where the nominal frequency is 60 Hz) without the variation in the reference dose exceeding ±10 %.

10.3 Method of test

The ambient dose equivalent per scan at the reference point should first be measured under reference conditions. Then the ambient dose equivalent per scan should be measured over the voltage and frequency ranges given in 10.1 and none of these values should differ from the reference ambient dose equivalent per scan by more than ± 10 %.

11 Environmental conditions

11.1 Ambient temperature

11.1.1 Requirements

The equipment should be capable of operating over the temperature range –10 °C to +50 °C with changes in the reference ambient dose equivalent per scan not exceeding ±10 % with all the safety systems operational.

11.1.2 Method of test

The reference ambient dose equivalent per scan at the reference position should first be measured at 20 °C under reference conditions.

The equipment shall be operated at a temperature of at or below –10 °C and the ambient dose equivalent per scan measured The equipment shall have been kept at –10 °C for at least 2 h before the test. The equipment shall also be operated at a temperature of 50 °C or higher and the test repeated after being at 50 °C for at least 2 h.

The high voltage applied to the X-ray tube and the current taken shall also be monitored under reference conditions and again after the equipment has been in the environment at –10 °C and at +50 °C for at least of 2 h .The applied voltage in both cases shall not exceed 1,02 times that under standard test conditions and the current drawn shall not exceed 1,05 times that under standard test conditions.

Verify that all the safety systems are operational over the above temperature range.

11.2 Relative humidity

11.2.1 Requirements

The equipment should be capable of operating over the relative humidity range 40 % to 93 % at +35 °C without changes in the reference ambient dose equivalent per scan exceeding ±10 % with all the safety systems operational.

11.2.2 Method of test

The reference ambient dose equivalent per scan at the reference position should first be measured at 65 % relative humidity and 35 °C under reference conditions. Then the ambient dose equivalent per scan should be measured over the humidity ranges given in 11.2.1 and none of these values should differ from the reference ambient dose equivalent per scan by more than ±10 %.

The high voltage applied to the X-ray tube and the current taken shall be monitored under standard test conditions and again after the equipment has been in an environment greater than +35 °C and with the relative humidity greater than 93 % in excess of 2 h and again at a temperature of +35 °C and with a relative humidity of 40 %. The applied voltage in both cases shall not exceed 1,02 of that under standard test conditions and the current drawn shall not exceed 1,05 of that of that under standard test conditions.

Verify that all the safety systems are operational over the above humidity range.

12 Electromagnetic compatibility

12.1 Susceptibility to electromagnetic fields

12.1.1 Requirements

There shall be no change in the operational status. No alarms or other outputs should be activated when the equipment is exposed to the field. The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to the radiated electromagnetic fields. All the safety systems shall remain operational during and after these tests.

12.1.2 Method of test

The field strength shall be 20 V/m over the frequency range from 80 MHz to 1 GHz and 1,4 GHz to 2,4 GHz and shall be varied in steps of 1 % (severity level 3 as described in IEC 61000-4-3). There shall also be no change in the operational status and no alarms or other outputs should be activated at any frequency.

Verify that all the safety systems are operational during and after these tests.

12.2 Conducted disturbances induced by bursts and radio frequencies

12.2.1 Requirements

There shall be no change in the operational status. No alarms or other outputs should be activated when the equipment is exposed to the field. The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to bursts and radio frequencies. The safety systems shall remain operational during and after these tests.

The test applies to devices used in the presence of radio-frequency transmitters in the frequency range from 150 kHz to 80 MHz.

12.2.2 Method of test

Perform the following operations both with and without the presence of conducted disturbances induced by bursts (IEC 61000-4-4) and conducted disturbances induced by radio-frequency fields (IEC 61000-4-6) (the severity level shall in both cases be level 3).

a) Set the equipment to perform a screening procedure.
b) Set the frequency range from 150 kHz to 80 MHz at afield strength of 10 V, 80 % amplitude modulated with a 1 kHz sine wave.

The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to the above bursts and radiofrequencies. There shall also be no change in the operational status and no alarms or other outputs should be activated. Verify that all the safety systems remain operational during and after these tests.

12.3 Surges and ring waves

12.3.1 Requirements

The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to surges and oscillatory waves. There shall be no change in the operational status. No alarms or other outputs should be activated. All the safety systems shall remain operational during and after these tests.

12.3.2 Method of test

Connect the mains supply terminal via a coupling/decoupling network to the pulse generator in accordance with IEC 61000-4-5 and IEC 61000-4-12 (the severity level shall be level 3) and conduct the following operations.

a) Ten pulses should be applied to the device with a minimum time between surges of 1 min.
b) Each pulse should consist of a combination wave (1,2/50 μs – 8/20 μs) at a voltage of 2 kV.

Ring wave pulses should be not more than 2 kV. The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to the ring waves. There shall be no change in the operational status. No alarms or other outputs should be activated when the assembly is exposed to the ring waves. Verify that all the safety systems remain operational during and after these tests.

12.4 Electrostatic discharge

12.4.1 Requirements

The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to electrostatic discharges. No alarms or other outputs should be activated when the device is exposed to the discharges. All the safety systems shall remain operational during and after these tests.

12.4.2 Method of test

User and operator accessible components shall be placed close to a suitable discharge test generator as described in IEC 61000-4-2, and the following operations are performed, with and without the presence of radiation sources.

a) Set the equipment to perform a scan.
b) Discharge at least five times to each of those various external parts of the complete equipment which may be touched by the operator.
c) For assemblies with conductive surfaces and coupling planes, the contact discharge method shall be employed as described in IEC 61000-4-2. The electrostatic discharge shall be equivalent to that from a capacitor of 150 pF charged to a voltage of 6 kV, and discharged through a resistor of 330 Ω (severity level 3).
d) When assemblies with insulated surfaces are tested, the air discharge method with a voltage of 8 kV (severity level 3) shall be used. The reference ambient dose equivalent per scan shall not change by more than ±10 % when the system is exposed to electrostatic discharges. There shall be no change in the operational status.

13 Mechanical characteristics

13.1 Mechanical shocks

13.1.1 Requirements

The equipment should be able to withstand, without affecting its performance, mechanical shocks (half-sine) from all directions at an acceleration of 300 $m \cdot s^{-2}$ over a time interval of 6 ms (IEC 60068-2-27). During this test the assembly should be operating.

13.1.2 Method of test

Mount the equipment on to a shock test device and perform a series of 10 mechanical shocks while observing the function of the monitor. The shocks (half-sine) shall be from each of three orthogonal directions at an acceleration of 300 $m \cdot s^{-2}$ over a time period of 6 ms (IEC 60068-2-27).

After exposure the equipment shall be inspected for loose or broken components and the operation of safety systems shall be checked.

13.2 Vibration test

13.2.1 Requirements

No alarms or other changes in operation should occur during the exposure to vibration.

Durability against vibration (recommended, not a requirement).

The physical condition of the equipment should not be affected by this vibration (e. g., solder joints shall hold, nuts and bolts shall not come loose).

13.2.2 Method of test

Compliance shall be checked by monitoring the operational status during and after the vibration test

Frequency scanning:

The equipment shall be subjected to harmonic loadings of 0,5 g_n whose frequency gradually increases from 10 Hz to 150 Hz and decreases from 150 Hz to 10 Hz in each of three orthogonal directions (1 min cycle is recommended).

Durability against vibration during shipment (recommended, not a requirement).

Subject the equipment to harmonic loadings of 2 g_n for 15 min in each of three orthogonal directions at one or more frequencies in each of the following ranges from 10 Hz to 21 Hz and from 22 Hz to 33 Hz. However, if any mechanical resonance is found in the test above the test frequency should be chosen among the resonance frequencies. After each 15 min vibration interval, the equipment shall be inspected for any physical damage and the operation of safety systems shall be checked.

13.3 Microphonic/impact

13.3.1 Requirements

The equipment's response shall be unaffected by microphonic conditions such as those that may occur from low intensity sharp contacts with hard surfaces.

13.3.2 Method of test

With the equipment making a scan and using an appropriate test device (i.e. spring hammer), expose the equipment to an impact at an energy of 1,0 joules (J) equivalent to a mass of 1 kg moving at 1,4 m/s or a fall from a height of 0,1 m (IEC 60068-2-75). The test shall be performed on each side of the equipment while observing the performance of the equipment.

The performance shall be unaffected.

14 Documentation

14.1 Manual

The equipment shall be supplied with a detailed operational manual.

14.2 Type test report

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

14.3 Certificate

A certificate shall be provided giving a description of the X-ray screening system. This should also include the following information in accordance with IEC 61187:

– operational mode, namely backscatter, (B), or transmission, (T), or combined backscatter and transmission (BT);
– field of application: intended uses, types of objects detected;
– X-ray operating conditions, high potential, tube current, filtration, HVL;
– scanning technique used for example pencil beam or slit collimator;
– radiation detector type;
– reference ambient dose equivalent per screening process;
– shielding thickness and leakage dose equivalent rate at 30 cm from external surfaces of the enclosure;
– list of safety interlocks and their purposes;
– scan speed, speed of the movable platform and/or of the X-ray unit;

– reference point at position of maximum ambient dose equivalent per scan;
– distance between focal spot of the X-ray tube and the beam outlet;
– maximum time for a scan.

For backscatter equipment only:

– pulse rate;
– velocity of beam on the surface of the object;
– beam spot size on the surface of the object;
– spatial resolution of the system.

Table 1 – Reference conditions and standard test conditions

Influence quantities	Reference conditions (unless otherwise indicated by the manufacturer)	Standard test conditions (unless otherwise indicated by the manufacturer)
Warm-up time	15 min	> 15 min
Ambient temperature	20 °C	18 °C to 22 °C
Relative humidity	65 %	50 % to 75 %
Atmospheric pressure	101,3 kPa	70 kPa to 106 kPa
Power supply voltage	Nominal power supply voltage	Nominal power supply voltage ±1 %
Power supply frequency	Nominal frequency	Nominal frequency ±1 %
Power supply waveform	Sinusoidal	Sinusoidal with total harmonic distortion lower than 5 %
Gamma radiation background	Air kerma rate 0,1 $\mu Gy \cdot h^{-1}$	Less than air kerma rate of 0,25 $\mu Gy \cdot h^{-1}$
Electromagnetic field of external origin	Negligible	Less than the lowest value that causes interference
Magnetic induction of external origin	Negligible	Less than twice the value of the induction due to earth's magnetic field
Equipment controls	Set up for normal operation	Set up for normal operation

Table 2 – Tests performed under standard test conditions

Characteristics under test	Requirements (subclause)	Method of test (subclause)
Ambient dose equivalent to person being scanned	9.1	9.2

Table 3 – Tests performed with variations of influence quantities

Characteristic under test or influence quantity	Range of values of influence quantities	Limits of variation of indications or of the dose to user	Method of tests (subclause)
Mains operation	From –12 % to +10 % of nominal power supply Voltage From 47 Hz to 51 Hz or 57 Hz to 61 Hz	±10 %	10.3
Temperature	From –10 °C to +50 °C	Operation to remain satisfactory. Dose change less than ± 10 %	11.1.2
Relative humidity	From 40 % to 93 % at 35 °C	Operation to remainsatisfactory. Dose change less than ± 10 %	11.2.2
Susceptibility to electromagnetic fields	20 V/m over the frequency range from 80 MHz to 1 GHz and 1,4 GHz to 2,4 GHz	No change in operational status. No alarms or other outputs should be activated when the assembly is exposed to the field. Dose change less than ± 10 %	12.1.2
Conducted RF	150 kHz to 80 MHz at an intensity of 10 V, 80 % amplitude modulated with a 1 kHz sinewave.	No change in operational status. No alarms or other outputs should be activated when the assembly is exposed to the field. Dose change less than ± 10 %	12.2.2
Surges and ring waves	Ten pulses applied to the device - Each pulse should consist of a combination wave (1,2/50 μs - 8/20 μs) at an intensity of 2 kV. Ring wave pulses should be not more than 2 kV.	No change in operational status. No alarms or other outputs should be activated. Dose change less than ± 10 %.	12.3.2
Electrostatic discharge	Conductive surfaces and coupling planes, the contact discharge method - equivalent to that from a capacitor of 150 pF charged to a voltage of 6 kV, and discharged through a resistor of 330 Ω. For insulated surfaces, the air discharge method with a voltage of 8 kV	No alarms or other outputs should be activated when the monitor is exposed to the discharge. Dose change less than ± 10 %	12.4.2
Mechanical shock	300 $m \cdot s^{-2}$ in 6 ms	Operation to remain satisfactory	13.1.2
Vibration	0,5 g_n at 10 Hz to 150 Hz	Operation to remain satisfactory	13.2.2
Microphonic/impact	1,0 J	Operation to remain satisfactory	13.3.2

Annex A
(normative)

Measurement and calculation of ambient dose equivalent per scan at the reference point

A.1 General

The reference point is the point in any part of the space that could be occupied by the person scanned when a screening procedure is being performed, without a person present, that receives the maximum or near maximum dose equivalent.

For the purpose of this test, a meter or a number of identical radiation meters are positioned at specific points in that space to determine the radiation dose equivalent at those points.

A.2 Measuring equipment

The radiation meters used to determine the reference point shall have an energy response uniform ±20 % between 25 keV and the maximum energy in keV corresponding to the maximum operating voltage of the X-ray tube. They shall have a response such that the standard deviation due to statistical fluctuations of the reading at the reference point shall be less than 5 % of that reading. Where the radiation level is too low to achieve this then the sum of the radiation from a sufficient number of screening procedures shall be measured such that the standard deviation is less than 5 %.

A.3 Procedure

In order to determine the reference point a number of specified measurement points are used. These specified measurement points form a three dimensional matrix in the space that is typically occupied by the person being screened, the points being 10 cm apart. The horizontal plane of this matrix is the area to where the person being monitored would be confined or an area 2 m × 2 m whichever is the lesser. In the latter case one edge of the matrix will be coincident with the face of the equipment and centred about the mean exit position of the x-ray beam. Each horizontal plane of the matrix shall be from 5 cm to 185 cm from the floor. The centre vertical planes will pass through the centre of each horizontal plane.

A.4 Preliminary tests

Measure the dose at the centre of the matrix from a sufficient number of screening procedures. Should the readout of dose take a significant time any increase in measured value due to natural background should be taken into account. Repeat the test ten times.

Calculate

$$\sqrt{\frac{1}{(n-1)x_{\mathrm{m}}} \cdot \sum_{i=1}^{n} (x_i - x_{\mathrm{m}})^2}$$

x_{m} being the mean of n measurements x_i

If this is greater than 0,05, repeat this test, increasing the number of screening procedures per reading until a value of less than 0,05 is achieved.

If more than one radiation meter is used, place each in the same position and repeat the above test. In the further tests use only radiation meters that agree with each other to 10 % or better.

A.5 Method of test

Two tests can be used, either:

a) Measure the dose equivalent at each point in the matrix described above and determine point of maximum dose. Take a further six measurements at 5 cm from the point of this maximum along the axis of the matrix. If any of these measurements show a higher dose than that position shall be taken as reference point otherwise the original position shall be taken as the maximum point in the matrix.

or

b) Measure the dose at each point along an axis from the centre of the matrix. From the point of maximum dose, measure at each point along an axis at right angles. From the point of maximum dose again measure at each point along the axis at right angles to the previous two and determine the maximum dose. If this dose is not significantly (less than 10 %) different from the dose at the centre, use this point of maximum dose found above as the starting point and repeat the process. Repeat this process until no dose is measured significantly different from that at the starting point of that particular process.

Take a further six measurements at 5 cm from the point of this maximum along the axes of the matrix. If any of these measurements show a higher dose that position shall be taken as the reference point otherwise it shall be taken as the maximum point in the matrix.

The maximum dose received per screening process is determined by dividing the maximum dose measured above by the number of screening procedures used in each measurement.

The active detector area should be between about 10 cm^2 and 100 cm^2.

A.6 Recommendations

Usually, dose values are in the range from less than 1 μSv per scan up to a few μSv per scan with a typical irradiation time of a few milliseconds. Owing to this pulse-like character of radiation fields, the dose rate may be several Sieverts per hour.

Ionization chambers are the most suitable measuring instruments to fulfill these requirements. To overcome the problem of leakage charge, time-resolved measurements are recommended. With this, it is possible to separate the amount of leakage charge from the charge being produced within the short time of irradiation. The read out has to allow time-resolved measurements of the generated charge to be performed in 100 ms intervals (or shorter).

The correction for air pressure and temperature to the registered charge has to be performed.

In Figure A.1 at typical result of a measurement is shown: The charge in an ionization chamber depending on the measurement time. To evaluate the dose the following procedure has to be applied:

a) Extrapolate the charge depending on time prior to and after the radiation pulse hits the ionization chamber as shown by the two straight lines in Figure A.1 below.

b) Determine the time of the middle of the radiation pulse. In Figure A.1, this is at about 22 s.

c) Calculate the difference of the two extrapolation curves determined in a) at the time determined at b). This is the charge caused by the radiation.

d) Multiply the charge obtained in b) with an appropriate calibration factor of the ionization chamber, see below.

Further information is given in the literature [2].

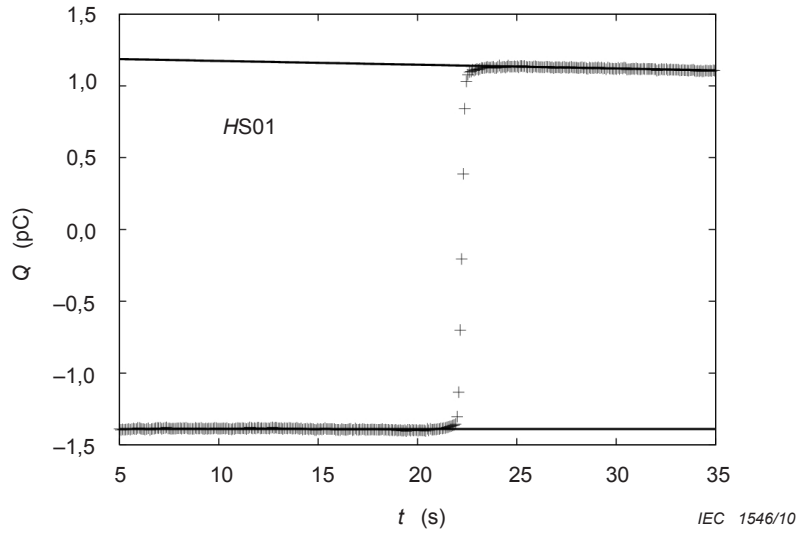

Figure A.1 – Charge *Q* versus time *t*, measured at a pencil-beam scanner (backscatter) by means of the *Hx*(10) secondary standard ionization chamber (the dose is about 0,1 µSv)

At least two different ionization chambers shall be used with flat energy response, calibrated in terms of ambient dose *Hx*(10), see for example [3] and [4] The measuring instruments used have to be calibrated to assure the traceability to the SI-system (represented by national primary standards). The reference radiation quality used for the calibration shall have an energy spectrum similar to the one of the X-ray scanner. This can be achieved by choosing a radiation quality with a high voltage and total filtration similar to the one of the X-ray scanner. The reference radiation can be chosen from the ISO 4037 series. In addition, the chambers shall have a flat energy response (better than ±10 %) in the energy range ±20 keV of the emitted radiation from the X-ray scanner.

The electrometer used shall have a charge resolution small enough to detect the expected amount of charge from the ionization chamber. The following numerical equation may serve to estimate the expected charge:

$$Q\,[\mathrm{pC}] \approx H\,[\mu\mathrm{Sv}] \times V_{\mathrm{ic}}\left[\mathrm{cm}^3\right] \times 0{,}03$$

where

Q is the charge from the ionization chamber in pC,

H is the expected dose in µSv, and

V_{ic} is the volume of the ionization chamber in cm^3.

This originates from the following equation:

---

2 Hupe,O., Ankerhold,U *Determination of ambient and personal dose equivalent for personnel and cargo security screening*. Radiat. Prot. Dosim. Vol.121 No. 4 pp. 429-437, (2006).

3 Ankerhold, U., Behrens, R., Ambrosi, P. *A prototype ionisation chamber as a secondary standard for the measurement of personal dose equivalent, $H_p(10)$, on a slab phantom*. Radiat. Prot. Dosim. Vol.86, 167 (1999).

4 Ankerhold, U. *Optimization of a secondary standard chamber for the measurement of the ambient dose equivalent, H*(10), for low photon energies*. Radiat. Prot. Dosim. Vol.118, 16 (2006).

$$Q \approx \frac{H}{\left(\frac{W}{\mathrm{e}}\right) \times \frac{1}{\rho} \times \frac{1}{V_{\mathrm{ic}}}}$$

where

$(W/\mathrm{e}) \approx 34$ J/C is the average energy required to produce an ion pair in dry air,

and

$\rho \approx 1{,}2 \times 10^{-3}$ g·cm^{-3} is the density of dry air.

Annex B
(informative)

Requirements of International Basic Safety Standards for Protection Against Ionizing Radiation and For the Safety of Radiation Sources (BSS). IAEA Safety Series No. 115, 1996.

“Practices and sources within practices may be exempt from the requirements of the Standards, including those for notification, registration or licensing, if the Regulatory Authority is satisfied that the sources meet the exemption criteria or exemption levels specified in Schedule 1. Exemptions or other exemption levels specified by the Regulatory Authority on the basis of these exemption criteria. Exemption should not be granted to permit practices that would otherwise not be justified.

A practice or a source within a practice may be exempted without further consideration provided that the following criteria are met in all feasible situations:

a) the effective dose expected to be incurred by any member of the public due to the exempted practice or source is of the order of 10 μSv or less in a year, and

b) either the collective effective dose committed by one year of performance of practice is no more than about 1 manSv or an assessment for the optimization of protection shows that exemption is the optimum option.”

Compliance with a).

Using the dose limit requirements in Section 9 of this standard of 0,4 μSv per screening procedure for backscatter systems would mean that an individual would be limited to 25 scans per year to comply with the limit of 10 μSv and for transmission systems where the limit of this standard is 5 μSv an individual would be limited to 2 scans per year.

Compliance with b).

For a single scanning system a total about 2 500 000 persons could be scanned in a year using backscatter systems and 200 000 persons for transmission systems

“EXEMPTED SOURCES AND EXEMPTION LEVELS

the following sources within practices are automatically exempted without further consideration from the requirements of the Standards, including those for notification, registration or licensing:

c) radiation generators, of a type approved by the Regulatory Authority, and any electronic tube, such as a cathode ray tube for the display of visual images, provided that:

   i) they do not cause in normal operating conditions an ambient dose equivalent rate or a directional dose equivalent rate, as appropriate, exceeding 1 $\mu Sv \cdot h^{-1}$ at a distance of 0,1 m from any accessible surface of the apparatus.”

Compliance with c), i).

The shielding requirements of 7.2.1 restrict the dose equivalent rate to 2,5 $\mu Sv \cdot h^{-1}$ at a distance of 30 cm which compares to the BSS limit which corresponds to about 0,11 $\mu Sv \cdot h^{-1}$ at 30 cm.

Annex C
(informative)

Leakage localization meter and use

This meter should have the following features:

a) The meter (or detached probe) should have multiple detectors in a linear array, covering an active length of at least 35 cm. Each detector should have no dimension greater than 5 cm.

b) Each detector output should have a separate meter or other means of providing an indication proportional to the signal. Such indicator should allow the indication of the detector yielding the highest momentary signal.

c) The meter should respond to photon radiation in the energy of 15 keV to 600 keV capable of measuring down to 0,1 $\mu Sv \cdot h^{-1}$ or better.

d) The meter should have a minimum dynamic range of 0,1 to 1 000 $\mu Sv \cdot h^{-1}$ ambient dose equivalent rate, with the lowest scale resolution of 0,1 $\mu Sv \cdot h^{-1}$ or better for the whole energy range. An overflow indication should occur when the meter's range is exceeded.

e) The meter should respond to the following pulses of radiation and provide a suitable indication for follow-up measurement: 100 ms, 1 nSv single pulses (i.e., 36 $\mu Sv \cdot h^{-1}$ instantaneous rate); 10 ms, 10 nSv pulses (i.e., 3 600 $\mu Sv \cdot h^{-1}$ instantaneous rate).

f) The meter should operate properly in temperatures between –10 °C and + 50 °C and up to 95 % relative humidity.

A scattering object should be placed at the location a person would normally stand to be screened. The scattering object shall approximate the surface area of an average adult and should have a density near 1 $g \cdot cm^{-3}$. With the scattering object in place the ambient dose equivalent should be measured at locations where bystander access is allowed.

Where the shielding is reliant on walls, partitions, etc., at the installation or on additional shielding that is not part of the basic equipment these tests should be undertaken after installation again repeating the tests where any panels, doors etc. that can be opened are removed or opened.

Bibliography

ICRU (International Commission on Radiation Units and Measurements) 17: 1970, *Radiation dosimetry: X-rays Generated at Potentials of 5 to 150 kV*

ICRU 39, *Determination of Dose Equivalents Resulting from External Radiation Sources*

ICRU 51, *Units in Radiation Protection*

_____

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the independent national body responsible for preparing British Standards and other standards-related publications, information and services.
It presents the UK view on standards in Europe and at the international level.

It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001

BSI offers Members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Tel: +44 (0)20 8996 7669 Fax: +44 (0)20 8996 7001
Email: plus@bsigroup.com

Buying standards

You may buy PDF and hard copy versions of standards directly using a credit card from the BSI Shop on the website **www.bsigroup.com/shop.** In addition all orders for BSI, international and foreign standards publications can be addressed to BSI Customer Services.

Tel: +44 (0)20 8996 9001 Fax: +44 (0)20 8996 7001
Email: orders@bsigroup.com

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Knowledge Centre.

Tel: +44 (0)20 8996 7004 Fax: +44 (0)20 8996 7005
Email: knowledgecentre@bsigroup.com

Various BSI electronic information services are also available which give details on all its products and services.

Tel: +44 (0)20 8996 7111 Fax: +44 (0)20 8996 7048
Email: info@bsigroup.com

BSI Subscribing Members are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration.

Tel: +44 (0)20 8996 7002 Fax: +44 (0)20 8996 7001
Email: membership@bsigroup.com

Information regarding online access to British Standards via British Standards Online can be found at **www.bsigroup.com/BSOL**

Further information about BSI is available on the BSI website at **www.bsigroup.com/standards**

Copyright

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Tel +44 (0)20 8996 9001
Fax +44 (0)20 8996 7001
www.bsigroup.com/standards

raising standards worldwide™