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BSI Standards Publication

Radiation protection instrumentation — Security screening of humans — Measuring the imaging performance of X-ray systems

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National foreword

This British Standard is the UK implementation of IEC 62709:2014.

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.

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Instrumentation pour la radioprotection – Contrôle de sécurité des individus – Mesure des performances de l'imagerie des systèmes radiographiques aux rayons X

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RADIATION PROTECTION INSTRUMENTATION – SECURITY SCREENING OF HUMANS – MEASURING THE IMAGING PERFORMANCE OF X-RAY SYSTEMS

FOREWORD

International Standard IEC 62709 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/780/FDIS	45B/786/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- withdrawn,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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This standard establishes standard test methods and test objects for measuring the imaging performance of X-ray systems for security screening of humans. For each image quality test, this standard also sets minimum acceptable levels of performance. These procedures and minimum acceptable requirements should not be construed as an all-inclusive measure of performance for any situation. Depending on the circumstances and detection needs, user institutions will continue to generate their own requirements and are encouraged to do so. Rather, it is hoped that this standard will provide a starting point for evaluating systems, provide a uniform set of readily available information to compare equipment, and offer a standard procedure for periodic quality control testing.

Four annexes are included. Annex A (normative) provides mechanical drawings of the imaging test objects. Sample test report forms are given in Annex B (informative). Annex C (informative) provides a generic description of the pentalith, the spatial resolution test object. Annex D (informative) seeks to describe the different types of security systems presently being used for whole-body imaging.

RADIATION PROTECTION INSTRUMENTATION – SECURITY SCREENING OF HUMANS – MEASURING THE IMAGING PERFORMANCE OF X-RAY SYSTEMS

1 Scope and object

This International Standard applies to security screening systems that utilize X-ray radiation and are used to inspect people who are not inside vehicles, containers, or enclosures. Specifically, this standard applies to systems used to detect objects carried on or within the body of the individual being inspected. This standard does not include requirements related to electromagnetic compatibility, radiological, electrical and mechanical safety. These requirements are covered in IEC 62463:2010.

The following types of systems are included in the scope of this standard:

- Systems designated as fixed, portal, transportable, mobile or gantry.
- Systems employing detection of primary radiation, backscattered radiation, forward-scattered radiation, (see Annex D) or some combination of these modalities to form two-dimensional X-ray images.
- Systems that are primarily imaging but that also may have complementary features such as material discrimination, automatic active or passive detection alerts. This standard will not address how to test these complementary features.

The objective is to provide standard methods of measuring and reporting imaging quality characteristics that enable system manufacturers, potential system users and other interested parties to:

a) Establish a consistent indicator of the expected technical performance of screening systems used for the inspection of individuals. Such technical performance testing complements explicit detection testing and evaluation. In this standard “detection” refers to items in an image.
b) Provide repeatable and verifiable imaging performance data that can be used to compare systems from different vendors.
c) Establish a baseline that can be used over time to calibrate the system or detect any performance degradation. (It is not intended that the entire test method be employed for daily quality assurance testing.)
d) Establish minimum acceptable performance requirements for the systems described above.

2 Normative references

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 Users of this standard should note that standards referenced herein may not fulfil the legal requirements and practices in all countries, or jurisdictions. Care should be taken to ensure regulatory compliance.

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, equipment and detectors*

IEC 60050-881:1983, *International Electrotechnical Vocabulary (IEV) – Part 881: Radiology and radiological physics*

IEC 62463:2010, *Radiation protection instrumentation – X-ray systems for the screening of persons for security and the carrying of illicit items*

ISO 683-17:1999, *Heat-treated steels, alloy steels and free-cutting steels – Part 17: Ball and roller bearing steels*

3 Terms and definitions, abbreviations, quantities and units

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply. The general terminology concerning X-ray systems and radiological physics is given in IEC 60050-393:2003, IEC 60050-394:2007 and IEC 60050-881:1983.

3.1.1
backscattered radiation
backscatter
scattering of photons by material through angles greater than 90° with respect to their initial direction

[SOURCE: IEC 60050-393:2003, 393-13-14]

3.1.2
backscatter system
security screening system that makes use of backscattered radiation to form an image

3.1.3
contrast sensitivity
the ability to distinguish a small difference of intensity in an area of an X-ray image from a surrounding uniform background

[SOURCE: IEC 62523:2010]

3.1.4
edge detection
ability to discern edges of objects or anomalies even when the bulk of the objects or anomalies may appear with the same brightness as the background

3.1.5
forward-scattered radiation
scattering of photons by material through angles less than 90° with respect to their initial direction

3.1.6
forward-scatter system
security screening system that makes use of forward-scattered radiation to form an image

3.1.7
influence quantity
quantity that is not the measurand but that affects the result of the measurement

[SOURCE: IEC 60050-394:2007, 394-40-27]

3.1.8
materials detection
test of the ability to detect materials on or off the body phantom

3.1.9
mobile system
system that is mounted on a vehicle which moves while scanning

3.1.10
operator
person authorised and fully trained to operate the system

[SOURCE: IEC 62463:2010]

3.1.11
partial body field of view
field of view of systems designed to scan parts of the body, such as cast and prostheses scanners or shoe scanners

3.1.12
penetration test
test of spatial resolution and wire detection as a function of body phantom thickness

3.1.13
pentalith
spatial resolution test object consisting of five equal spheres placed at the vertices of a regular pentagon. The vertices are separated by twice the diameter of the spheres

Note 1 to entry: See Annex C for a complete description.

3.1.14
primary radiation
ionizing radiation emitted directly by a radiation source

[SOURCE: IEC 60050-393:2003, 393-12-19]

3.1.15
radiation source
equipment or matter emitting or capable of emitting ionizing radiation

[SOURCE: IEC 60050-393:2003, 393-12-23]

3.1.16
reference location
required location where test objects are placed for assessing imaging performance according to this standard

Note 1 to entry: The reference location is specified in 4.2.

Note 2 to entry: Other testing locations may be used for additional information.

3.1.17
scan area
field of view of a screening system at a given distance from the source of radiation

3.1.18
scanning speed
the speed of the inspected object moving relative to the inspection system, or vice versa

[SOURCE: IEC 62523:2010]

3.1.19
scattered radiation
scatter
radiation which, during passage through a material, has been deviated from its original direction or changed in energy by scattering

Note 1 to entry: Backscatter and forward-scatter systems use scatter to form backscatter and/or forward-scatter images.

[SOURCE: IEC 60050-881:1983, 881-03-19]

3.1.20
security screening
inspection of personnel, goods, cargo, vehicles and other objects to detect prohibited, controlled or dangerous items. In the case pertaining to this standard the objects inspected are carried on or within the body of a person

3.1.21
spatial resolution
minimum separation between two objects at which they can be resolved as separate entities

3.1.22
system
scanning system
whole equipment used to produce a scanned image, including the X-ray generator, collimator, detector assembly, computer and display console

3.1.23
transmission system
system using the conventional means of projection radiographic imaging in which X rays pass through a target (e.g., person or container) and create shadowgrams of enclosed objects (e.g., contraband) based on their radiation attenuating properties

3.1.24
transportable system
system that is designed to be easily redeployed and transported

3.1.25
whole body field of view
field of view of systems designed to completely scan and image one person at a time

3.1.26
wide field of view
field of view of systems for which one scan covers an area that may contain more than one person

3.1.27
wire detection
the minimum diameter of a wire in mm, that can be detected and distinguished from the background

[SOURCE: IEC 62523:2010]

3.2 Abbreviations

3.2.1
HDPE
high-density polyethylene

3.2.2
MTF
modulation transfer function

3.3 Quantities and units

In this standard, the units are the multiples and sub-multiples of units of the International System of Units (SI)[1]. The definitions of radiation quantities are given in IEC 60050-393 and IEC 60050-394.

4 Imaging performance evaluation procedures

4.1 General characteristics and test procedures

The procedures of this standard shall be used to measure the following four characteristics of imaging performance or image quality:

a) Spatial resolution

b) Wire detection

c) Materials detection (may be by means of contrast sensitivity or edge detection)

d) Penetration

The test procedures provide for the measurement of systems that use the following imaging modes: detection of primary radiation, backscattered radiation, forward-scattered radiation, or some combination of these modalities (see Annex D).

For each test, the test object shall be scanned as in normal use; this is defined to mean standard operating procedure, software, and hardware settings of lateral and/or vertical scan speed, source voltage and current, and filtration. Since dose to scanned individuals and image quality are interrelated, these machine settings shall be included in the test report (for an example, see Annex B). If the dose to scanned persons is also being measured (e.g., IEC 62463:2010) for this system, the same machine settings should be used for both the image quality and radiation safety testing to facilitate the assessment of overall system performance. If image-enhancement software features are available to the operator in normal use, these may be used to achieve the best possible image. Examples are zoom, edge enhancement, expanded density, black-and-white reverse, and pseudo-color. The use of these software features shall be recorded in test documentation in addition to the hardware settings listed above.

The score for each test shall be repeatable at least two thirds of the time.

4.2 Location of testing

At a minimum, all the image quality tests shall be performed at the reference location. The reference location is defined as follows:

a) the surface of the body phantom and test object combination closest to the radiation source shall be at the optimum operating distance as specified by the manufacturer, and

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

b) the centre of the body phantom shall be in the lateral centre of the scan area and, for full-body systems, at a height 1 m from the ground. For partial body systems the reference location should be centred about the subject imaging location. A generic illustration of this testing configuration is given in Figure 1.

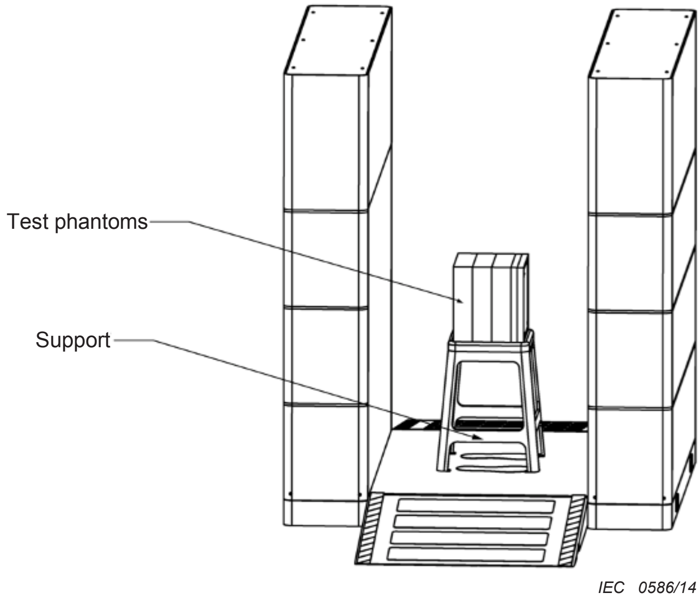


Figure 1 – Generic illustration of the testing configuration showing a HDPE body phantom with a test object on one end supported 1 m off the ground

Additionally, off-centre tests should be performed at specified locations. Prospective users may request test results for specific locations in the scan area (e.g., head, feet, sides, edge of scan area). For off-centre tests, a 300 mm × 300 mm × 100 mm block of high-density polyethylene (HDPE) may be placed in the centre of the field of view if needed for proper functioning of the auto gain control.

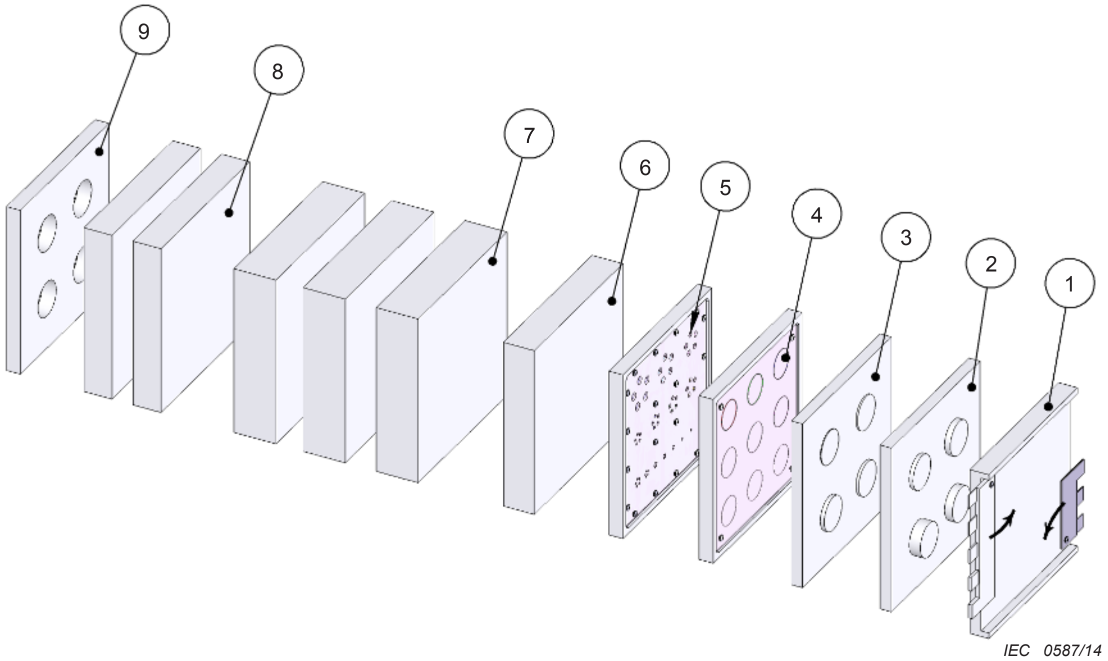
4.3 Body phantom and test objects

The test objects for each of the image quality tests shall be mounted on a body phantom. The body phantom shall be made of HDPE. The body phantom and all the other HDPE parts of test objects described in this standard shall have a density of 0,95 g·cm^{-3} ± 0,05 g·cm^{-3}.

The body phantom shall have dimensions of 300 mm wide × 300 mm high × 280 mm deep. The body phantom shall have a means of supporting each of the test object assemblies described in 4.4 through 4.7 so that the overall HDPE depth of the body phantom and test object assembly (excluding the 1,5 mm overlay) shall be 300 mm. That is, a HDPE cube, 300 mm on each side, is used to simulate the human body.

For the penetration test the overall depth shall be expandable from 300 mm to 400 mm by attaching two additional 50 mm thick slabs of HDPE. A diagram of the body phantom and test objects is shown in Figure 2. Complete mechanical drawings of the body phantom and test objects are provided in normative Annex A.

All the dimensions of the body phantom and test objects shall be within ±2 % or 0,2 mm, whichever is greater, unless otherwise specified.



Key

1	materials detection in air
2 and 3	materials detection on body
4	wire detection
5	spatial resolution
6 and 7	body phantom, four pieces
8	penetration test, two pieces
9	storage spacer

NOTE For each test the respective test object, (1) through (5), is placed over the four body phantom pieces, (6) and (7). The body phantom extensions, (8), are used for the penetration test. The last piece, (9), is only a spacer used for storing and stacking pieces (2) and (3) with the other blocks. The combs of piece (1) swivel inward for storage.

Figure 2 – Body phantom and test objects

4.4 Spatial resolution test

4.4.1 Purpose

The purpose of this test is to measure the ability to distinguish as separate, objects that are themselves separated by a space equal to the object width.

4.4.2 Test object description

The spatial resolution test object consists of fourteen sets of five equal spheres, forming fourteen regular pentagons, called pentaliths (see also informative Annex C). The spheres are made of bearing steel, ISO 683-17:1999, grade designation 100Cr6 or equivalent (e.g. AISI/SAE 52100, EN 10027-2 1.3505; JIS SUJ2) and are imbedded in a block of HDPE, 300 mm × 300 mm × 25 mm, so that the front surface of each sphere is flush with the surface of the block. The five spheres are placed at the vertices of a regular pentagon. The space between adjacent spheres is equal to the sphere diameter. Each pentagon is aligned such that no side is perfectly vertical or horizontal. There is a pentagon for each of the following sphere diameters: 1 mm, 1,2 mm, 1,5 mm, 2 mm, 2,5 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, 10 mm, 12 mm, and 14 mm. The tolerance for each sphere diameter and the hole containing each sphere shall be no greater than ±0,1 mm. A 1,5 mm thick sheet of HDPE is placed over the spheres to simulate a layer of thick clothing and to hold the spheres in place.

The pentalith assembly is attached to the body phantom to form a solid HDPE block that is 300 mm on a side. Mechanical drawings of the spatial resolution test object are given in Figures A.1, A.13, A.14, A.15, and A.16 of Annex A.

4.4.3 Procedure

A test object meeting the description in 4.4.2 and a body phantom as described in 4.3 shall be used for this test.

The test object shall be mounted on the body phantom and positioned at the reference location (see 4.2) as follows. For backscatter and/or forward-scatter systems, the surface of the body phantom containing the test object shall be the surface closest to the radiation source. For transmission systems, either the surface containing the test object or the opposite surface shall face the radiation source (the orientation of the body phantom shall be recorded in the test report).

The test object shall be scanned as in normal use as defined in 4.1.

The procedure may be repeated at other desired testing locations.

4.4.4 Evaluation and record

Find the smallest pentagon for which all five spheres are visible as completely separate objects. Software image adjustments available to the operator may be used to obtain optimum contrast and brightness. The settings for any adjustments shall be recorded in the test report. For example, if contrast and brightness adjustments are available to the operator, the following is an acceptable procedure for testing separation and for achieving reproducible measurements: turn the contrast all the way up, adjust the brightness to see if five separate islands can be formed. See Annex C for further information related to objectively scoring this test.

Record the smallest sphere diameter meeting the above analysis.

4.5 Wire detection test

4.5.1 Purpose

The purpose of this test is to determine the minimum diameter of copper wire that can be detected.

4.5.2 Test object description

The wire detection test object consists of nine copper wires, each forming a circle with a nominal diameter of 50 mm. The wires are attached on the surface of a HDPE block having dimensions of 300 mm × 300 mm × 25 mm. (Alternatively, the wires may be mounted on a 6,4 mm thick sheet using an additional 19 mm HDPE spacer). A 1,5 mm thick sheet of HDPE is placed over the wires to simulate a layer of thick clothing.

The following wire sizes are included on the test object (see Table 1):

Table 1 – Wire sizes for the wire detection test

Nominal diameter mm
0,812
0,644
0,511
0,405
0,321
0,255
0,202
0,160
0,127

Mechanical drawings of the wire detection test object are given in Figures A.1, A.10, A.11, and A.12 of Annex A.

4.5.3 Procedure

A test object meeting the description in 4.5.2 and body phantom as described in 4.3 shall be used for this test.

The test object shall be mounted on the body phantom so that the surface on which the wires are placed faces away from the HDPE cube. The body phantom and test object shall be positioned at the reference location (see 4.2) as follows. For backscatter and/or forward systems the surface of the body phantom containing the test object shall be the surface closest to the radiation source. For transmission systems, either the surface containing the test object or the opposite surface shall face the radiation source (the orientation of the body phantom shall be recorded in the test report).

The test object shall be scanned using the normal scanning procedure as defined in 4.1.

The procedure may be repeated at other desired testing locations.

4.5.4 Evaluation and record

Identify and record the smallest wire gauge for which a contiguous length of at least half the circle circumference is visible. Image adjustments available to the operator may be used to obtain optimum contrast and brightness. The settings for any adjustments shall be recorded in the test report.

4.6 Materials detection on body test

4.6.1 General

This test is intended to measure the ability to detect objects on the body that are of a density similar to that of the body. Depending on the properties of the scanning system, this test may serve as either a contrast sensitivity test or edge detection test.

4.6.2 Purpose

The purpose of this test is to measure the ability to observe step changes in thickness of flat organic material superimposed on the flat body phantom.

4.6.3 Test object description

The test object consists of HDPE discs placed over the body phantom. The discs are 60 mm in diameter and have thicknesses of 1,5 mm, 3 mm, 5 mm, 7 mm, 10 mm, 14 mm, and 20 mm. The discs are attached on the surface of a 300 mm × 300 mm × 25 mm HDPE sheet and are spaced at least 60 mm apart. (Alternatively the discs may be mounted on a 6,4 mm thick sheet using an additional 19 mm HDPE spacer). In order to adequately space the discs the seven thicknesses are distributed on two HDPE sheets. The 7 mm thickness is repeated on each set for reference. Mechanical drawings of the materials detection on body test object are given in Figures A.1, A.8, and A.9 of Annex A.

4.6.4 Procedure

A test object meeting the description in 4.6.2 and body phantom as described in 4.3 shall be used for this test.

The test object shall be mounted on the body phantom and positioned at the reference location (see 4.2) as follows. For backscatter and/or forward-scatter systems the surface of the body phantom containing the test object shall be the surface closest to the radiation source. For transmission systems, either the surface containing the test object or the opposite surface shall face the radiation source (the orientation of the body phantom shall be recorded in the test report).

Each set of discs shall be scanned using the normal scanning procedure as defined in 4.1.

The procedure may be repeated at other desired testing locations.

4.6.5 Evaluation and record

Identify and record the smallest disc thickness that is observable. Observable means that at least one half of the circumference can be discerned. Image adjustments that are available to the operator may be used to obtain optimum contrast and brightness. The settings for any adjustments shall be recorded in the test report.

4.7 Materials detection in air test

4.7.1 General

This test is intended to measure the ability to detect objects hidden in clothing on the sides of the body, when the image of the objects is not superimposed on the image of the body.

4.7.2 Purpose

The purpose of this test is to measure the ability to observe objects of different materials and thicknesses in air.

4.7.3 Test object description

The test object consists of two “combs” having square teeth of varying thickness. The teeth are 25 mm wide by 25 mm long and are separated by 25 mm. The first comb is made of HDPE and includes teeth thicknesses of 1,2 mm, 2,0 mm, 3,0 mm, 5,0 mm, and 7,0 mm. The second comb is made of stainless steel, SST-304 alloy (an equivalent material may be utilized, provided it is no more radio-opaque under comparable penetrating radiation energy conditions), and includes teeth thicknesses of 0,8 mm, 1,6 mm, and 3,2 mm. The combs are placed on a 300 mm × 300 mm × 25 mm HDPE sheet for mounting on the body phantom. (Alternatively the combs may be mounted on a 6,4 mm thick sheet using an additional 19 mm HDPE spacer). The supporting sheet may also contain another test object. The combs are placed so that the teeth extend beyond the upright edges of the body phantom and do not overlap any part of the body phantom in the image. Mechanical drawings of the materials detection in air test object are given in Figures A.1 to A.7 of Annex A.

4.7.4 Procedure

A test object meeting the description in 4.7.2 and a body phantom as described in 4.3 shall be used for this test.

The test object shall be mounted on the body phantom and positioned at the reference location (see 4.2) as follows. For backscatter and/or forward-scatter systems, the surface of the body phantom containing the test object shall be the surface closest to the radiation source. For transmission systems, either the surface containing the test object or the opposite surface shall face the radiation source (the orientation of the body phantom shall be recorded in the test report).

The test object shall be scanned using the normal scanning procedure as defined in 4.1.

The procedure may be repeated at other desired testing locations.

4.7.5 Evaluation and record

Identify and record the thinnest tooth observable for each material. Observable means that at least one half of the 25 mm × 25 mm tooth area can be discerned. Image adjustments that are available to the operator may be used to obtain optimum contrast and brightness. The settings for any adjustments shall be recorded in the test report.

4.8 Penetration test

4.8.1 General

This test applies only to transmission systems or other modalities if the intent is to image inside the body.

4.8.2 Purpose

The purpose of this test is to measure any degradation of spatial resolution and wire detection with increased body size.

4.8.3 Test object description

The test object consists of two 300 mm × 300 mm × 50 mm slabs of HDPE to be added to the body phantom on the opposite side as the other test objects. Mechanical drawings of the penetration test object are given in Figures A.1 and A.19 of Annex A.

4.8.4 Procedure

Repeat the spatial resolution and wire detection tests of 4.4 and 4.5 with a 50 mm thickness of HDPE added to the body phantom (on the side opposite the resolution or wire detection test object) and again with a total of 100 mm of HDPE added.

4.8.5 Evaluation and record

Evaluate and record the results as in 4.4.4 and 4.5.4.

5 Minimum acceptable imaging performance

The security screening systems covered by the scope of this standard shall meet the minimum imaging performance requirements shown in Table 2. These minimum requirements apply to the testing performed at the reference location, as described in 4.2, according to the methods in 4.4 through 4.8. Different minimum performance requirements are given for systems employing the three fields of view, viz., partial body (3.1.11), whole body (3.1.25), and wide (3.1.26).

Table 2 – Minimum acceptable imaging performance at the reference location

Image quality test	Whole body field of view	Partial body field of view	Wide field of view	Relevant clause or subclause
1. Spatial resolution: smallest sphere diameter resolved	6 mm	2,5 mm	14 mm	4.4
2. Wire detection: smallest wire detected	0,511 mm	0,321 mm	RO[c]	4.5
3. Materials detection on body: thinnest disc discerned	5 mm	5 mm	RO	4.6
4. Materials detection in air: smallest plastic thickness discerned smallest metal thickness discerned	 3 mm 1,6 mm	 2 mm 0,8 mm	 RO RO	4.7
5. Penetration test a) through 350 mm HDPE[a]: smallest sphere diameter resolved smallest wire detected b) through 400 mm HDPE[b]: smallest sphere diameter resolved smallest wire detected	 RO RO RO RO			4.8

[a] Body phantom plus 50 mm.

[b] Body phantom plus 100 mm.

[c] RO: Report only; there is no minimum requirement.

6 Environmental requirements

To ensure uniformity of test results, all the image quality tests in this standard summarized in first column of Table 2 shall be performed under the standard test conditions specified in Table 3.

Table 3 – Standard test conditions

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

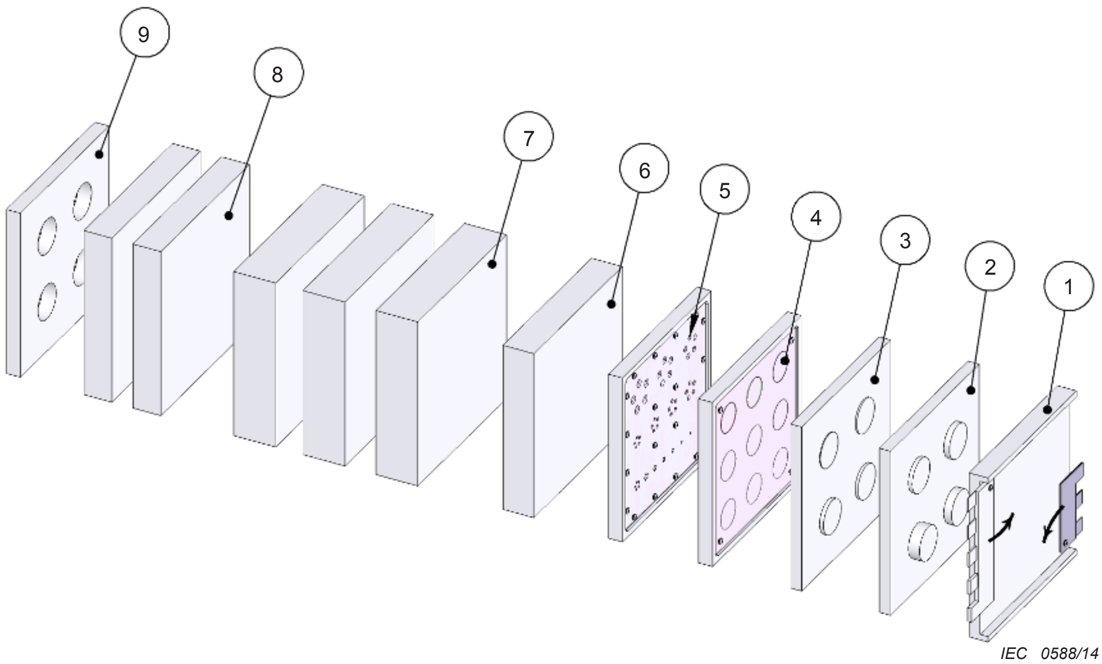
If the system is intended for operation in environmental conditions significantly outside the ranges specified in Table 3, additional testing should be done to demonstrate that the imaging performance reported for standard test conditions remains unchanged at the low-temperature/low-humidity limit and at the high-temperature/high-humidity limit of the intended range.

The value of ambient air temperature, relative humidity, and atmospheric pressure at the time of the test shall be recorded (see, e.g., Annex B). The environmental conditions stated in Table 3 take priority over other environmental conditions stated in the referenced standards.

Annex A
(normative)

Mechanical drawings of the test objects

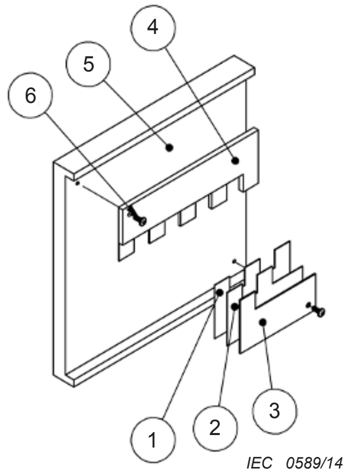
This Annex contains a complete set of mechanical drawings for the test objects specified in this standard and is normative in the sense that it reflects the requirements of this standard. Other implementations of test objects that deviate from these drawings but continue to conform to the dimensional and material specifications of this standard are permitted. Unless otherwise specified, dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.



Key

1	material detection in air	Figures A.2 to A.7	Quantity 1
2	material detection on body 1	Figure A.8	Quantity 1
3	material detection on body 2	Figure A.9	Quantity 1
4	wire detection test	Figures A.10 to A.12	Quantity 1
5	spatial resolution	Figures A.13 to A.16	Quantity 1
6	body phantom, 55 mm thick	Figure A.17	Quantity 1
7	body phantom, 75 mm thick	Figure A.18	Quantity 3
8	penetration test, 50 mm thick	Figure A.19	Quantity 2
9	storing spacer	Figure A.20	Quantity 1

Figure A.1 – Components of the test phantom



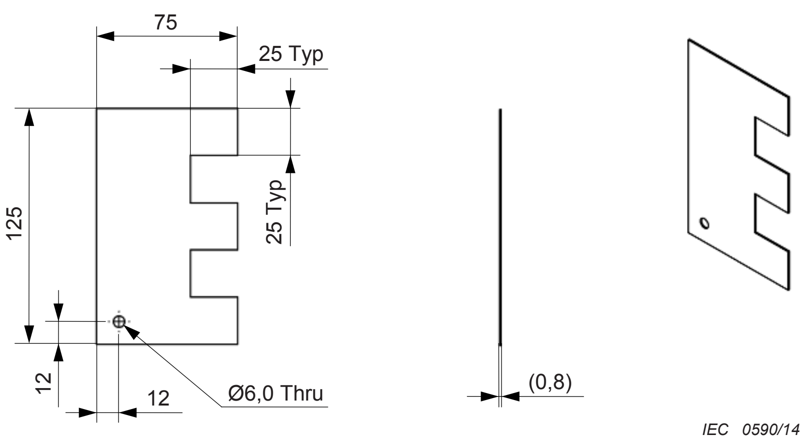
Key

1	metal comb, three teeth	Quantity 1
2	metal comb, two teeth	Quantity 1
3	metal comb, one tooth	Quantity 1
4	plastic comb, five teet	Quantity 1
5	combs mounting sheet	Quantity 1
6	Phillips head screws, M5 × 12, 18-8 SST	Quantity 2

NOTE 1 See 4.7.2 for detailed materials specifications.

NOTE 2 Figures A.3 through A.7 show additional details.

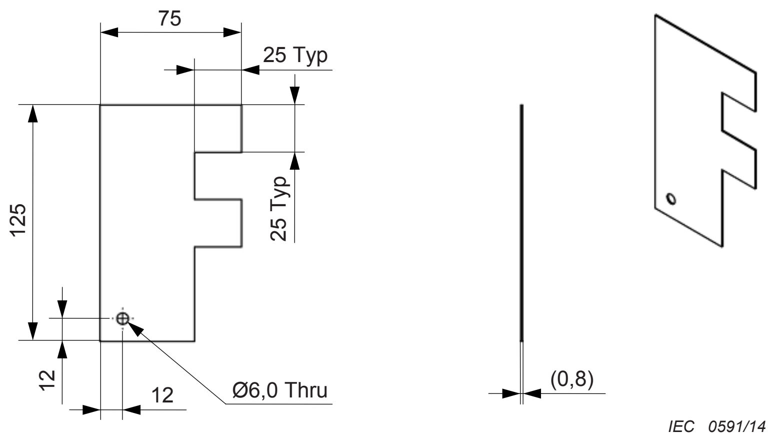
Figure A.2 – Material detection in air phantom



NOTE 1 This is fabricated from stainless steel (SST-304 alloy or equivalent).

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

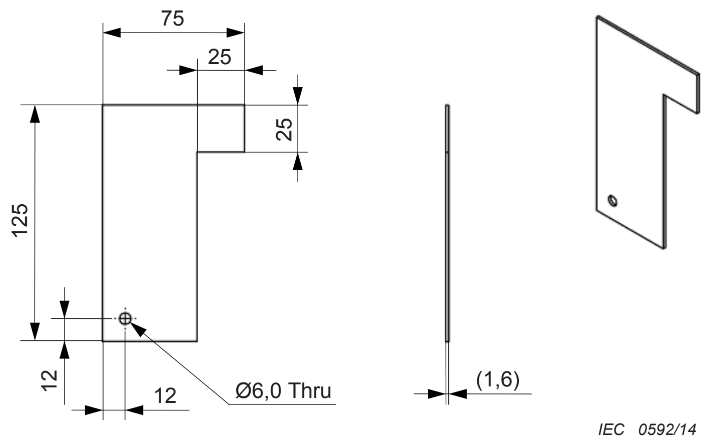
Figure A.3 – Subassembly of the material detection in air phantom (Figure A.2), metal comb, three teeth



NOTE 1 This is fabricated from stainless steel (SST-304 alloy or equivalent).

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

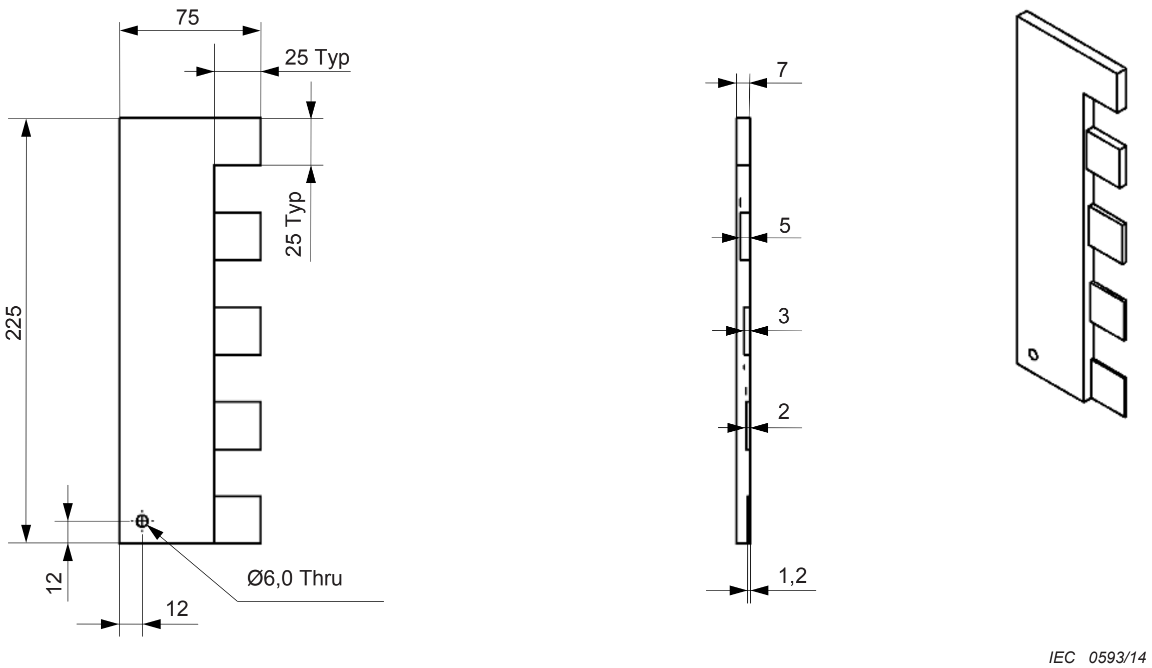
Figure A.4 – Subassembly of the material detection in air phantom (Figure A.2), metal comb, two teeth



NOTE 1 This is fabricated from stainless steel (SST-304 alloy or equivalent).

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

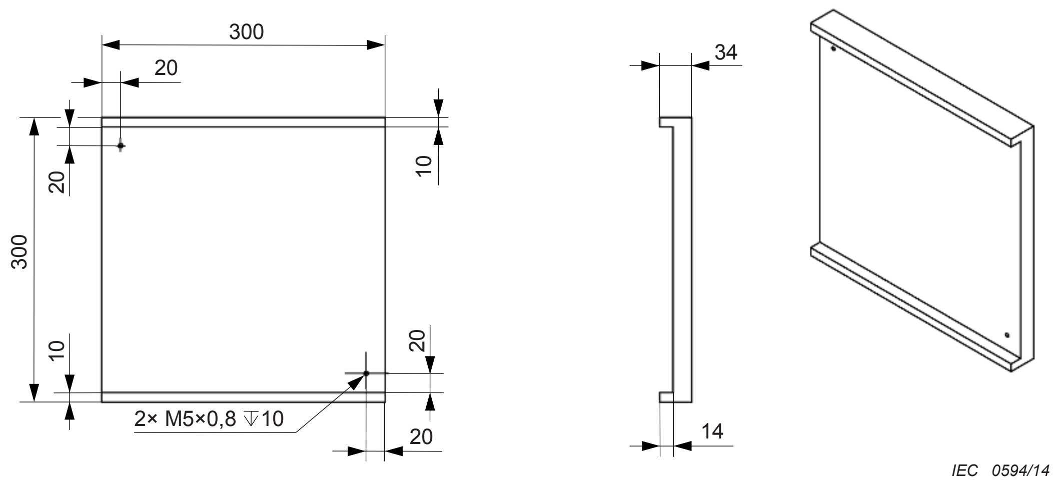
Figure A.5 – Subassembly of the material detection in air phantom (Figure A.2), metal comb, one tooth



NOTE 1 This is fabricated from stainless steel (SST-304 alloy or equivalent).

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

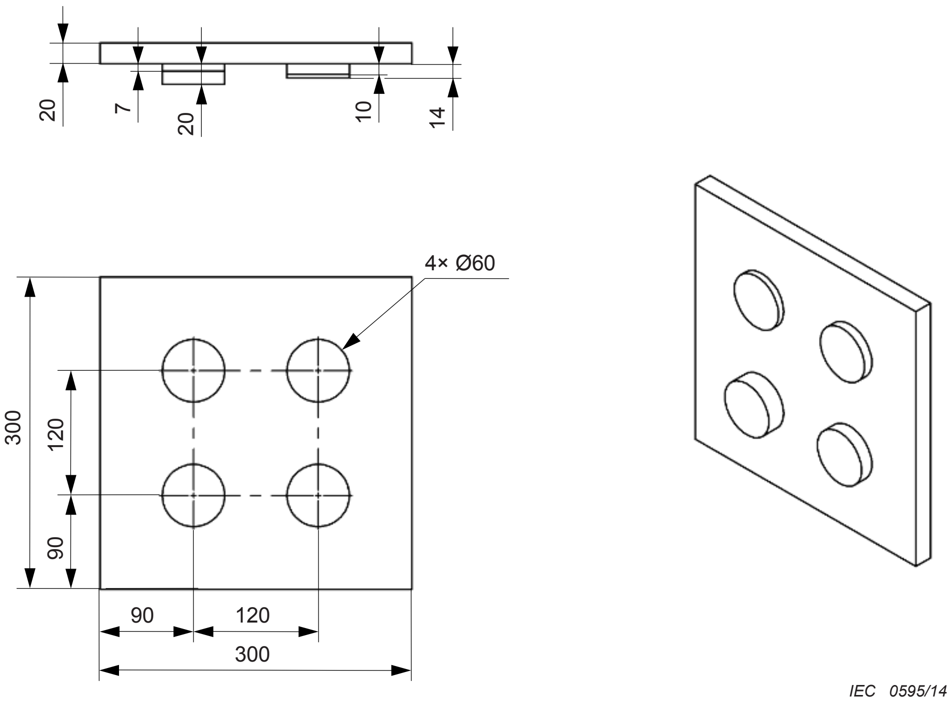
Figure A.6 – Subassembly of the material detection in air phantom (Figure A.2), plastic comb



NOTE 1 This is fabricated from stainless steel (SST-304 alloy or equivalent).

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

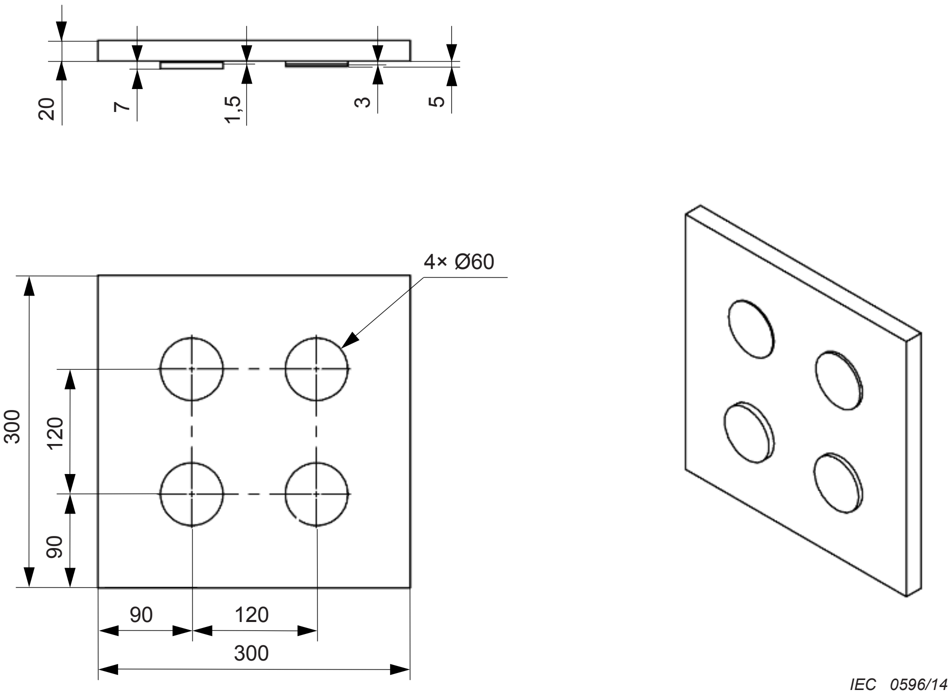
Figure A.7 – Subassembly of the material detection in air phantom (Figure A.2), mounting sheet



NOTE 1 This is fabricated from HDPE.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

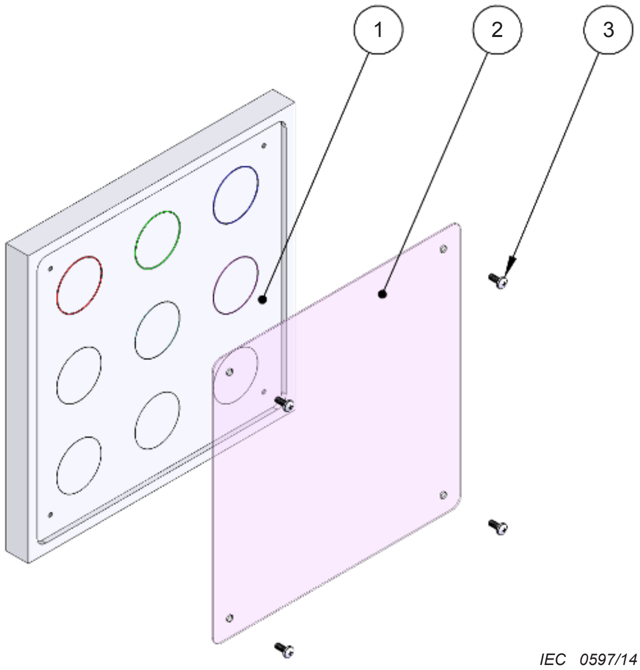
Figure A.8 – Material detection on body 1



NOTE 1 This is fabricated from HDPE.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3 mm; 0,xx ±0,15 mm.

Figure A.9 – Material detection on body 2



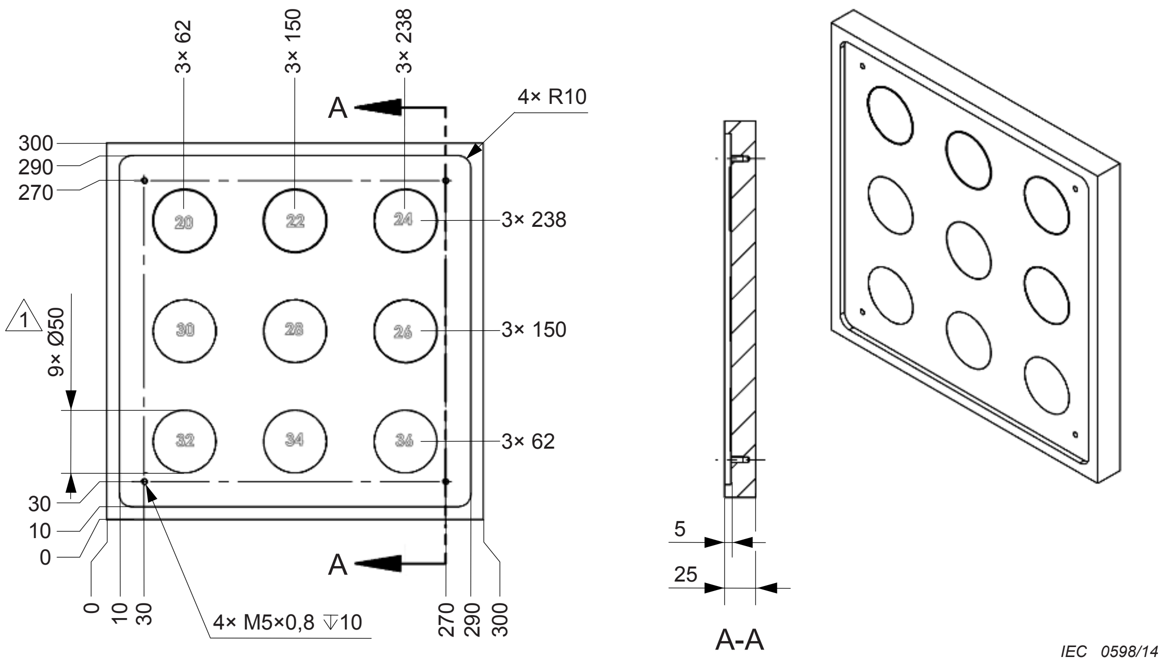
Key

1 base, see Figure A.11

2 cover, see Figure A.12

3 screws

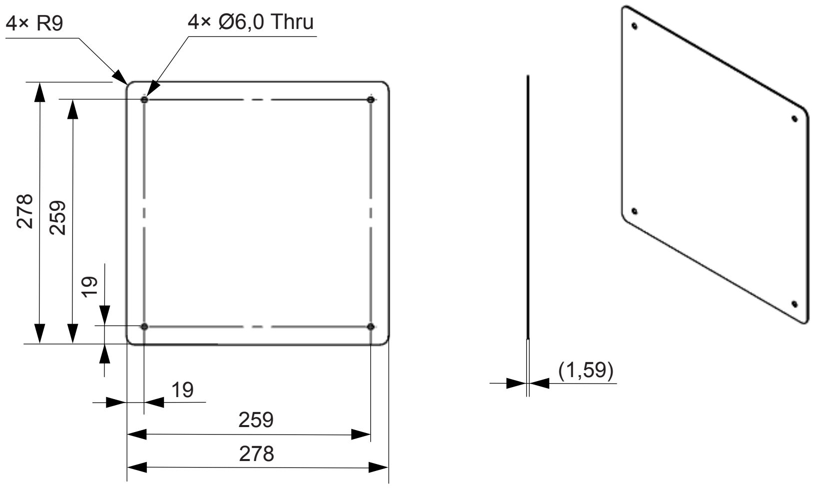
Figure A.10 – Wire detection phantom



NOTE 1 The base is fabricated from HDPE plastic. The thicknesses of the copper wires are given in Table 1.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

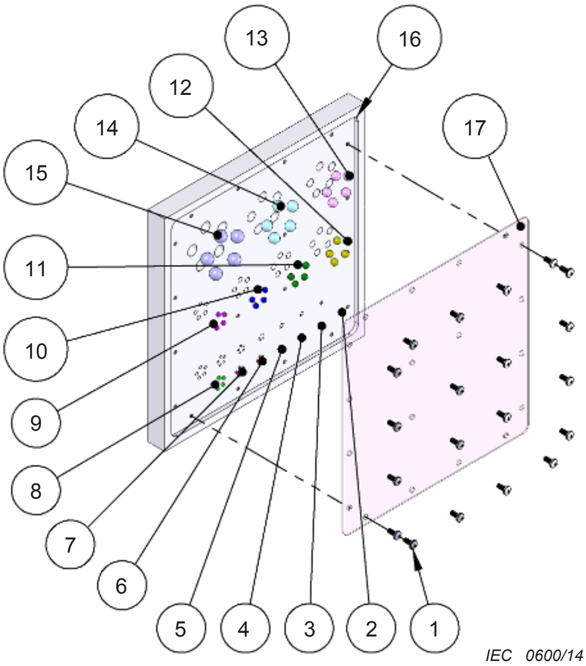
Figure A.11 – Subassembly of the wire detection phantom (Figure A.10), mounting base



NOTE 1 This part is fabricated from transparent polycarbonate plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

Figure A.12 – Subassembly of the wire detection phantom (Figure A.10), cover



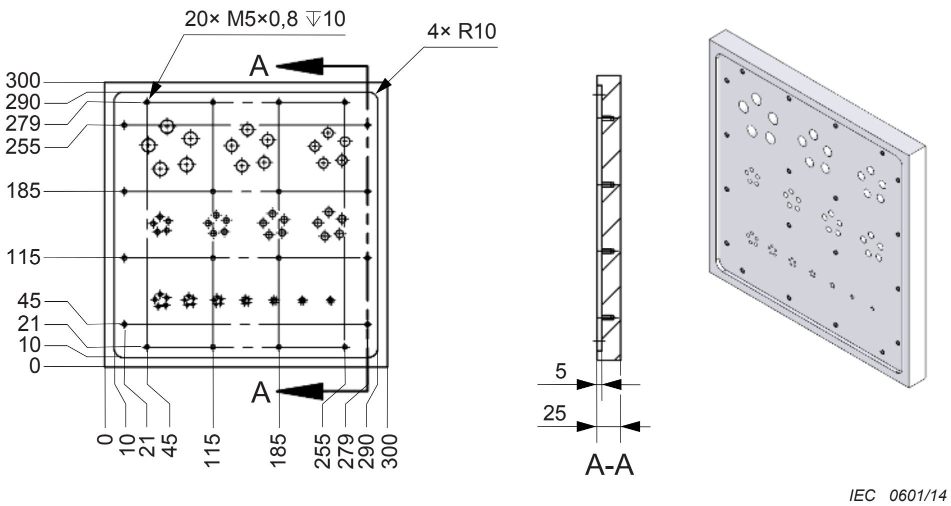
Key

1) Phillips screws, M5 × 12, nylon, quantity 20
2) steel ball bearing, 1,0 mm diameter, quantity 5
3) steel ball bearing, 1,2 mm diameter, quantity 5
4) steel ball bearing, 1,5 mm diameter, quantity 5
5) steel ball bearing, 2,0 mm diameter, quantity 5
6) steel ball bearing, 2,5 mm diameter, quantity 5
7) steel ball bearing, 3,0 mm diameter, quantity 5
8) steel ball bearing, 4,0 mm diameter, quantity 5
9) steel ball bearing, 5,0 mm diameter, quantity 5
10) steel ball bearing, 6,0 mm diameter, quantity 5
11) steel ball bearing, 7,0 mm diameter, quantity 5
12) steel ball bearing, 8,0 mm diameter, quantity 5

13) steel ball bearing, 10,0 mm diameter, quantity 5
14) steel ball bearing, 12,0 mm diameter, quantity 5
15) steel ball bearing, 14,0 mm diameter, quantity 5
16) base, resolution test, quantity 1
17) cover, resolution test, quantity 1

NOTE Figures A.14 through A.16 show additional details.

Figure A.13 – Spatial resolution phantom



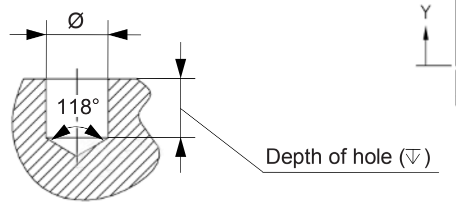
NOTE 1 This part is fabricated from HDPE plastic.

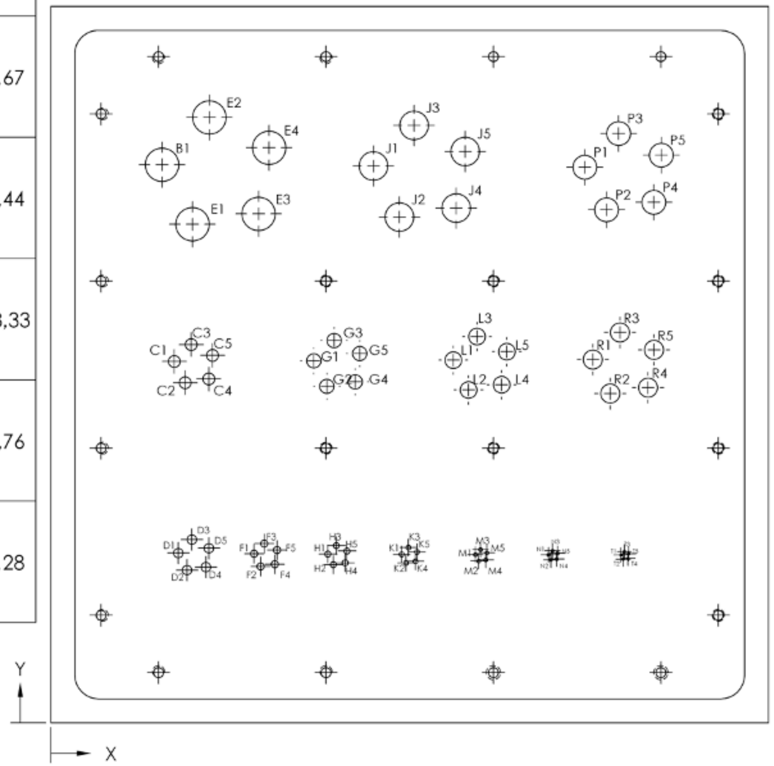
NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

Figure A.14 – Subassembly of the spatial resolution phantom (Figure A.13), mounting base

Hole Table			
TAG	X LOC	Y LOC	SIZE
B1	46,47	233,73	Ø14,0 DRILL ∇ 11,46
E1	59,19	208,78	
E2	66,27	253,53	
E3	86,84	213,16	
E4	91,22	240,81	
C1	51,60	151,33	Ø5,0 DRILL ∇ 4,41
C2	56,14	142,42	
C3	58,67	158,40	
C4	66,02	143,99	
C5	67,58	153,86	
D1	53,28	71,06	Ø4,0 DRILL ∇ 3,63
D2	56,91	63,94	
D3	58,94	76,72	
D4	64,81	65,19	
D5	66,06	73,09	
F1	84,96	70,80	Ø3,0 DRILL ∇ 2,85
F2	87,68	65,45	
F3	89,20	75,04	
F4	93,61	66,39	
F5	94,55	72,32	
G1	109,92	151,60	Ø6,0 DRILL ∇ 5,20
G2	115,37	140,90	
G3	118,40	160,08	
G4	127,22	142,78	
G5	129,10	154,63	
H1	115,80	70,67	Ø2,5 DRILL ∇ 2,46
H2	118,07	66,21	
H3	119,33	74,20	
H4	123,01	66,99	
H5	123,79	71,93	
J1	134,84	233,19	Ø12,0 DRILL ∇ 9,89
J2	145,73	211,81	
J3	151,81	250,16	
J4	169,44	215,56	
J5	173,19	239,27	
K1	146,64	70,53	Ø2,0 DRILL ∇ 2,07
K2	148,46	66,97	
K3	149,47	73,36	
K4	152,41	67,59	
K5	153,03	71,54	

Hole Table			
TAG	X LOC	Y LOC	SIZE
L1	168,24	151,86	Ø7,0 DRILL ∇ 5,98
L2	174,59	139,39	
L3	178,14	161,76	
L4	188,42	141,58	
L5	190,61	155,41	
M1	177,48	70,40	Ø1,5 DRILL ∇ 1,67
M2	178,84	67,73	
M3	179,60	72,52	
M4	181,80	68,20	
M5	182,27	71,16	
N1	207,98	70,32	Ø1,2 DRILL ∇ 1,44
N2	209,07	68,18	
N3	209,68	72,02	
N4	211,44	68,56	
N5	211,82	70,93	
P1	223,20	232,66	Ø10,0 DRILL ∇ 8,33
P2	232,28	214,84	
P3	237,34	246,80	
P4	252,03	217,97	
P5	255,16	237,72	
R1	226,56	152,13	Ø8,0 DRILL ∇ 6,76
R2	233,82	137,87	
R3	237,87	163,44	
R4	249,62	140,38	
R5	252,13	156,18	
T1	238,32	70,27	Ø1,0 DRILL ∇ 1,28
T2	239,23	68,48	
T3	239,73	71,68	
T4	241,20	68,80	
T5	241,52	70,77	

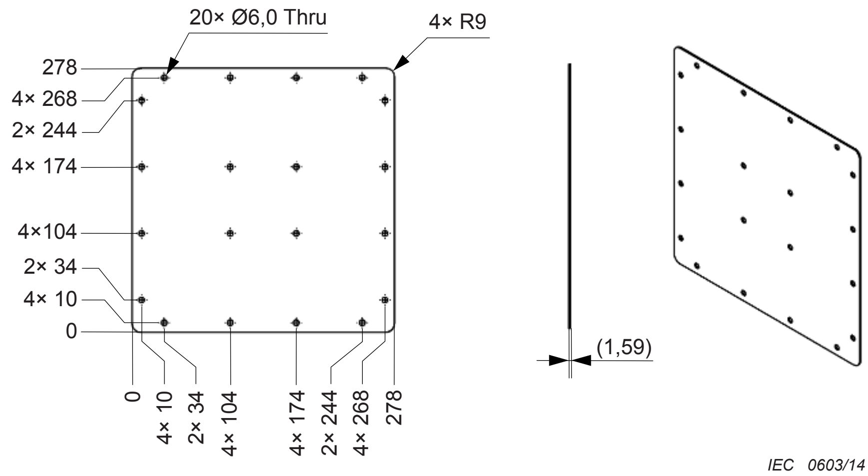




IEC 0602/14

NOTE All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

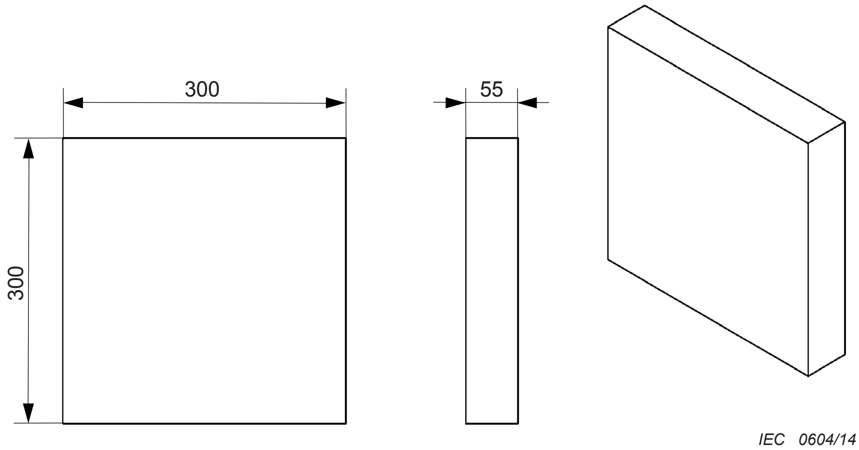
Figure A.15 – Subassembly of the spatial resolution phantom (Figure A.13); hole placement in mounting base



NOTE 1 This part is fabricated from transparent polycarbonate plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

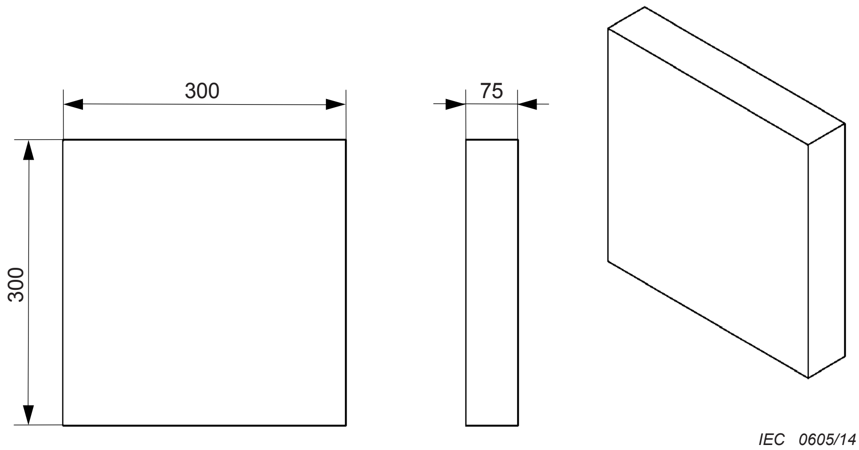
Figure A.16 – Subassembly of the spatial resolution phantom (Figure A.13), cover



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

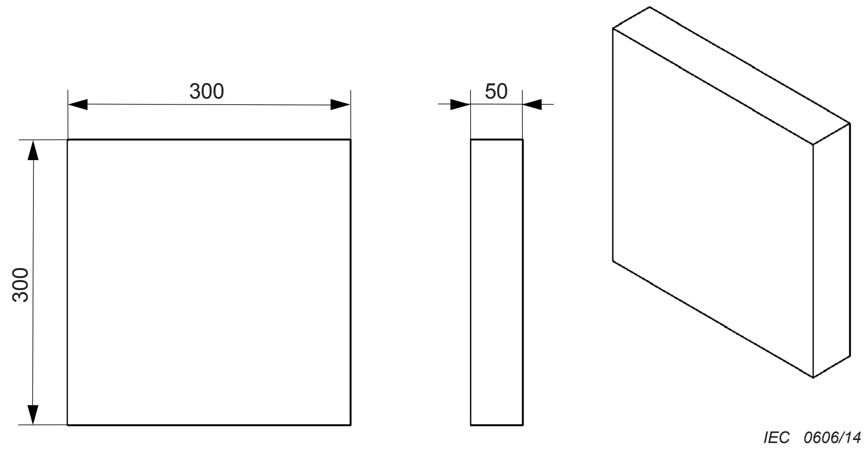
Figure A.17 – Body phantom, 55 mm thick



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

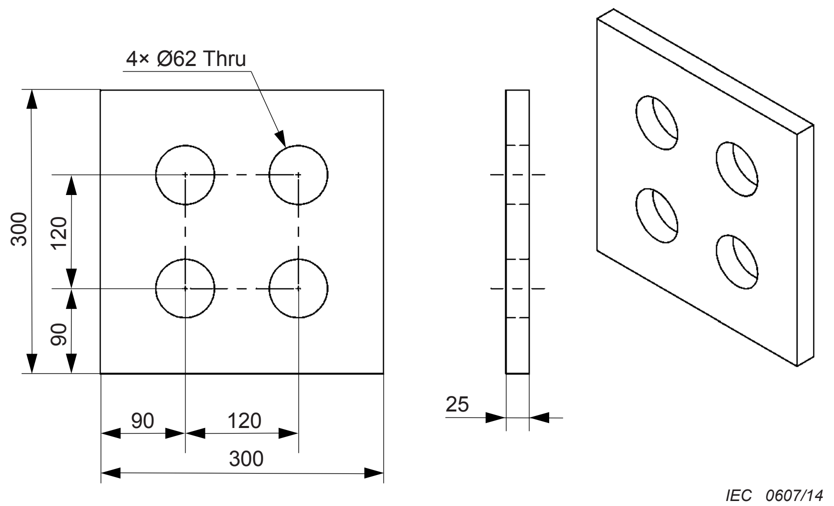
Figure A.18 – Body phantom, 75 mm thick



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

Figure A.19 – Body phantom, 50 mm thick



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular: ±0,5°; X/.x ±0,3; 0,xx ±0,15.

Figure A.20 – Storing space

Annex B
(informative)

Example of reporting form

The following pages contain a sample form for recording the results of the imaging test.

IEC 62709 body scanner imaging test report

Doc. Ref. #:______________, Page 1 of 2

Tester(s):	Place:	Date/Time:
System manufacturer:	Model/Type:	Serial #:
Ambient temperature:	Relative humidity:	Barometric pressure:
Body phantom ID No.:		
Test objects ID Nos.:		
Machine settings (include all the operator control settings necessary to reproduce this test; for example kV, mA, scan speed, filtration, mode, software version):		
Other test conditions:		
Test object placement		
Is the test object at the reference location (RL)? ☐ Yes ☐ No For transmission systems: test object facing ☐ source ☐ away from source		
Distance from beam-exit surface:		
If not RL: Lateral position __________________________ ☐ left of RL ☐ right of RL Height __________________________		
Transmission systems only: test objects placed on side of phantom ☐ nearest ☐ furthest from the radiation source.		

Other objects in field of view	Distance and location

IEC 62709 body scanner imaging test report

Doc. Ref. #:______________, Page 2 of 2

Test	Image enhancement features and settings used
1. Spatial resolution	
2. Wire detection	
3. Materials detection on body	
4. Materials detection in air	
5. Penetration	

Test	Description	Minimum requirement			Test results	Pass (✓)
		Whole body	Partial body	Wide view		
1	Spatial resolution: smallest sphere diameter resolved	6 mm	2,5 mm	14 mm		
2	Wire detection: smallest wire detected	0,51 mm	0,32 mm	RO[c]		
3	Materials detection on body: thinnest disc discerned	5 mm	5 mm	RO		
4	Materials detection in air:					
	smallest plastic thickness discerned	3 mm	2 mm	RO		
	smallest metal thickness discerned	1,6 mm	0,8 mm	RO		
5	Penetration test (applies to transmission systems only):					
	1) through 350 mm HDPE[a]					
	smallest sphere diameter resolved	RO	RO	RO		
	smallest wire detected	RO	RO	RO		
	2) through 400 mm HDPE[b]					
	smallest sphere diameter resolved	RO	RO	RO		
	smallest wire detected	RO	RO	RO		

List of attachments:

Notes:

The image evaluation tests above were conducted in accordance with IEC 62709.

____
Signature

[a] Body phantom plus 50 mm HDPE

[b] Body phantom plus 100 mm HDPE

[c] Report result only (RO)

Annex C
(informative)

Image resolution measurement using the pentalith

C.1 General

A variety of methods are available to measure the spatial resolution of images, such as the modulation transfer function (MTF) and the edge response. These methods have been used for over a century in analog applications such as optics and film-based photography. Digital imaging systems have become commonplace in the last 30 years and these same techniques are often used to characterize their performance. However, digital images have an attribute that can make these previous methods difficult to use, a rectangular sampling grid. This Annex proposes a new method of measuring the spatial resolution of digital images that overcomes this and other related problems: the pentalith. This technique is a general method with application to a wide variety of digital imaging systems.

C.2 Strategy

The guiding principle of this approach can be stated as follows:

An imaging system has a spatial resolution D, if it can resolve two circles of diameter D, separated by a distance D, regardless of the circle's placement on the sampling grid.

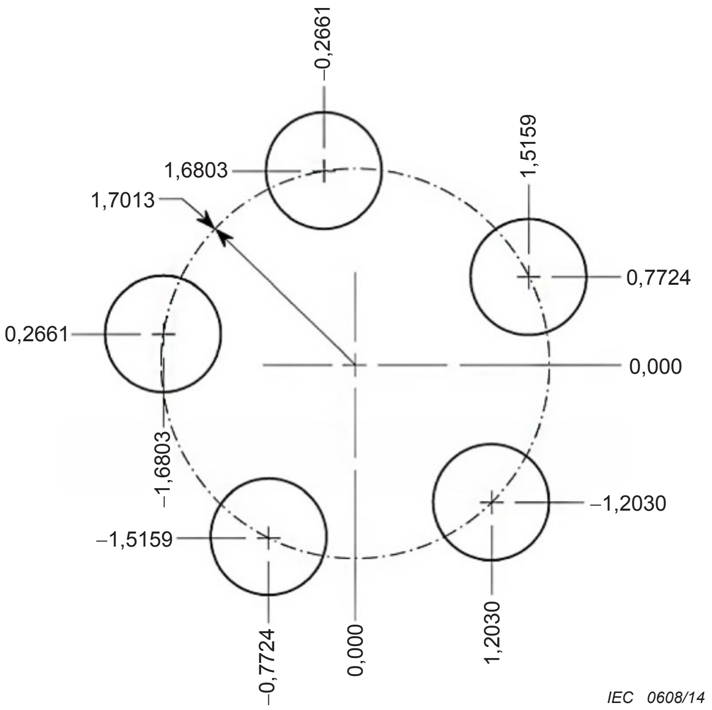
This principle takes into account three separate problems that are associated with spatial resolution:

a) Analog blurring, such as lens aberration in optical systems, focal spot blurring in X-ray devices, and the illumination spot size in scanning beam applications.
b) Sampling grid size, that is, the spacing between pixels. This essentially represents the information lost when an analog image is converted into a digital image.
c) Signal-to-noise ratio.

The ability to detect small objects in a digital image requires a certain level of performance in all three of these areas; however, the interaction between these three parameters can be quite complex. In an engineering setting it is usually important to understand each of these independent of the others. For instance, both the MTF and edge response methods do not take into account the signal-to-noise ratio. The pentalith approach combines all three of these factors into a single measurement, making it useful for tasks such as quality control and the comparison of dissimilar systems. However, the combined information provided by the pentalith is clearly not sufficient for all engineering tasks.

C.3 Pentalith description

The name pentalith is derived from the Greek words for five stones. Figure C.1 shows the dimensional construction of the basic pentalith pattern. Five dark circles or elements (stones), each with diameter of 1 unit, are placed around a circle of radius 1,7013 units. This geometry makes the centre-to-centre spacing between adjacent circles a distance of 2 units. The placement of the circles around the circle is rotated slightly to prevent any two circles from aligning either vertically or horizontally.



NOTE Each element (shown as circles) is one unit in diameter, with one unit spacing between adjacent elements.

Figure C.1 – Dimensional design of the pentalith pattern

The importance of this geometry is illustrated in Figure C.2, where a pentalith is superimposed on an example pixel grid. As shown, some of the circles are centred on squares that represent individual pixels; however, other circles straddle the lines. The pentalith geometry was designed by computer simulation to minimize the alignment of the elements with the pixel grid, regardless of the shift or scaling between the two.

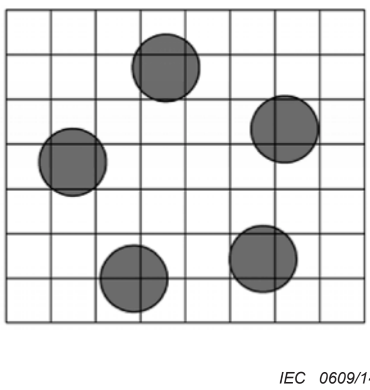
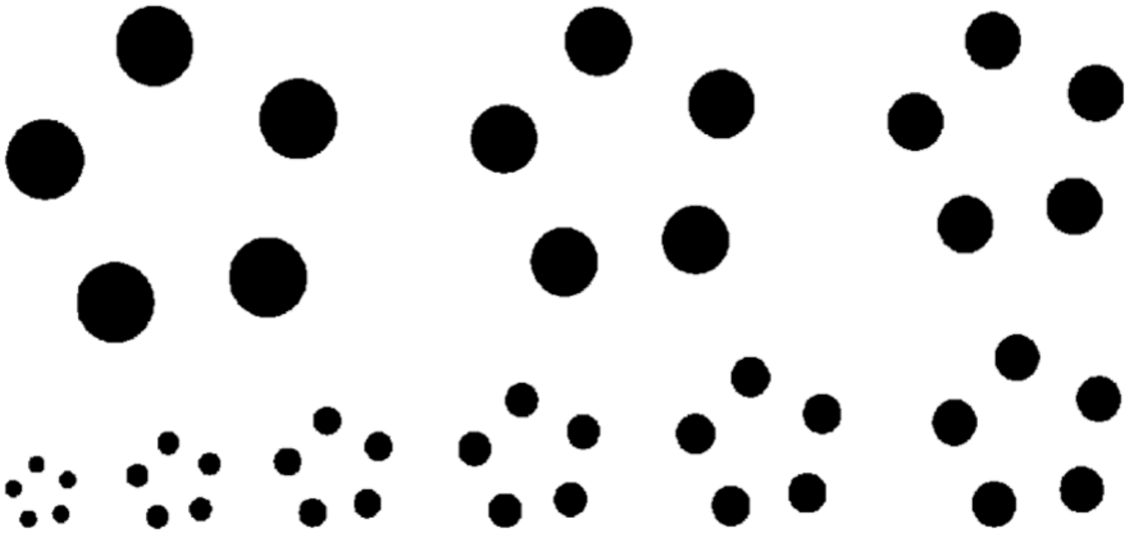


Figure C.2 – Example of a pentalith overlying a pixel grid

Figure C.3 shows a typical pentalith test phantom with circle sizes ranging from 3 to 14, in relative units. This pattern may be useful, for example, to measure the resolution of a video camera. Figure C.4 shows another example of a pentalith test phantom designed for X-ray imaging. In this case the five elements are metal spheres mounted into a block of plastic. As shown by these examples, the pentalith test phantom is constructed to provide the highest contrast between the circles and the background for the particular application being considered.

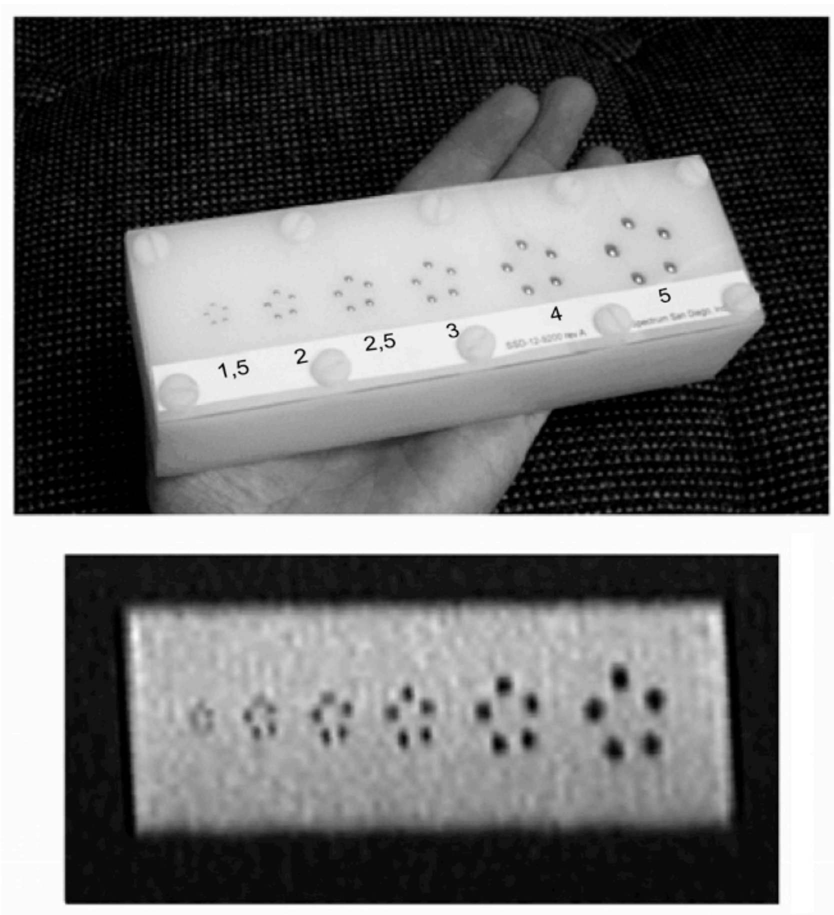


IEC 0610/14

NOTE 1 The circle sizes are 14, 12, 10, 8, 7, 6, 5, 4, and 3 units.

NOTE 2 Black circles on a white background provide the maximum contrast for this particular application.

Figure C.3 – Example of a pentalith test phantom suitable for optical measurements



IEC 0611/14

NOTE Metal spheres mounted in a plastic background provide the maximum contrast for this application. The lower image was acquired with backscatter X-ray imaging.

Figure C.4 – Example of a pentalith test phantom suitable for X-ray imaging

C.4 Pass/fail criterion

A pentalith test passes the detection criterion only if all five of its elements are observable and resolved from each other. In many cases this can be determined by simple inspection of the grayscale image, with the operator allowed to adjust the brightness and contrast as needed. However, an objective pass/fail criterion is available based on thresholding of the image. This can be implemented by setting the digital contrast adjustment to its maximum, and then moving the brightness adjustment from low to high while observing the image.

Figure C.5 shows an example of this. Figure C.5.A is a grayscale image of four pentalith patterns, with element sizes of 3,0 mm, 2,5 mm, 2,0 mm, and 1,5 mm. In Figure C.5.B the contrast has been turned to maximum, with the brightness set to a relatively low level. Figures C, D and E show the effect of successively increasing the brightness control (which is equivalent to increasing the threshold level).

All five elements of the 3 mm pentalith are detected and resolved from each other in each of the five images, A to E.

The 2,5 mm pentalith is only detected and resolved in C and D. In B, only four elements are detected. In E, two of the elements connect into a single object. That is, they have not been resolved as separate objects.

In this same manner, the 2 mm elements are detected and resolved in C, but not B, D, or E. Pay special attention to the 2 mm pattern in D, where two of the elements are connected by pixels diagonal to each other. Diagonally touching pixels are considered connected when scoring the pentalith.

Lastly, the 1,5 mm pentalith does not appear as five distinct elements regardless of the threshold setting. Since there is a threshold setting where the 2 mm pattern is detected and resolved, but not for the 1,5 mm pattern, the spatial resolution of this image is classified as between 1,5 mm and 2,0 mm.

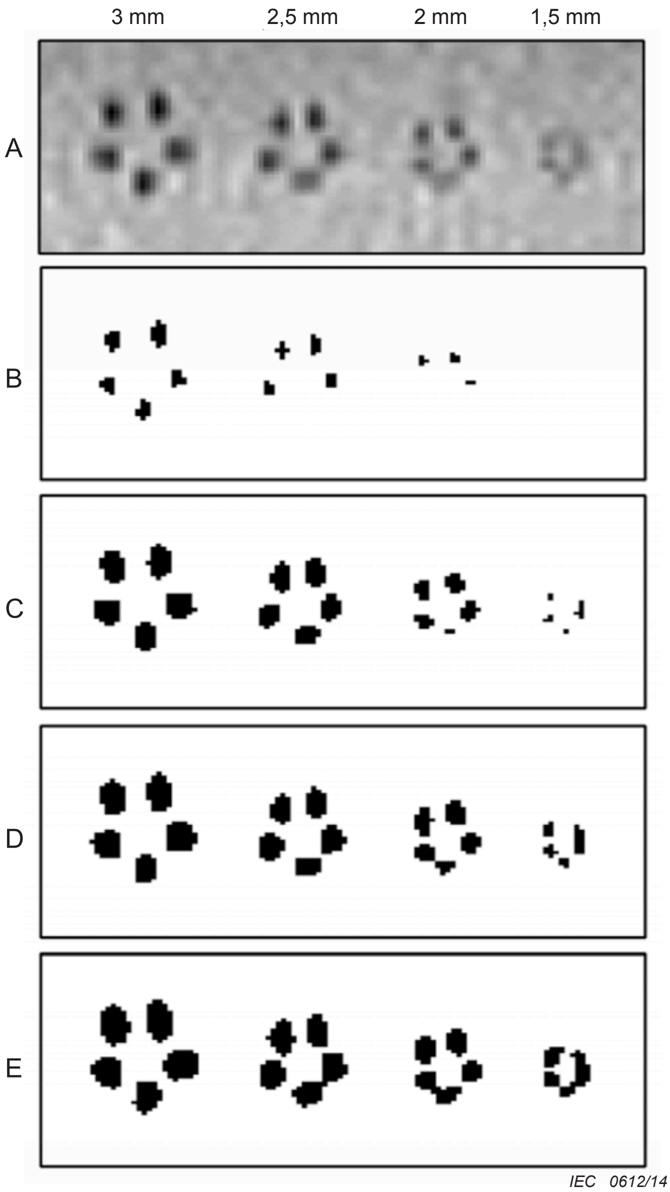


Figure C.5 – Example of using image thresholding as an objective pass/fail criterion

C.5 Repeatability

To provide a rough estimate of repeatability, the above example was repeated 16 times with random repositioning of the test phantom between scans. The 2 mm pentalith was detected and resolved in all 16 scans. However, the 1,5 mm pentalith was not detected and resolved in any of the 16 scans. In other words, the repeatability of the measurement using this method is better than the spacing between the two pentaliths. That is, the repeatability of this measurement is better than ±15 % (i.e., ±100 % × 0,25 mm / 1,75 mm). This is especially significant considering the image noise of this system is relatively high, with a coefficient of variation of about 5 %. Lower noise systems will likely experience even better repeatability using the pentalith.

Annex D
(informative)

Comparison of whole body imaging systems

A variety of methods have been implemented to use X rays to screen persons for reasons related to security and law enforcement. The different types of systems that exist at present are described in this Annex. Some commercially-available whole body imaging systems also combine more than one of these methods into a screening system.

The conventional "transmission" or "projection" X-ray image is formed by passing X rays through an object to create a shadowgram, which is the result of the differential attenuation due to variations of composition, density and thickness of every portion of the object/person in the path of the X-ray beam. In most implementations the X-ray source produces a fan beam that passes through the object to be screened and is registered by a linear (one row of pixels) solid-state detector as both the source and detector are translated across the height of an individual. The resolution of the resultant image is usually determined by the size of the detector pixels.

In contrast, backscatter and forward-scatter systems employ a "flying spot" of X rays and large-area integrating detectors. A small spot is rastered across an individual and the collected scatter signal from these detectors is briefly integrated and assigned to a pixel value in an image corresponding to the transient location of the flying spot. In this modality the image resolution is primarily determined by the size of the flying spot.

It should be noted that different modalities generally are intended to detect threats or anomalies at different locations with respect to the body. As noted in Table D.1, backscatter systems primarily are intended to see objects on the body; forward-scatter systems, on the side of the body; and transmission systems, inside the body. It is also noted that some primary radiation is registered in a forward-scatter image, and that some scatter is always present in a projection image. Finally we note that when forward-scatter systems were first introduced, they were sometimes referred to as transmission systems. Because of the different imaging methodology and intent, we have introduced the term "forward-scatter" in this standard.

Table D.1 – Comparison of whole body imaging systems for security screening

Type of system	Primary detection intent	Imaging method	Type of radiation used to form image	Security venues
Backscatter	objects on body	flying spot; large, non-imaging detectors	backscatter	aviation; military checkpoints
Forward-scatter	objects on side of body	flying spot; large, non-imaging detectors	forward scatter (and some primary)	aviation; military checkpoints
Transmission	objects inside body	projection imaging with small-pixel detectors	primary (and some scatter)	smuggling of contraband; mines, prisons

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