

# INTERNATIONAL STANDARD



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

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# INTERNATIONAL STANDARD



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

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

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

## FOREWORD

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IEC 62709 has been prepared by subcommittee 45B: Radiation protection instrumentation, of IEC technical committee 45: Nuclear instrumentation. It is an International Standard.

This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Clarified the test procedures to maintain consistency with IEC 62463.
- b) Changed the term "spatial resolution" to "pentolith resolution".
- c) Modified some standard test conditions.
- d) Modified some terms and definitions.
- e) Changed the imaging requirements for transmission general-use systems.

The text of this International Standard is based on the following documents:

| Draft         | Report on voting |
|---------------|------------------|
| 45B/1059/FDIS | 45B/1069/RVD     |

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under [webstore.iec.ch](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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## INTRODUCTION

This document 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 document 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 document 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 pentolith, ~~the spatial~~ resolution test object. Annex D (informative) seeks to describe the different types of security systems presently being used for whole-body imaging.

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

## 1 ~~Scope and object~~

This document 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 document 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 document:

- Systems designated as ~~fixed, portal, transportable~~, mobile or ~~gantry fixed~~.
- 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 document does 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 document "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 are referred to in the text in such a way that some or all of their content constitutes requirements 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.

~~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 60050-395:2014, *International Electrotechnical Vocabulary (IEV) – Part 395: Nuclear instrumentation – Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

IEC 60050-395:2014/AMD1:2016

IEC 60050-395:2014/AMD2:2020

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

IEC 60050-881:1983/AMD1:2014

IEC 60050-881:1983/AMD2:2019

IEC 60050-881:1983/AMD3:2020

IEC 62463:2010/2024, *Radiation protection instrumentation – X-ray systems for the security screening of persons* ~~for security and the carrying of illicit items~~

ISO 683-17:1999/2023, *Heat-treated treatable steels, alloy steels and free-cutting steels – Part 17: Ball and roller bearing steels*

### 3 Terms, definitions, abbreviated terms, quantities and units

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

#### 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~~ IEC 60050-395:2014 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

##### **body phantom**

object whose absorption and scattering effects on ionizing radiation are equivalent to a human

##### 3.1.4

##### **contrast sensitivity**

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, 3.11]

### 3.1.5

#### **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

### 3.1.6

#### **effective dose**

dose quantity intended to reflect the stochastic health risk to the whole body due to radiation exposure. It is calculated based on the sum of the equivalent doses in various organs multiplied by the appropriate tissue weighting factors

### 3.1.7

#### **forward-scattered radiation**

##### **forward-scatter**

scattering of photons by material through angles less than 90° with respect to their initial direction

### 3.1.8

#### **forward-scatter system**

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

### 3.1.9

#### **floor of the scanner**

surface that individuals stand on when scanned

### 3.1.10

#### **general-use system**

X-ray screening system that is configured to deliver an effective dose of less than 0,25 µSv per screening (using the dose estimation methods defined in IEC 62463) and operating using the administrative controls specified in IEC 62463. Given proper justification and certain restrictions, general-use systems may be operated without specific controls that would limit the number of individuals scanned or the number of scans per individual in a year

Note 1 to entry: This definition was reproduced, with the permission of the Health Physics Society (HPS), from ANSI/HPS N43.17-2009 (R2018)

[SOURCE: IEC 62463:2024, 3.4]

### 3.1.11

#### **influence quantity**

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

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

### 3.1.12

#### **limited-use system**

personnel screening system that is configured to deliver an effective dose that does not exceed 10 µSv per screening (using the dose estimation methods defined in IEC 62463) which does not meet the definition of a general-use system. Limited-use systems require additional controls and documentation to ensure that annual individual dose limits are not exceeded.

Note 1 to entry: This definition was reproduced, with the permission of the Health Physics Society (HPS), from ANSI/HPS N43.17.

[SOURCE: IEC 62463:2024, 3.7]

### 3.1.13

#### **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~~

**3.1.14****operator**

~~person authorised and fully trained to operate the system~~

person that controls one or more aspects of the screening procedure. An operator is authorized to perform their duties, appropriately trained, and performs their duties according to the standard operating procedure

[SOURCE: IEC 62463:2010, 3.9]

**3.1.15****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

**3.1.16****penetration test**

test of ~~spatial~~ **pentalith** resolution and wire detection as a function of body phantom thickness

**3.1.17****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.

**3.1.18****~~spatial~~ pentalith resolution**

minimum separation between two **spherical** objects at which they can be resolved as separate entities, **as measured using the pentalith test**

**3.1.19****primary radiation**

ionizing radiation emitted ~~directly~~ by a radiation source **which has not undergone scattering**

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

**3.1.20****radiation source**

equipment or matter emitting or capable of emitting ionizing radiation

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

**3.1.21****reference location**

required location where test objects are placed for assessing imaging performance according to this document

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.

### 3.1.22

#### Screening procedure

Procedure, described in the SOP, that is followed to completely inspect something using the X-ray system

Note 1 to entry: Depending on the concept of operation of the system, this could involve taking multiple scans.

[SOURCE: IEC 62463:2024, 3.17]

### 3.1.23

#### scan area

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

### 3.1.24

#### scanning speed

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

[SOURCE: IEC 62523:2010, 3.15]

### 3.1.25

#### 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]

### 3.1.26

#### 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~~

Note 1 to entry: In the case of this document, the objects inspected are carried on or within the body of a person.

### 3.1.27

#### system

#### scanning system

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

### 3.1.28

#### 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~~

### 3.1.29

#### whole body field of view

field of view of systems designed to completely scan and image ~~one~~ a person ~~at a time~~ in one image

**3.1.30****wide field of view**

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

**3.1.31****wire detection**

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

[SOURCE: IEC 62523:2010, 3.10]

**3.2 Abbreviated terms****3.2.1**

HDPE high-density polyethylene

**3.2.2**

MTF

modulation transfer function

**3.3 Quantities and units**

In this document, the units are the multiples and sub-multiples of units of the International System of Units(SI)<sup>1</sup>. The definitions of radiation quantities are given in ~~IEC 60050-393 and IEC 60050-394~~ IEC 60050-395.

**4 Imaging performance evaluation procedures****4.1 General characteristics and test procedures**

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

- a) ~~Spatial~~Penalith 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.~~

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

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

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, power supply, source voltage and current, and filtration, and which are the same as the machine settings for radiation safety testing (measuring the effective dose). Since effective dose and image quality are interrelated, the system shall comply with the effective dose requirements in IEC 62463. General-use systems shall deliver an effective dose of less than 0,25 µSv per screening. Limited-use systems shall deliver a dose of less than 10 µSv per screening. See IEC 62463 for more details on the system classes and effective dose estimation methods.

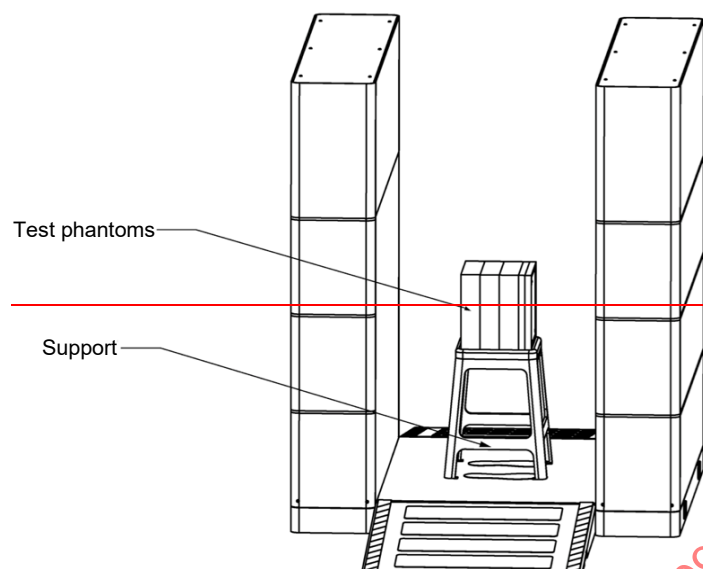
These machine settings and the effective dose shall be included in the test report (for an example, see Annex B) to facilitate the evaluation of overall system performance. If image-enhancement software features are available to the operator in normal use, these may be used to achieve the best possible 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.

Each test should be repeated 3 times.

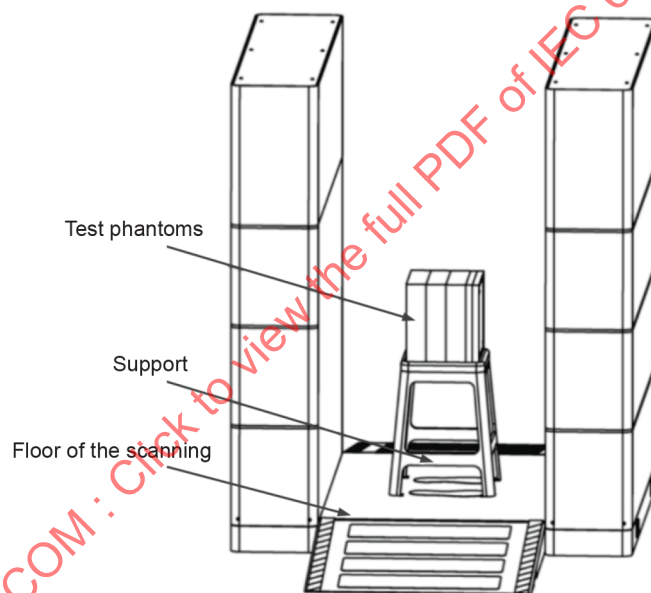
#### 4.2 Location of testing

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 perpendicular with the floor and at the optimum operating distance as specified by the manufacturer, and,
- 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 floor of the scanner. 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.



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IEC

**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~~ may 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 document shall have a density of  $0,95 \text{ g cm}^{-3} \pm 0,05 \text{ g cm}^{-3}$ .

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, an HDPE cube, 300 mm on each side, is used to simulate the human body.

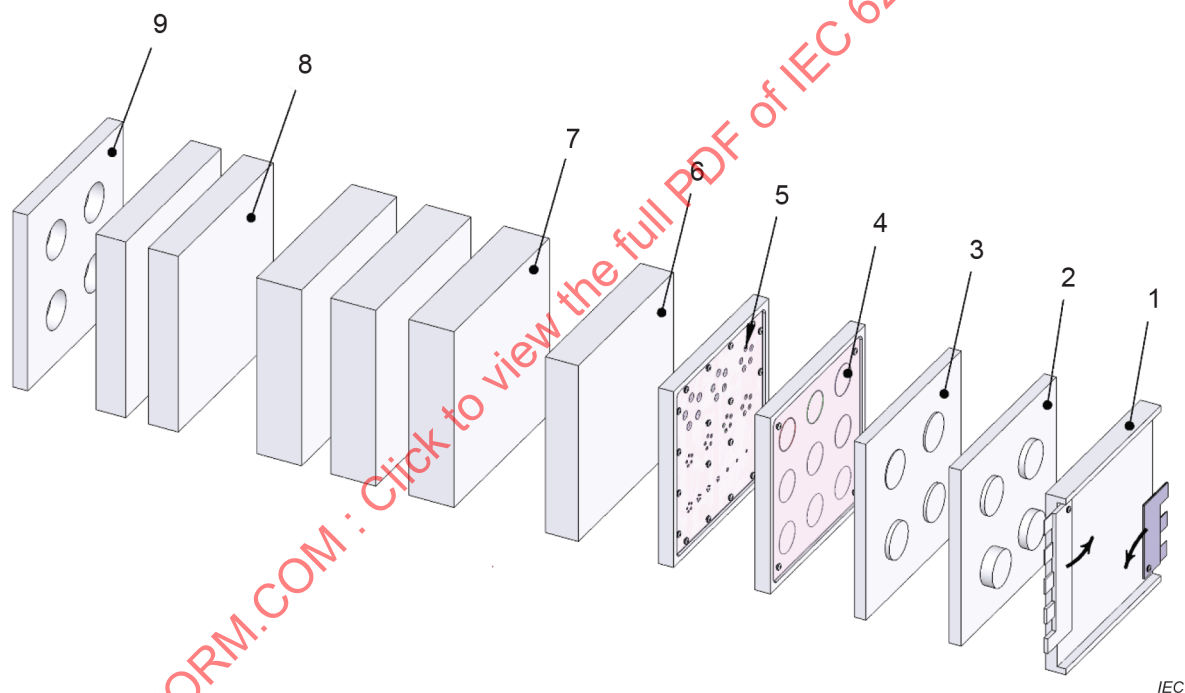
For general-use transmission systems, it is acceptable to use a reduced body phantom with dimensions of 300 mm wide × 300 mm high × 230 mm deep, so that the overall HDPE depth of the body phantom and test object assembly shall be 250 mm.

For the penetration test for limited-use systems, the overall depth shall be expandable from 300 mm to 400 mm by attaching ~~two~~ additional 50 mm thick HDPE slabs ~~of HDPE~~.

For the penetration test of general-use systems, the overall depth shall be expandable from 250 mm to 300 mm by attaching additional 25 mm thick HDPE slabs.

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  $\pm 2\%$  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~~ additional phantom, 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 SpatialPentalith 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~~ pentalith 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 683-17:19992023, grade designation 100Cr6 or equivalent (e.g. AISI/SAE 52100 in ASTM A295/A295M-14:2020, 1.3505 in EN 10027-2:1.3505; SUJ2 in JIS G4805) 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~~ pentalith resolution test object are given in Figure A.1, Figure A.13, Figure A.14, Figure A.15 and Figure A.16.

### 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.

The reported results shall be the sphere diameter of the smallest pentalith that was detected in at least two thirds of the images.

## 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<br>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 Figure A.1, Figure A.7, Figure A.11 and Figure A.9.

### 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.

The reported results shall be the diameter of the smallest wire gauge that was detected in at least two thirds of the images.

## **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 Figure A.1, Figure A.8 and Figure A.9.

### **4.6.4 Procedure**

A test object meeting the description in 4.6.3 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.

The reported results shall be the thickness of the smallest disc that was detected in at least two thirds of the images.

## 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 Figure A.1 through Figure A.7.

### 4.7.4 Procedure

A test object meeting the description in 4.7.3 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.

The reported results shall be the thicknesses of the thinnest tooth that was detected in at least two thirds of the images.

## 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~~ ~~pentalith~~ 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 Figure A.1 and Figure A.19.

#### 4.8.4 Procedure

Repeat the ~~spatial~~ ~~pentalith~~ 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 document 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. ~~The machine settings and the effective dose requirements during the test are described in 4.1.~~ Different minimum performance requirements are given for systems employing the three fields of view, viz., partial body (3.1.12), whole body (3.1.29), and wide (3.1.30).

For general-use transmission systems the test results are all report only (i.e. the minimum acceptable imaging performance requirements do not apply).

**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 subclause |
|-----------------------------------------------------------------------------------------|--------------------------|----------------------------|--------------------|--------------------|
| 1 <del>Spatial</del> <del>Pentalith</del> 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 <sup>c</sup>    | 4.5                |
| 3 Materials detection on body: thinnest disc discerned                                  | 5 mm                     | 5 mm                       | RO                 | 4.6                |
| 4 Materials detection in air:                                                           |                          |                            |                    | 4.7                |
| smallest plastic thickness discerned                                                    | 3 mm                     | 2 mm                       | RO                 |                    |
| smallest metal thickness discerned                                                      | 1,6 mm                   | 0,8 mm                     | RO                 |                    |
| 5 Penetration test                                                                      |                          |                            |                    | 4.8                |
| a) through 350 mm HDPE <sup>a</sup> :                                                   |                          |                            |                    |                    |
| smallest sphere diameter resolved                                                       | RO                       | RO                         | optional           |                    |
| smallest wire detected                                                                  | RO                       | RO                         | optional           |                    |
| b) through 400 mm HDPE <sup>b</sup> :                                                   |                          |                            |                    |                    |
| smallest sphere diameter resolved                                                       | RO                       | RO                         | optional           |                    |
| smallest wire detected                                                                  | RO                       | RO                         | optional           |                    |

| Image quality test                                                                                                                                                                                                                                                                       | Whole body field of view | Partial body field of view | Wide field of view | Relevant subclause |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|----------------------------|--------------------|--------------------|
| <del>a</del> <del>Body phantom plus 50 mm.</del><br><del>b</del> <del>Body phantom plus 100 mm.</del><br>a Though 275 mm HDPE for transmission general-use systems.<br>b Though 300 mm HDPE for transmission general-use systems.<br>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 document 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<br>(unless otherwise indicated by the manufacturer) |
|------------------------------------------|------------------------------------------------------------------------------|
| Warm-up time                             | >15 min                                                                      |
| Ambient temperature                      | <del>18 °C to 22 °C</del> 22 °C ± 5 °C                                       |
| Relative humidity                        | <del>50</del> 30 % to 75 %                                                   |
| Atmospheric pressure                     | <del>70</del> 86 kPa to 106 kPa                                              |
| Power supply voltage                     | <del>Nominal</del> Rated power supply voltage ±1 ±10 %                       |
| 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 µGy·h <sup>-1</sup>                         |
| 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                                                  |

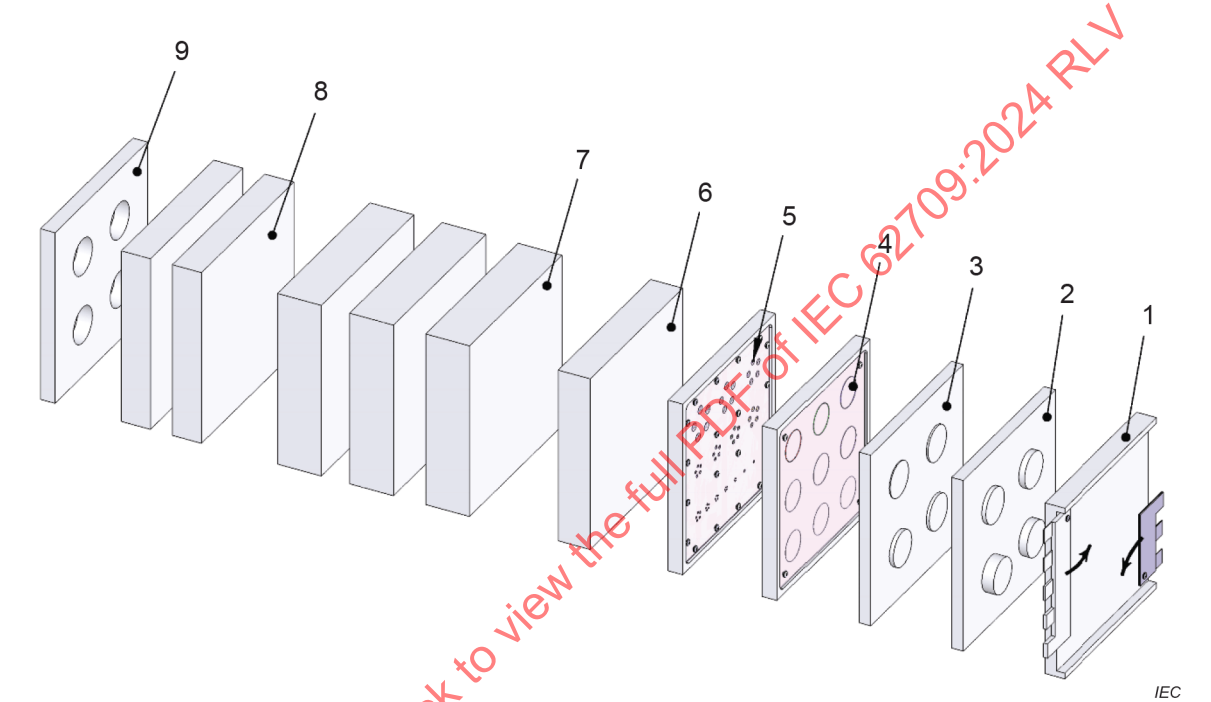
If the system is intended for operation in environmental conditions significantly outside the ranges specified in Table 3, additional testing should be done to demonstrate that the imaging performance reported for standard test conditions remains unchanged at the low temperature/low-humidity limit and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

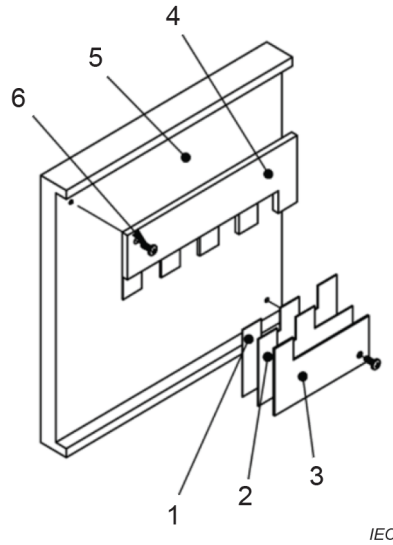
This Annex contains a complete set of mechanical drawings for the test objects specified in this document and is normative in the sense that it reflects the requirements of this document See Figure A.1 through Figure A.20. Other implementations of test objects that deviate from these drawings, but continue to conform to the dimensional and material specifications of this document, are permitted. Unless otherwise specified, dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ;  $X/.x\pm 0,3$  mm; 0,  $xx\pm 0,15$  mm.



Key

|   |                              |                                 |            |
|---|------------------------------|---------------------------------|------------|
| 1 | material detection in air    | Figure A.2 through Figure 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          | Figure A.10 through Figure A.12 | Quantity 1 |
| 5 | spatial resolution           | Figure A.13 through Figure 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



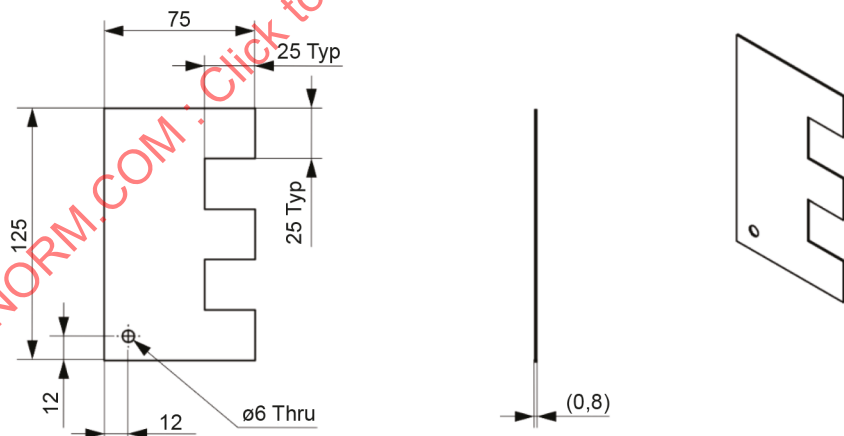
#### Key

|   |                                      |            |
|---|--------------------------------------|------------|
| 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 teeth             | 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 Figure A.3 through Figure A.7 show additional details.

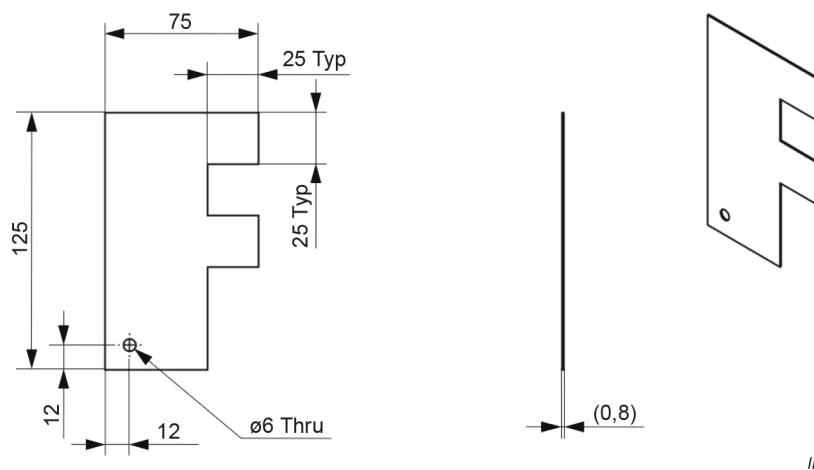
**Figure A.2 – Material detection in air phantom**



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

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ;  $X/.x \pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

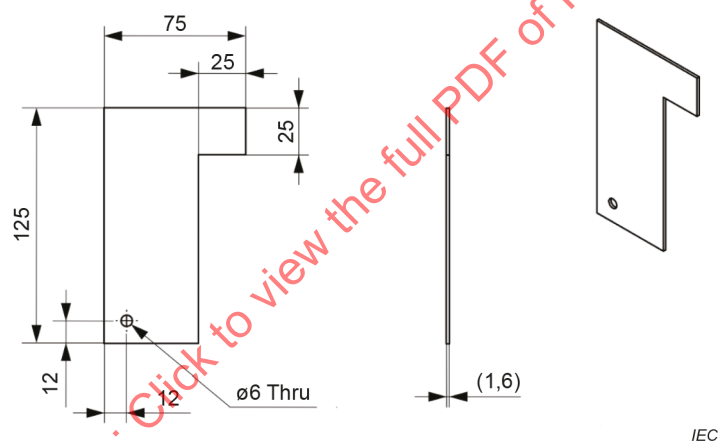
**Figure A.3 – Subassembly of the material detection in air phantom (Figure A.2), metal comb, three teeth**



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

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

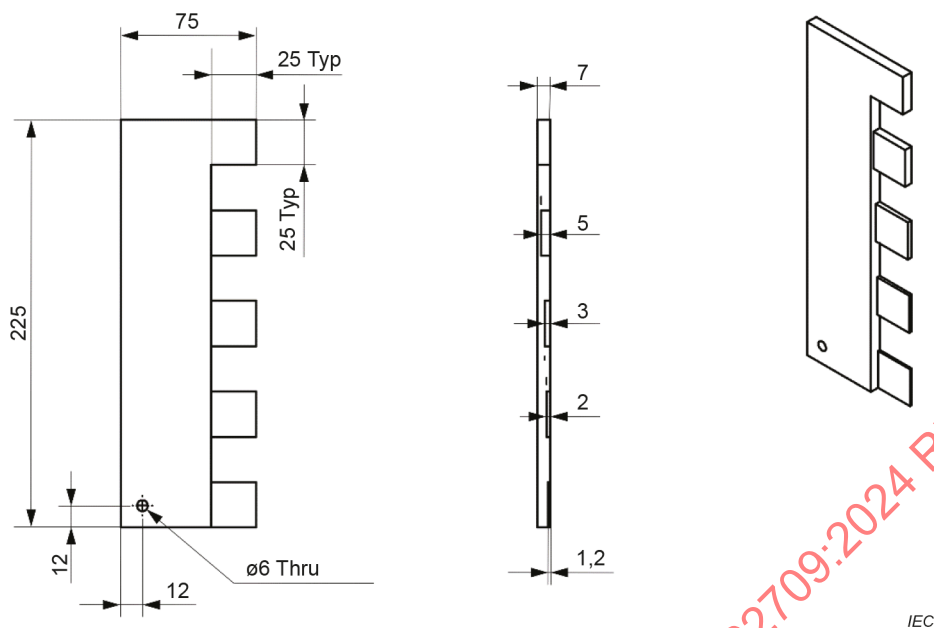
**Figure A.4 – Subassembly of the material detection in air phantom (Figure A.2), metal comb, two teeth**



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

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

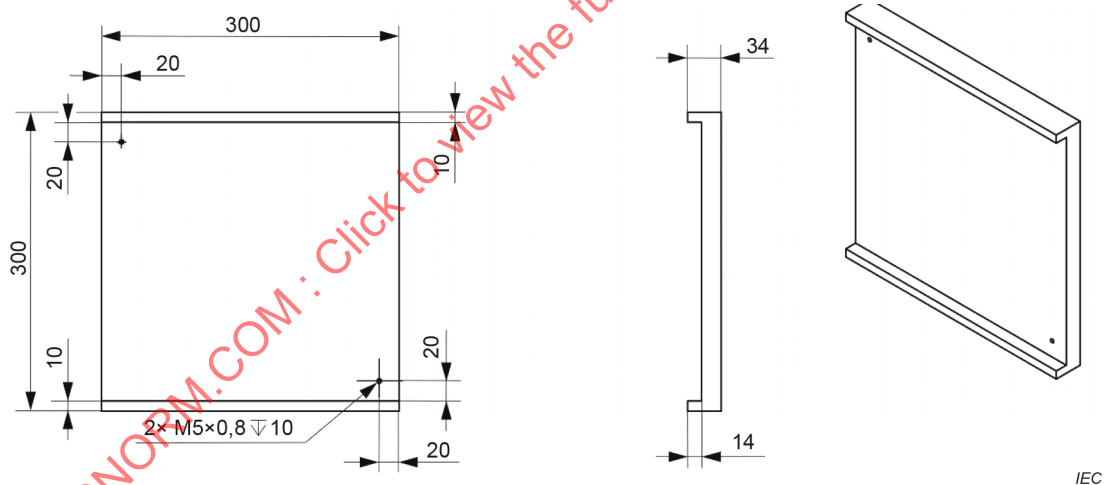
**Figure A.5 – Subassembly of the material detection in air phantom (Figure A.2), metal comb, one tooth**



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

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

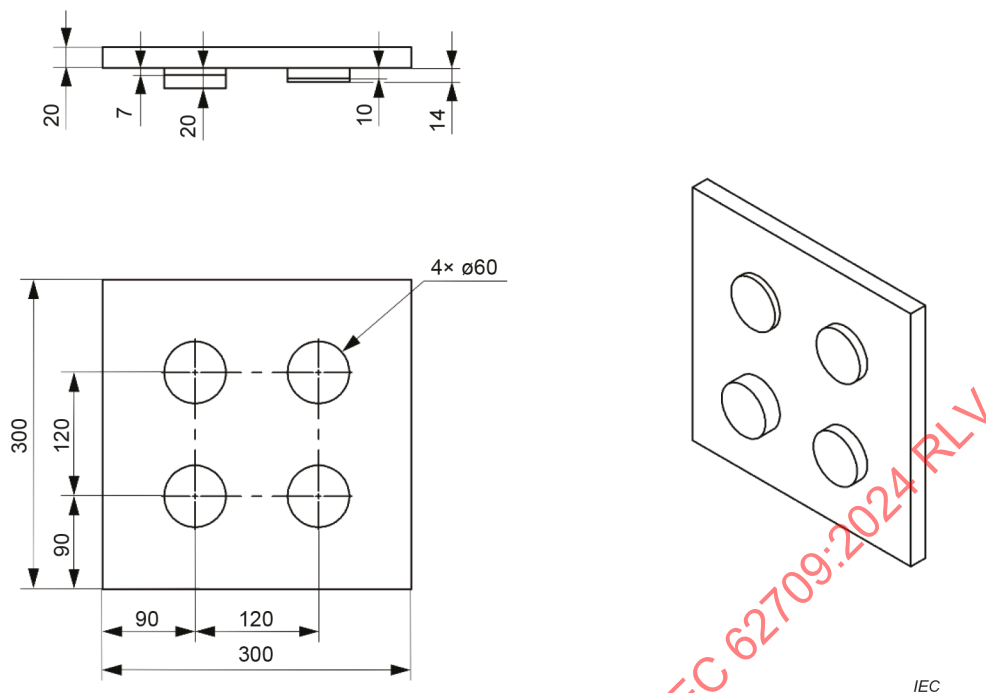
**Figure A.6 – Subassembly of the material detection in air phantom (Figure A.2), plastic comb**



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

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

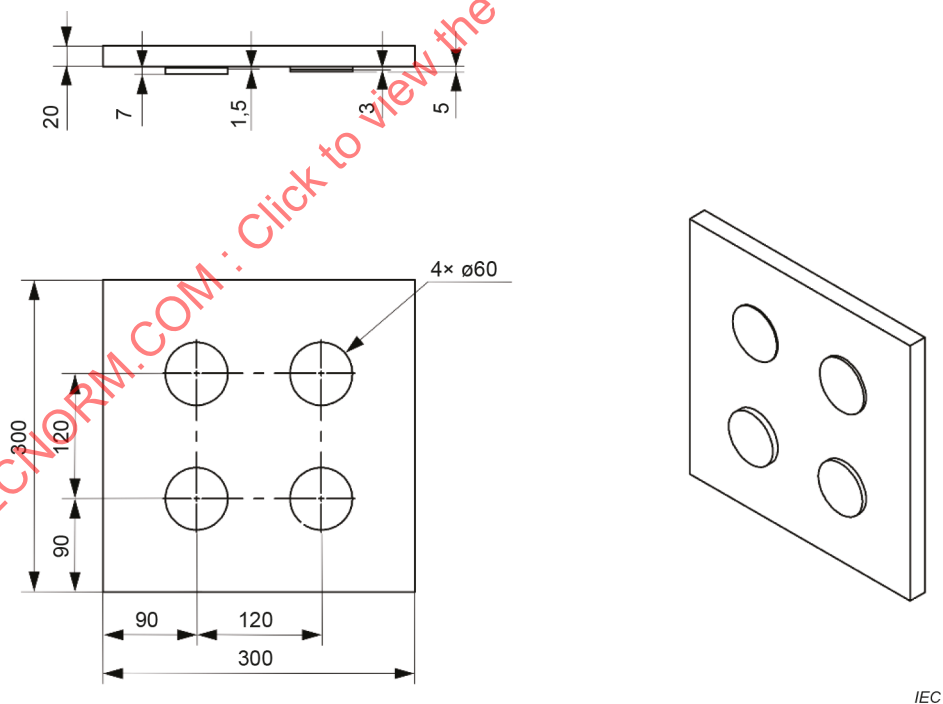
**Figure A.7 – Subassembly of the material detection in air phantom (Figure A.2), mounting sheet**



NOTE 1 This is fabricated from HDPE.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

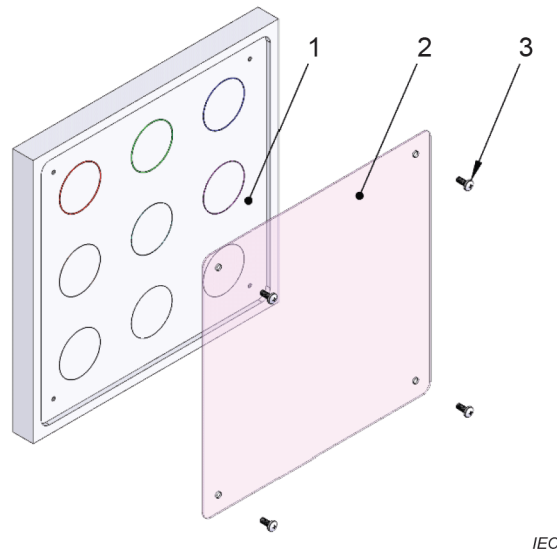
**Figure A.8 – Material detection on body 1**



NOTE 1 This is fabricated from HDPE.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

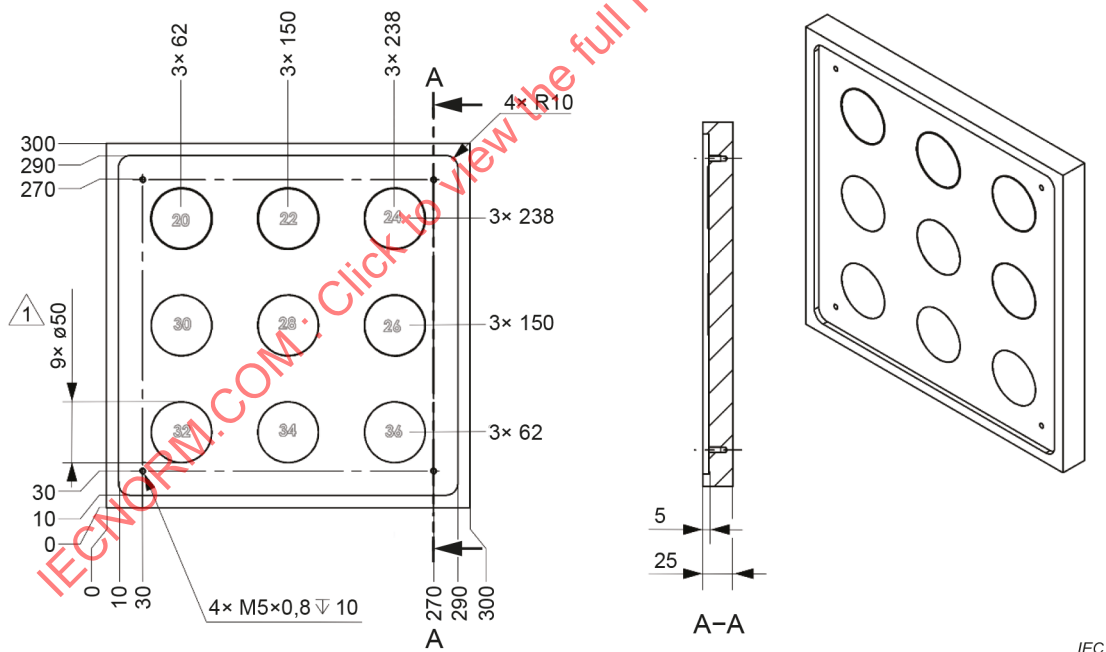
**Figure A.9 – Material detection on body 2**



**Key**

- 1 base, see Figure A.11
- 2 cover, see Figure A.12
- 3 screws

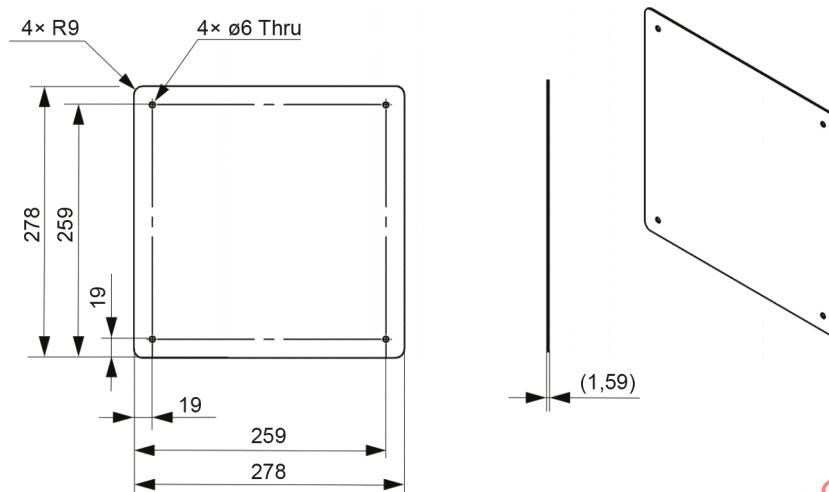
**Figure A.10 – Wire detection phantom**



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:  $\pm 0,5^\circ$ ;  $X/.x \pm 0,3$ ; 0, xx  $\pm 0,15$ .

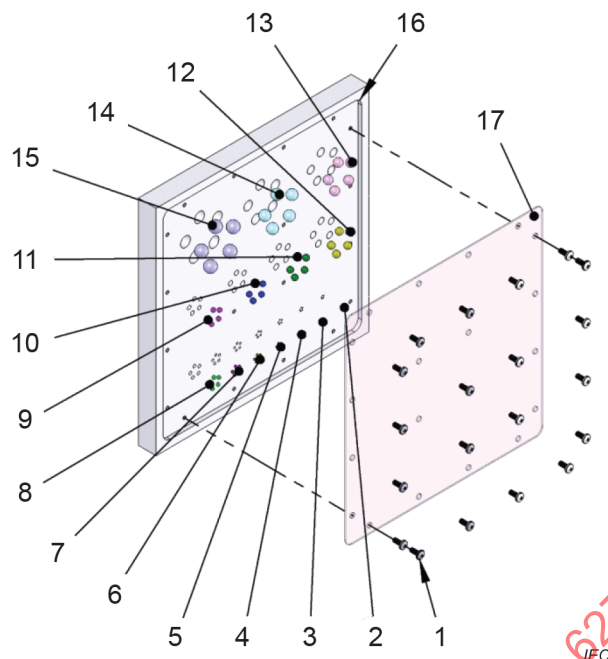
**Figure A.11 – Subassembly of the wire detection phantom (Figure A.10), mounting base**



NOTE 1 This part is fabricated from transparent polycarbonate plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$ ; 0, xx  $\pm 0,15$ .

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

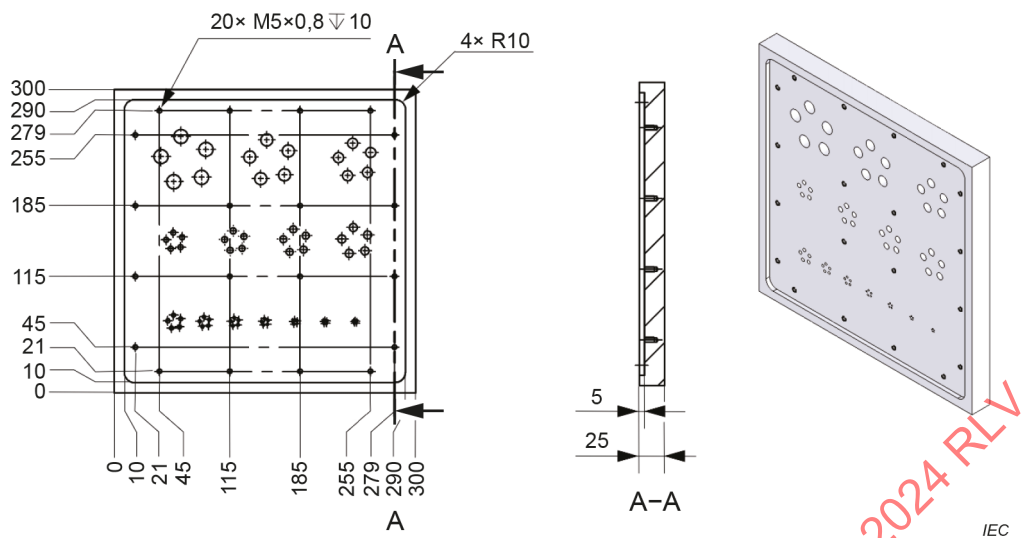


#### Key

- 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 Figure A.14 through Figure A.16 show additional details.

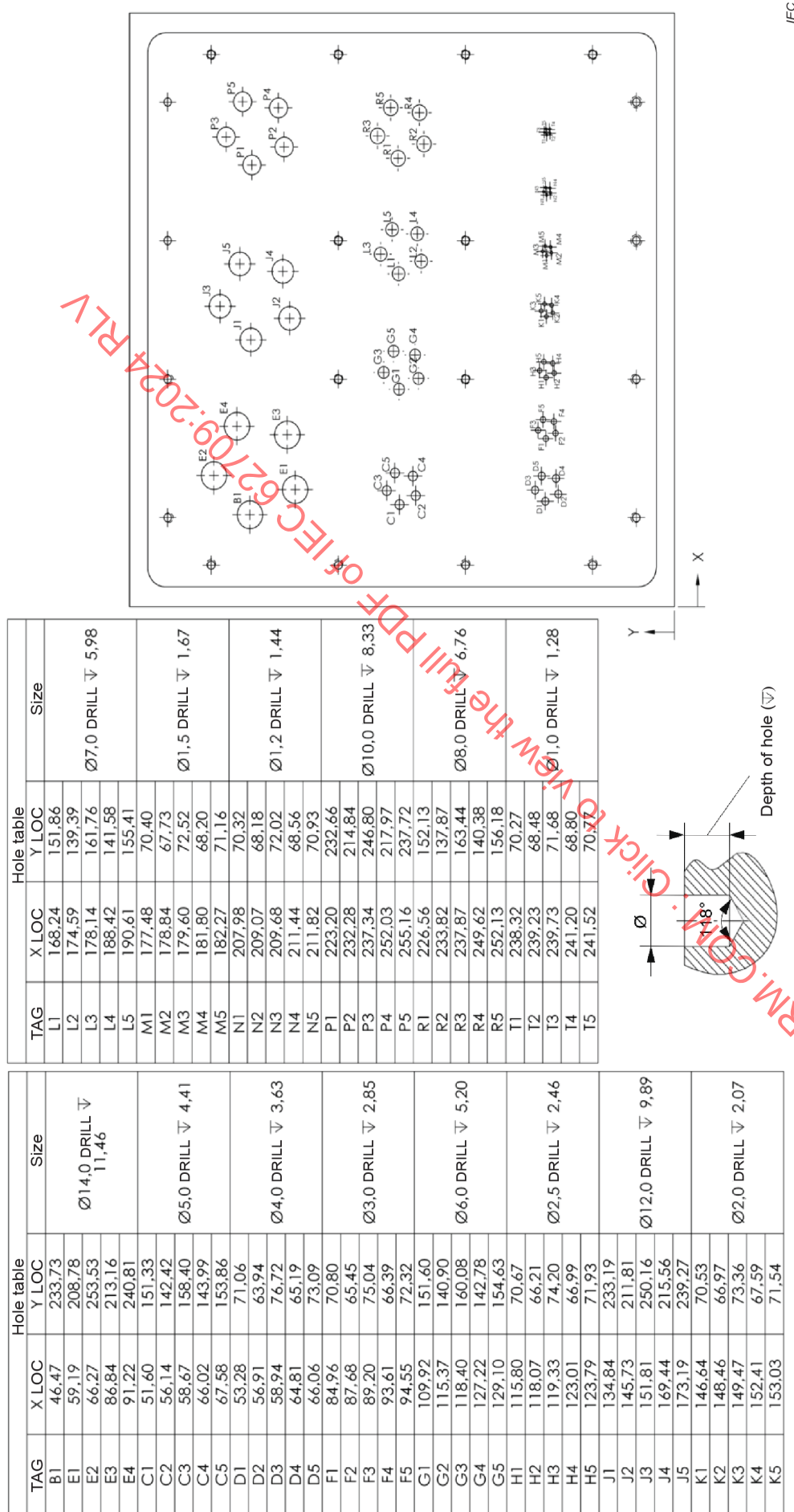
**Figure A.13 – Pentalith resolution phantom**

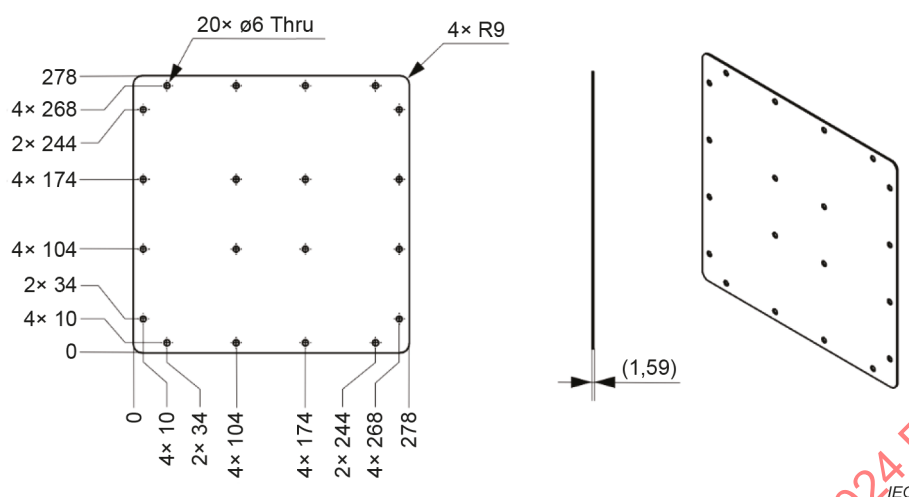


NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$ ; 0, xx  $\pm 0,15$ .

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

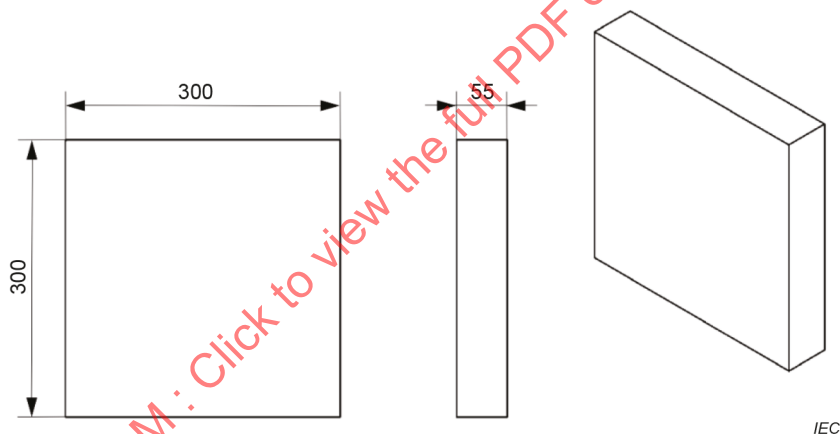




NOTE 1 This part is fabricated from transparent polycarbonate plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ;  $X/.x \pm 0,3$ ;  $0,xx \pm 0,15$ .

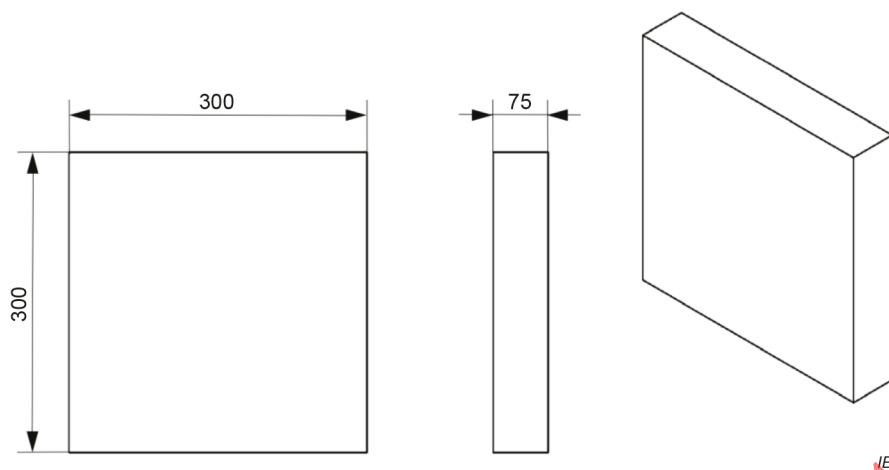
**Figure A.16 – Subassembly of the ~~spatial~~ pentolith resolution phantom (Figure A.13), cover**



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ;  $X/.x \pm 0,3$ ;  $0,xx \pm 0,15$ .

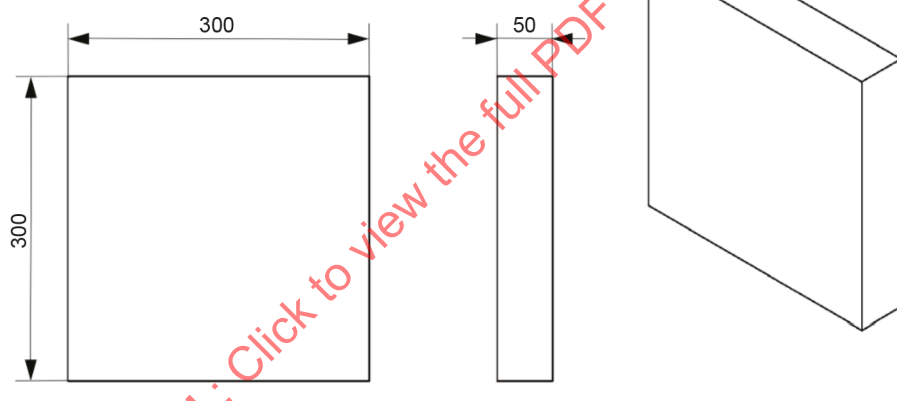
**Figure A.17 – Body phantom, 55 mm thick**



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$ ; 0,xx  $\pm 0,15$ .

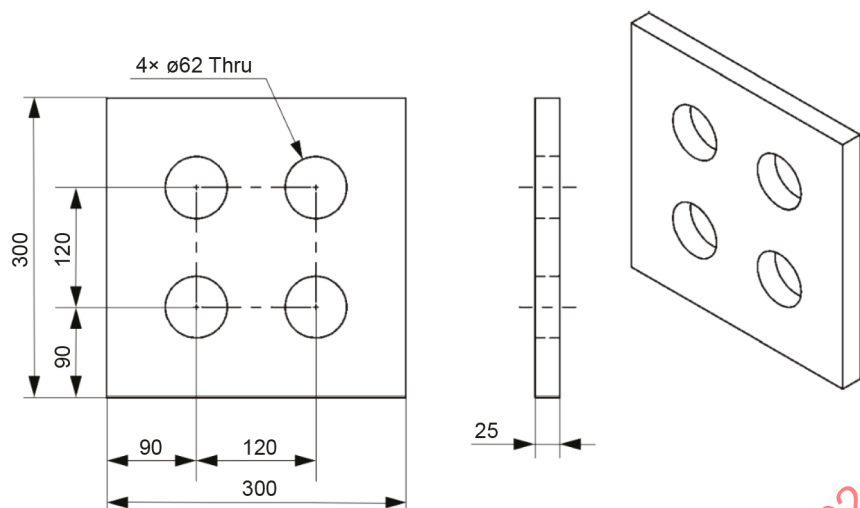
**Figure A.18 – Body phantom, 75 mm thick**



NOTE 1 This part is fabricated from HDPE plastic.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$ ; 0,xx  $\pm 0,15$ .

**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:  $\pm 0,5^\circ$ ;  $X/.x \pm 0,3$ ;  $0,xx \pm 0,15$

**Figure A.20 – Storing space**

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### Example of reporting form

## IEC 62709 body scanner imaging test report

Doc. Ref.#: \_\_\_\_\_, Page 1 of 2

|                                                                                                                                                                        |                                                                            |                                                                           |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Tester(s):                                                                                                                                                             | Place:                                                                     | Date/Time:                                                                |
| System manufacturer:                                                                                                                                                   | Model/Type:                                                                | Serial#:                                                                  |
| Class of system:                                                                                                                                                       | <input type="checkbox"/> Transmission <input type="checkbox"/> Backscatter | <input type="checkbox"/> General-use <input type="checkbox"/> Limited-use |
| 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, scanning speed, filtration, mode, software version): |                                                                            |                                                                           |
| Effective dose:                                                                                                                                                        |                                                                            |                                                                           |
| Other test conditions:                                                                                                                                                 |                                                                            |                                                                           |
| <b>Test object placement</b>                                                                                                                                           |                                                                            |                                                                           |
| Is the test object at the reference location (RL)?                                                                                                                     | <input type="checkbox"/> Yes                                               | <input type="checkbox"/> No                                               |
| For transmission systems: test object facing                                                                                                                           | <input type="checkbox"/> source                                            | <input type="checkbox"/> away from source                                 |
| Distance from beam-exit surface:                                                                                                                                       |                                                                            |                                                                           |
| If not RL:                                                                                                                                                             |                                                                            |                                                                           |
| Lateral position _____                                                                                                                                                 | <input type="checkbox"/> left of RL <input type="checkbox"/> right of RL   |                                                                           |
| Height _____                                                                                                                                                           |                                                                            |                                                                           |
| Transmission systems only: test objects placed on side of phantom <input type="checkbox"/> nearest <input type="checkbox"/> furthest from the radiation source.        |                                                                            |                                                                           |
| <b>Other objects in field of view</b>                                                                                                                                  | <b>Distance and location</b>                                               |                                                                           |
|                                                                                                                                                                        |                                                                            |                                                                           |
|                                                                                                                                                                        |                                                                            |                                                                           |
|                                                                                                                                                                        |                                                                            |                                                                           |
|                                                                                                                                                                        |                                                                            |                                                                           |

## 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:<br>smallest sphere diameter resolved            | 6 mm                                         | 2,5 mm       | 14 mm           |              |          |
| 2                                                                                                                               | Wire detection:<br>smallest wire detected                           | 0,51 mm                                      | 0,32 mm      | RO <sup>c</sup> |              |          |
| 3                                                                                                                               | Materials detection on body:<br>thinnest disc discerned             | 5 mm                                         | 5 mm         | RO              |              |          |
| 4                                                                                                                               | Materials detection in air:<br>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 <sup>a</sup>                                 |                                              |              |                 |              |          |
|                                                                                                                                 | smallest sphere diameter resolved                                   | RO                                           | RO           | RO              |              |          |
|                                                                                                                                 | smallest wire detected                                              | RO                                           | RO           | RO              |              |          |
|                                                                                                                                 | 2) through 400 mm HDPE <sup>b</sup>                                 |                                              |              |                 |              |          |
|                                                                                                                                 | 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.                                                   |                                                                     |                                              |              |                 |              |          |
| <div style="text-align: right;">           _____<br/>           Signature         </div>                                        |                                                                     |                                              |              |                 |              |          |
| <sup>a</sup> Body phantom plus 50 mm HDPE<br><sup>b</sup> Body phantom plus 100 mm HDPE<br><sup>c</sup> Report result only (RO) |                                                                     |                                              |              |                 |              |          |

| Test                                                                         |                                                                  | Image enhancement features and settings used |                                       |                                    |              |             |
|------------------------------------------------------------------------------|------------------------------------------------------------------|----------------------------------------------|---------------------------------------|------------------------------------|--------------|-------------|
| 1. Pentalith resolution                                                      |                                                                  |                                              |                                       |                                    |              |             |
| 2. Wire detection                                                            |                                                                  |                                              |                                       |                                    |              |             |
| 3. Materials detection on body                                               |                                                                  |                                              |                                       |                                    |              |             |
| 4. Materials detection in air                                                |                                                                  |                                              |                                       |                                    |              |             |
| 5. Penetration                                                               |                                                                  |                                              |                                       |                                    |              |             |
| Type                                                                         | Image quality test                                               | Minimum requirement                          |                                       |                                    |              | Pass<br>(√) |
|                                                                              |                                                                  | <input type="checkbox"/> Whole body          | <input type="checkbox"/> Partial body | <input type="checkbox"/> Wide view | Test results |             |
| 1                                                                            | Pentalith resolution: smallest sphere diameter resolved          | 6 mm                                         | 2,5 mm                                | 14 mm                              |              |             |
| 2                                                                            | Wire detection: smallest wire detected                           | 0.511 mm                                     | 0.321 mm                              | RO <sup>c</sup>                    |              |             |
| 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):         |                                              |                                       |                                    |              |             |
|                                                                              | through 350 mm HDPE <sup>a</sup>                                 | RO                                           | RO                                    | Optional                           |              |             |
|                                                                              | smallest sphere diameter resolved                                | RO                                           | RO                                    | Optional                           |              |             |
|                                                                              | smallest wire detected                                           |                                              |                                       |                                    |              |             |
|                                                                              | through 400 mm HDPE <sup>b</sup> :                               |                                              |                                       |                                    |              |             |
|                                                                              | smallest sphere diameter resolved                                | RO                                           | RO                                    | Optional                           |              |             |
|                                                                              | smallest wire detected                                           | RO                                           | RO                                    | Optional                           |              |             |
| List of attachments:                                                         |                                                                  |                                              |                                       |                                    |              |             |
| Notes:                                                                       |                                                                  |                                              |                                       |                                    |              |             |
| The image evaluation tests above were conducted in accordance with IEC 62709 |                                                                  |                                              |                                       |                                    |              |             |
| _____ Signature                                                              |                                                                  |                                              |                                       |                                    |              |             |
| <sup>a</sup> Though 275 mm HDPE for transmission general-use systems.        |                                                                  |                                              |                                       |                                    |              |             |
| <sup>b</sup> Though 300 mm HDPE for transmission general-use systems.        |                                                                  |                                              |                                       |                                    |              |             |
| <sup>c</sup> RO: Report only.                                                |                                                                  |                                              |                                       |                                    |              |             |

## Annex C (informative)

### Image resolution measurement using the pentolith

#### 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 pentolith. This technique is a general method with application to a wide variety of digital imaging systems.~~

Spatial resolution can be measured by a variety of methods, including the modulation transfer function (MTF) and the edge response. Methods for comprehensively characterizing resolution as a function of contrast are used in the medical domain. This Annex proposes a pentolith method of measuring the spatial resolution of digital images that is suitable for characterizing X-ray systems for security screening of humans.

#### 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:

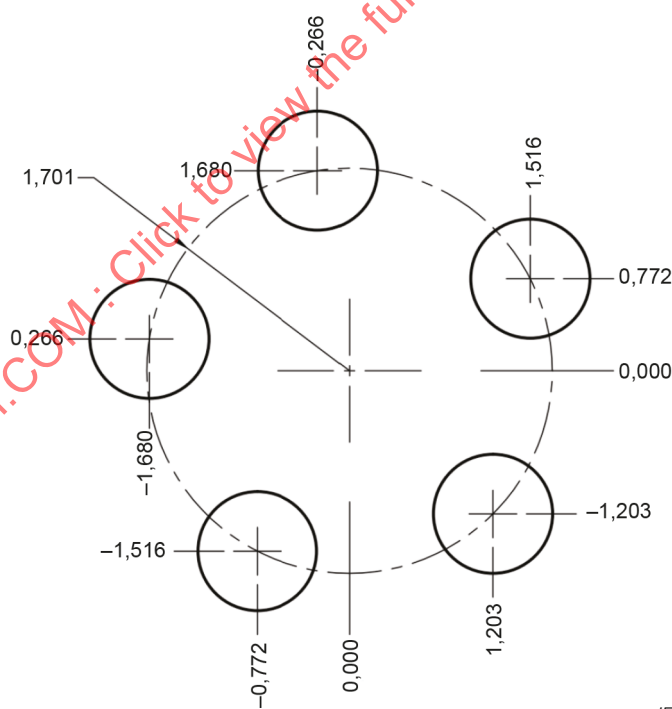
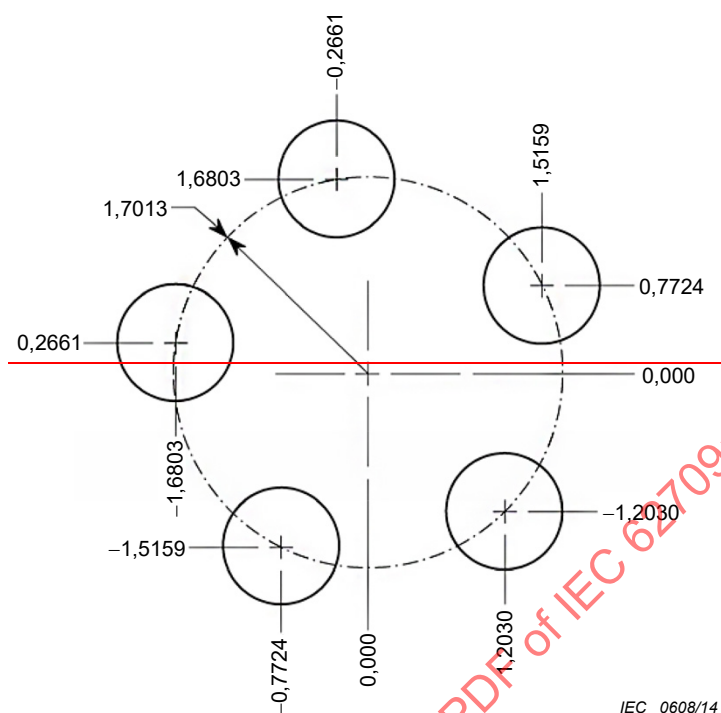
- Analog blurring, such as lens aberration in optical systems, focal spot blurring in X-ray devices, and the illumination spot size in scanning beam applications.
- Sampling grid size, that is, the spacing between pixels. This essentially represents the information lost when an analog image is converted into a digital image.
- 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 pentolith 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 pentolith is clearly not sufficient for all engineering tasks.

#### C.3 Pentolith description

The name pentolith is derived from the Greek words for five stones. Figure C.1 shows the dimensional construction of the basic pentolith pattern. Five dark circles or elements (stones), each with diameter of 1 unit, are placed around a circle of radius 1,70137 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.

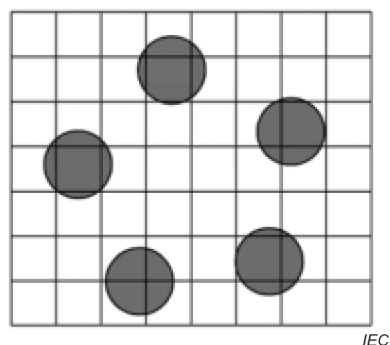


NOTE Each element (shown as circles) is one unit in diameter, with one unit spacing between adjacent elements.

**Figure C.1 – Dimensional design of the pentalith pattern**

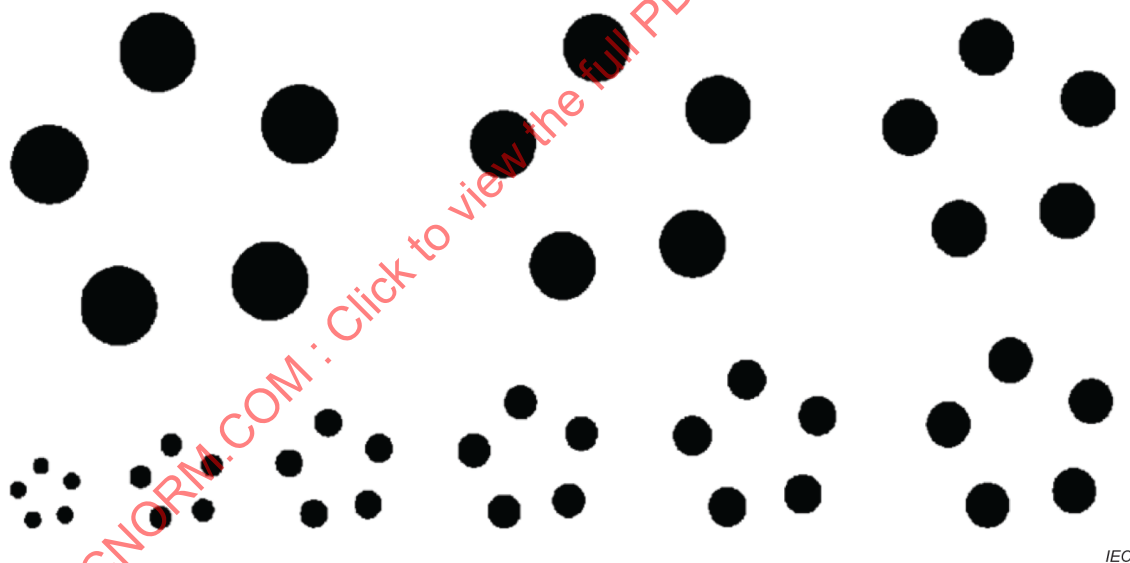
The importance of this geometry is illustrated in Figure C.2, where a pentalith is superimposed on an example pixel grid. As shown, some of the circles are centred on squares that represent individual pixels; however, other circles straddle the lines. The pentalith geometry was designed

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**

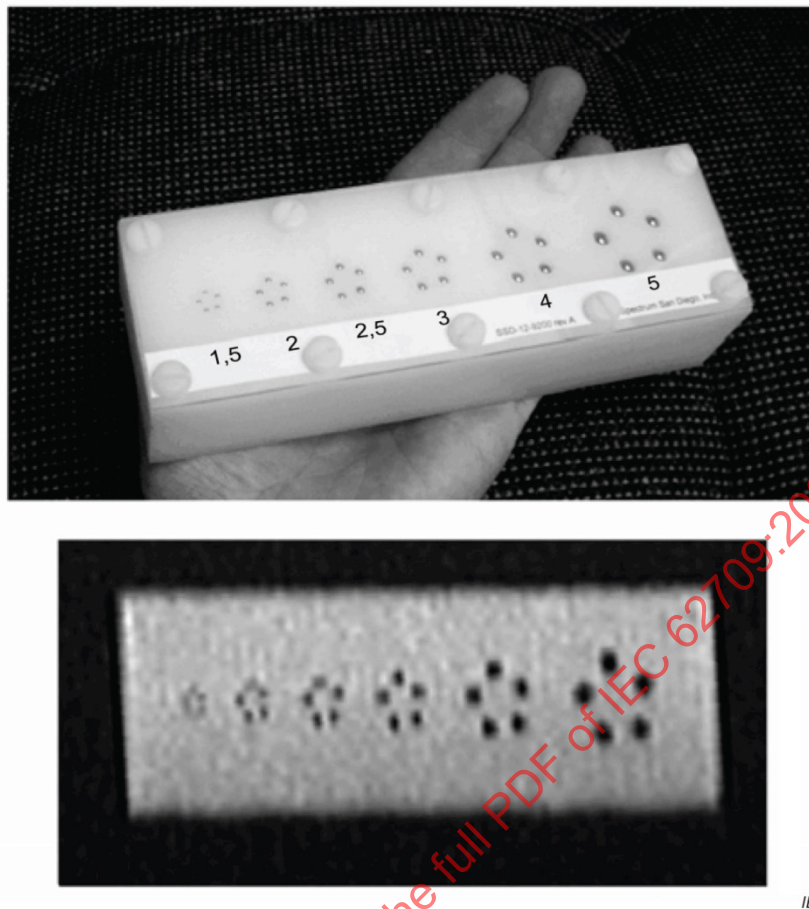
Figure C.3 shows a typical pentalith test phantom with circle sizes ranging from 3 to 14, in relative units. This pattern may be useful, for example, to measure the resolution of a video camera. Figure C.4 shows another example of a pentalith test phantom designed for X-ray imaging. In this case the 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.



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**



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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~~ pentalith resolution of this image is classified as between 1,5 mm and 2,0 mm.

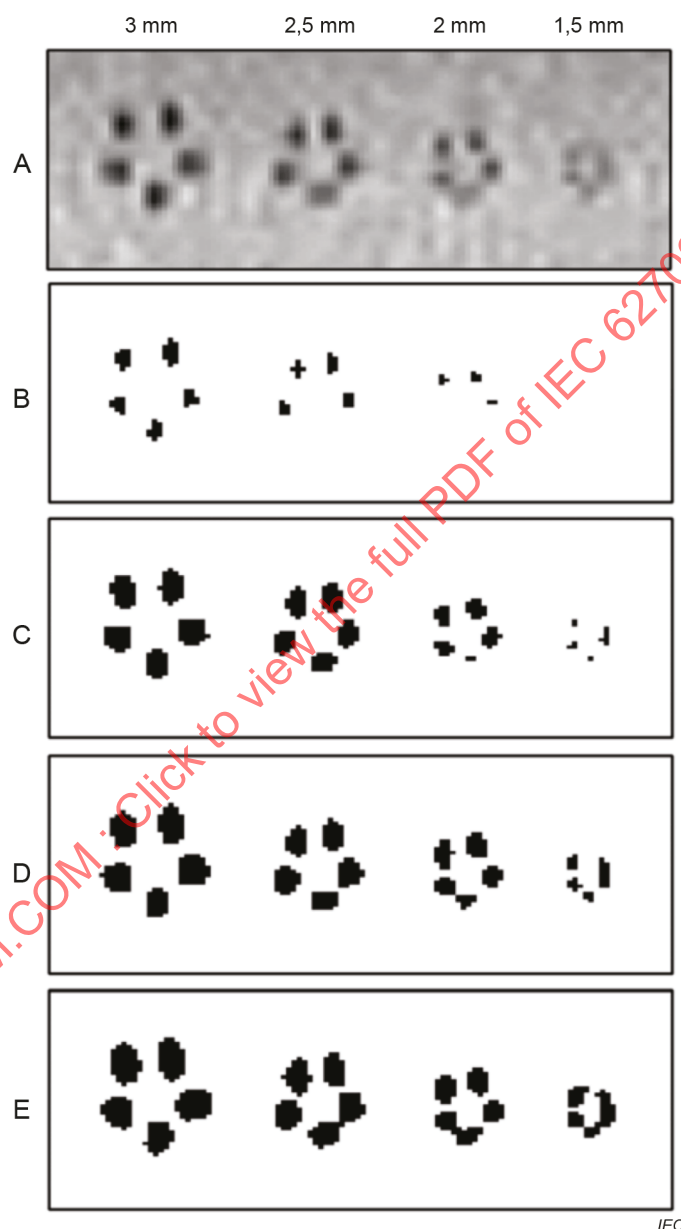


Figure C.5 – Example of using image thresholding as an objective pass/fail criterion

### 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 pentoliths. That is, the repeatability of this measurement is better than  $\pm 15\%$  (i.e.,  $\pm 100\% \times 0,25\text{ mm}/1,75\text{ mm}$ ). 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 pentolith.

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## 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                         |
|------------------------|--------------------------|-----------------------------------------------|--------------------------------------|-----------------------------------------|
| <b>Backscatter</b>     | objects on body          | flying spot; large, non-imaging detectors     | backscatter                          | aviation; military checkpoints          |
| <b>Forward-scatter</b> | objects on side of body  | flying spot; large, non-imaging detectors     | forward-scatter (and some primary)   | aviation; military checkpoints          |
| <b>Transmission</b>    | objects inside body      | projection imaging with small-pixel detectors | primary (and some scatter)           | smuggling of contraband; mines, prisons |

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# INTERNATIONAL STANDARD



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

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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

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This second edition cancels and replaces the first edition published in 2014. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) Clarified the test procedures to maintain consistency with IEC 62463.
- b) Changed the term "spatial resolution" to "pentalith resolution".
- c) Modified some standard test conditions.
- d) Modified some terms and definitions.
- e) Changed the imaging requirements for transmission general-use systems.

The text of this International Standard is based on the following documents:

| Draft         | Report on voting |
|---------------|------------------|
| 45B/1059/FDIS | 45B/1069/RVD     |

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at [www.iec.ch/members\\_experts/refdocs](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://www.iec.ch/publications).

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- reconfirmed,
- withdrawn, or
- revised.

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## INTRODUCTION

This document 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 document 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 document 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 pentolith resolution test object. Annex D (informative) seeks to describe the different types of security systems presently being used for whole-body imaging.

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

## **1 Scope**

This document 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 document applies to systems used to detect objects carried on or within the body of the individual being inspected.

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

- Systems designated as mobile or fixed.
- 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 document does 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 document "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 are referred to in the text in such a way that some or all of their content constitutes requirements 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 60050-395:2014, *International Electrotechnical Vocabulary (IEV) – Part 395: Nuclear instrumentation – Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

IEC 60050-395:2014/AMD1:2016

IEC 60050-395:2014/AMD2:2020

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

IEC 60050-881:1983/AMD1:2014

IEC 60050-881:1983/AMD2:2019

IEC 60050-881:1983/AMD3:2020

IEC 62463:2024, *Radiation protection instrumentation – X-ray systems for the security screening of persons*

ISO 683-17:2023, *Heat-treatable steels, alloy steels and free-cutting steels – Part 17: Ball and roller bearing steels*

### 3 Terms, definitions, abbreviated terms, quantities and units

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

#### 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 60050-395:2014 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

##### 3.1.2 backscatter system

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

##### 3.1.3 body phantom

object whose absorption and scattering effects on ionizing radiation are equivalent to a human

##### 3.1.4 contrast sensitivity

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, 3.11]

##### 3.1.5 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

##### 3.1.6 effective dose

dose quantity intended to reflect the stochastic health risk to the whole body due to radiation exposure. It is calculated based on the sum of the equivalent doses in various organs multiplied by the appropriate tissue weighting factors

### **3.1.7**

#### **forward-scattered radiation**

##### **forward-scatter**

scattering of photons by material through angles less than 90° with respect to their initial direction

### **3.1.8**

#### **forward-scatter system**

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

### **3.1.9**

#### **floor of the scanner**

surface that individuals stand on when scanned

### **3.1.10**

#### **general-use system**

X-ray screening system that is configured to deliver an effective dose of less than 0,25 µSv per screening (using the dose estimation methods defined in IEC 62463) and operating using the administrative controls specified in IEC 62463. Given proper justification and certain restrictions, general-use systems may be operated without specific controls that would limit the number of individuals scanned or the number of scans per individual in a year

Note 1 to entry: This definition was reproduced, with the permission of the Health Physics Society (HPS), from ANSI/HPS N43.17-2009 (R2018)

[SOURCE: IEC 62463:2024, 3.4]

### **3.1.11**

#### **influence quantity**

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

### **3.1.12**

#### **limited-use system**

personnel screening system that is configured to deliver an effective dose that does not exceed 10 µSv per screening (using the dose estimation methods defined in IEC 62463) which does not meet the definition of a general-use system. Limited-use systems require additional controls and documentation to ensure that annual individual dose limits are not exceeded.

Note 1 to entry: This definition was reproduced, with the permission of the Health Physics Society (HPS), from ANSI/HPS N43.17.

[SOURCE: IEC 62463:2024, 3.7]

### **3.1.13**

#### **materials detection**

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

### **3.1.14**

#### **operator**

person that controls one or more aspects of the screening procedure. An operator is authorized to perform their duties, appropriately trained, and performs their duties according to the standard operating procedure

[SOURCE: IEC 62463:2024, 3.9]

### **3.1.15**

#### **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

**3.1.16****penetration test**

test of pentalith resolution and wire detection as a function of body phantom thickness

**3.1.17****pentalith**

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.

**3.1.18****pentalith resolution**

minimum separation between two spherical objects at which they can be resolved as separate entities, as measured using the pentalith test

**3.1.19****primary radiation**

ionizing radiation emitted by a radiation source which has not undergone scattering

**3.1.20****radiation source**

equipment or matter emitting or capable of emitting ionizing radiation

**3.1.21****reference location**

required location where test objects are placed for assessing imaging performance according to this document

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.

**3.1.22****Screening procedure**

Procedure, described in the SOP, that is followed to completely inspect something using the X-ray system

Note 1 to entry: Depending on the concept of operation of the system, this could involve taking multiple scans.

[SOURCE: IEC 62463:2024, 3.17]

**3.1.23****scan area**

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

**3.1.24****scanning speed**

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

[SOURCE: IEC 62523:2010, 3.15]

**3.1.25****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]

### 3.1.26

#### **security screening**

inspection of personnel, goods, cargo, vehicles and other objects to detect prohibited, controlled or dangerous items

Note 1 to entry: In the case of this document, the objects inspected are carried on or within the body of a person.

### 3.1.27

#### **system**

#### **scanning system**

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

### 3.1.28

#### **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

### 3.1.29

#### **whole body field of view**

field of view of systems designed to completely scan and image a person in one image

### 3.1.30

#### **wide field of view**

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

### 3.1.31

#### **wire detection**

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

[SOURCE: IEC 62523:2010, 3.10]

## 3.2 Abbreviated terms

HDPE high-density polyethylene

## 3.3 Quantities and units

In this document, the units are the multiples and sub-multiples of units of the International System of Units (SI)<sup>1</sup>. The definitions of radiation quantities are given in IEC 60050-395.

# 4 Imaging performance evaluation procedures

## 4.1 General characteristics and test procedures

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

- a) Pentolith resolution.
- b) Wire detection.
- c) Materials detection (may be by means of contrast sensitivity or edge detection).

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

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, power supply, source voltage and current, and filtration, and which are the same as the machine settings for radiation safety testing (measuring the effective dose). Since effective dose and image quality are interrelated, the system shall comply with the effective dose requirements in IEC 62463. General-use systems shall deliver an effective dose of less than 0,25  $\mu\text{Sv}$  per screening. Limited-use systems shall deliver a dose of less than 10  $\mu\text{Sv}$  per screening. See IEC 62463 for more details on the system classes and effective dose estimation methods.

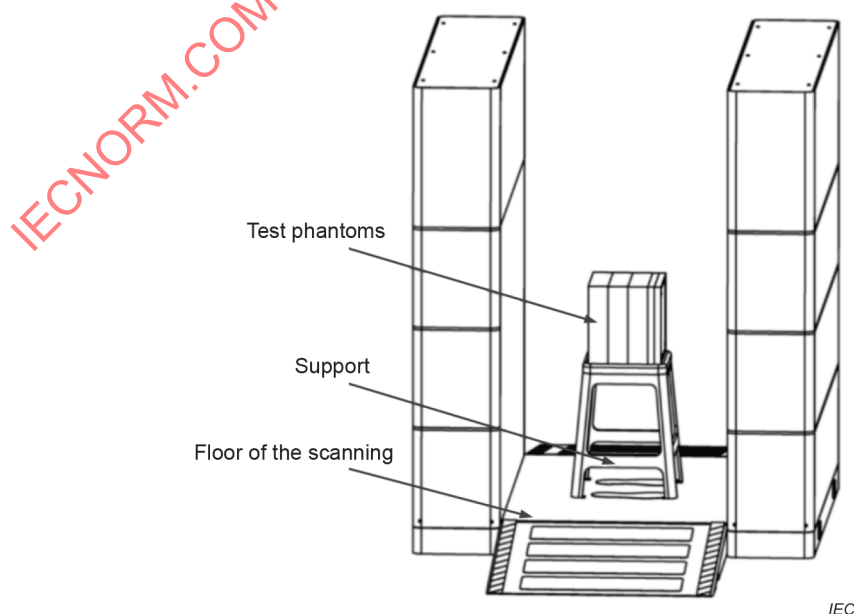
These machine settings and the effective dose shall be included in the test report (for an example, see Annex B) to facilitate the evaluation of overall system performance. If image-enhancement software features are available to the operator in normal use, these may be used to achieve the best possible 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.

Each test should be repeated 3 times.

#### 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:

- the surface of the body phantom and test object combination closest to the radiation source shall be perpendicular with the floor and at the optimum operating distance as specified by the manufacturer and,
- 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 floor of the scanner. 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 may 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 document shall have a density of  $0,95 \text{ g cm}^{-3} \pm 0,05 \text{ g cm}^{-3}$ .

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, an HDPE cube, 300 mm on each side, is used to simulate the human body.

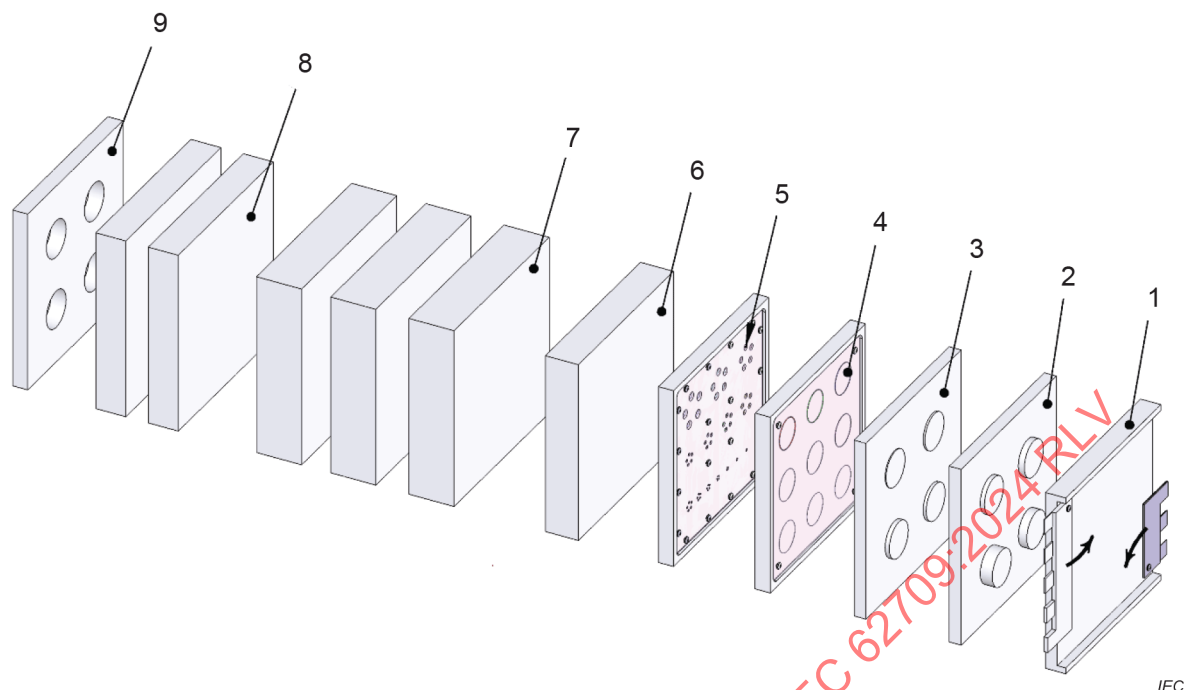
For general-use transmission systems, it is acceptable to use a reduced body phantom with dimensions of 300 mm wide × 300 mm high × 230 mm deep, so that the overall HDPE depth of the body phantom and test object assembly shall be 250 mm.

For the penetration test for limited-use systems, the overall depth shall be expandable from 300 mm to 400 mm by attaching additional 50 mm thick HDPE slabs.

For the penetration test of general-use systems, the overall depth shall be expandable from 250 mm to 300 mm by attaching additional 25 mm thick HDPE slabs.

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  $\pm 2 \%$  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 additional phantom, 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 Pentalith 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 pentalith 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 683-17:2023, grade designation 100Cr6 or equivalent (e.g. AISI/SAE 52100 in ASTM A295/A295M-14:2020, 1.3505 in EN 10027-2; SUJ2 in JIS G4805) 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  $\pm 0,1$  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 pentalith resolution test object are given in Figure A.1, Figure A.13, Figure A.14, Figure A.15 and Figure A.16.

#### 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.

The reported results shall be the sphere diameter of the smallest pentalith that was detected in at least two thirds of the images.

### 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<br>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 Figure A.1, Figure A.7, Figure A.11 and Figure A.9.

#### 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 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.

The reported results shall be the diameter of the smallest wire gauge that was detected in at least two thirds of the images.

## **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 Figure A.1, Figure A.8 and Figure A.9.

### **4.6.4 Procedure**

A test object meeting the description in 4.6.3 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.

The reported results shall be the thickness of the smallest disc that was detected in at least two thirds of the images.

## **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 Figure A.1 through Figure A.7.

#### 4.7.4 Procedure

A test object meeting the description in 4.7.3 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.

The reported results shall be the thicknesses of the thinnest tooth that was detected in at least two thirds of the images.

### 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 penaltith 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 Figure A.1 and Figure A.19.

### 4.8.4 Procedure

Repeat the pentalith 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 document 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. The machine settings and the effective dose requirements during the test are described in 4.1. Different minimum performance requirements are given for systems employing the three fields of view, viz., partial body (3.1.12), whole body (3.1.29), and wide (3.1.30).

For general-use transmission systems the test results are all report only (i.e. the minimum acceptable imaging performance requirements do not apply).

**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 subclause |
|-----------------------------------------------------------------------|---------------------------------------------------------|--------------------------|----------------------------|--------------------|--------------------|
| 1                                                                     | Pentalith 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 <sup>c</sup>    | 4.5                |
| 3                                                                     | Materials detection on body: thinnest disc discerned    | 5 mm                     | 5 mm                       | RO                 | 4.6                |
| 4                                                                     | Materials detection in air:                             |                          |                            |                    | 4.7                |
|                                                                       | smallest plastic thickness discerned                    | 3 mm                     | 2 mm                       | RO                 |                    |
|                                                                       | smallest metal thickness discerned                      | 1,6 mm                   | 0,8 mm                     | RO                 |                    |
| 5                                                                     | Penetration test                                        |                          |                            |                    | 4.8                |
|                                                                       | a) through 350 mm HDPE <sup>a</sup> :                   |                          |                            |                    |                    |
|                                                                       | smallest sphere diameter resolved                       | RO                       | RO                         | optional           |                    |
|                                                                       | smallest wire detected                                  | RO                       | RO                         | optional           |                    |
|                                                                       | b) through 400 mm HDPE <sup>b</sup> :                   |                          |                            |                    |                    |
|                                                                       | smallest sphere diameter resolved                       | RO                       | RO                         | optional           |                    |
|                                                                       | smallest wire detected                                  | RO                       | RO                         | optional           |                    |
| <sup>a</sup> Though 275 mm HDPE for transmission general-use systems. |                                                         |                          |                            |                    |                    |
| <sup>b</sup> Though 300 mm HDPE for transmission general-use systems. |                                                         |                          |                            |                    |                    |
| <sup>c</sup> RO: Report only; there is no minimum requirement.        |                                                         |                          |                            |                    |                    |

## 6 Environmental requirements

To ensure uniformity of test results, all the image quality tests in this document 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<br>(unless otherwise indicated by the manufacturer) |
|------------------------------------------|------------------------------------------------------------------------------|
| Warm-up time                             | >15 min                                                                      |
| Ambient temperature                      | 22 °C ± 5 °C                                                                 |
| Relative humidity                        | 30 % to 75 %                                                                 |
| Atmospheric pressure                     | 86 kPa to 106 kPa                                                            |
| Power supply voltage                     | Rated power supply voltage ±10 %                                             |
| 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 µGy·h <sup>-1</sup>                         |
| 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                                                  |

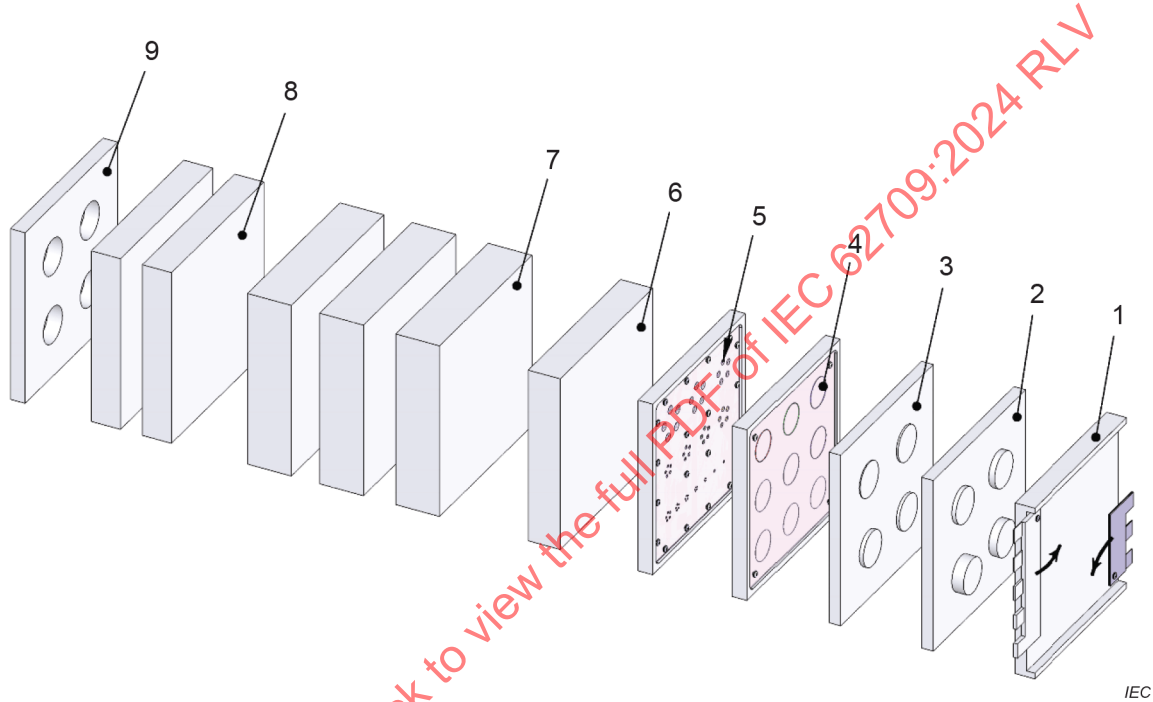
If the system is intended for operation in environmental conditions significantly outside the ranges specified in Table 3, additional testing should be done to demonstrate that the imaging performance reported for standard test conditions remains unchanged at the low temperature/low-humidity limit and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

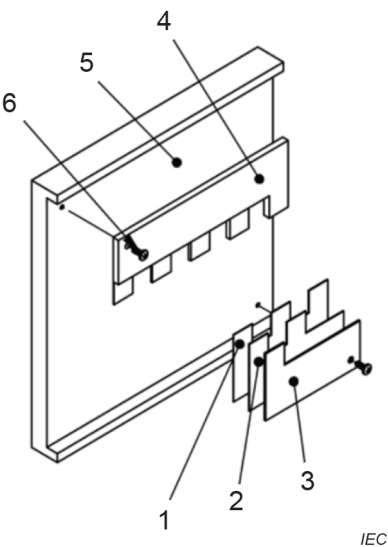
This Annex contains a complete set of mechanical drawings for the test objects specified in this document and is normative in the sense that it reflects the requirements of this document. See Figure A.1 through Figure A.20. Other implementations of test objects that deviate from these drawings, but continue to conform to the dimensional and material specifications of this document, are permitted. Unless otherwise specified, dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ;  $X/x \pm 0,3$  mm; 0,  $xx \pm 0,15$  mm.



#### Key

|   |                               |                                 |            |
|---|-------------------------------|---------------------------------|------------|
| 1 | material detection in air     | Figure A.2 through Figure 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           | Figure A.10 through Figure A.12 | Quantity 1 |
| 5 | pentalith resolution          | Figure A.13 through Figure 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**



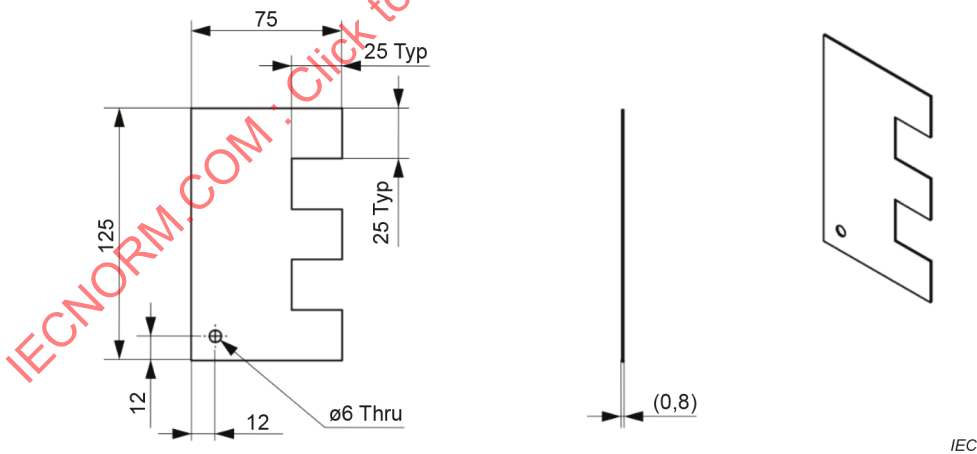
Key

|   |                                      |            |
|---|--------------------------------------|------------|
| 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 teeth             | 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 Figure A.3 through Figure 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).

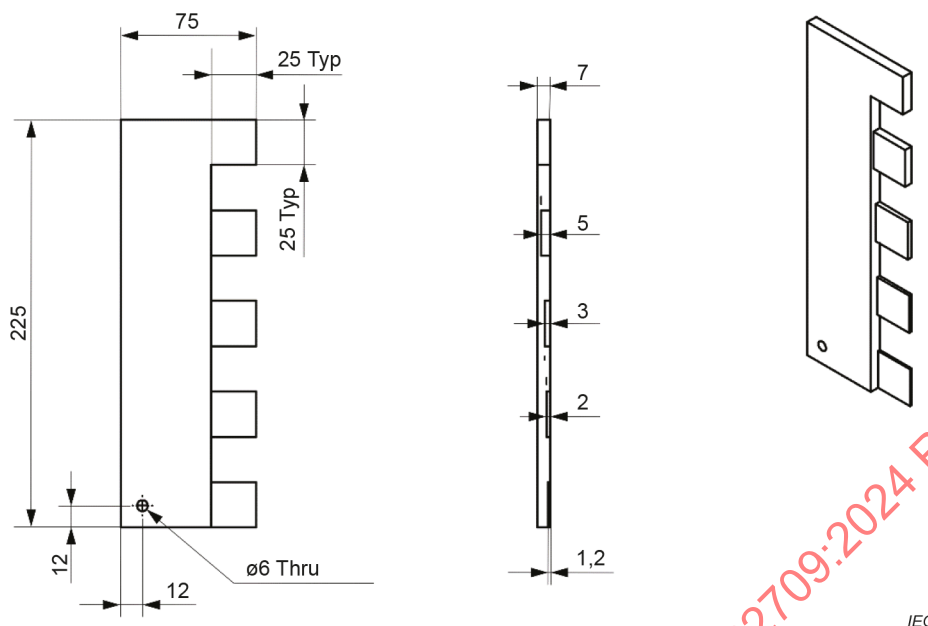
NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

**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:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

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

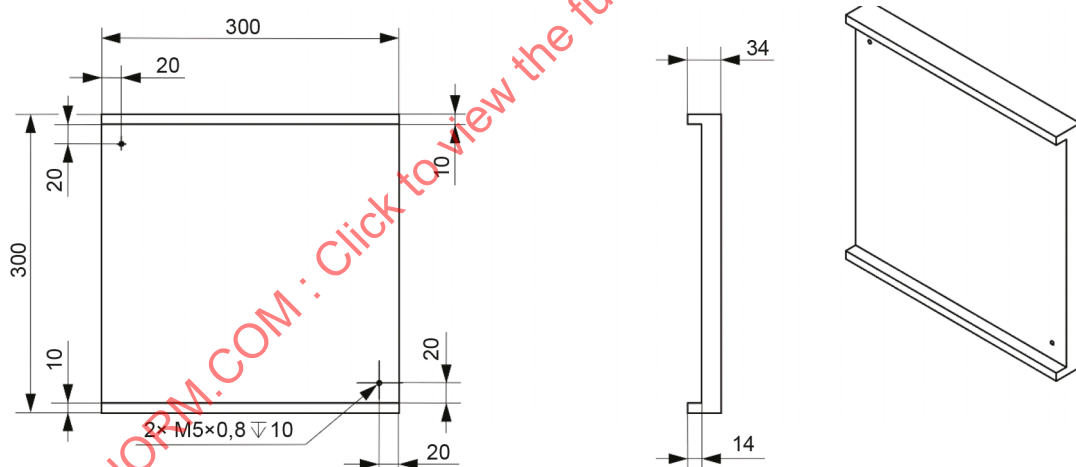


IEC

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

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

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

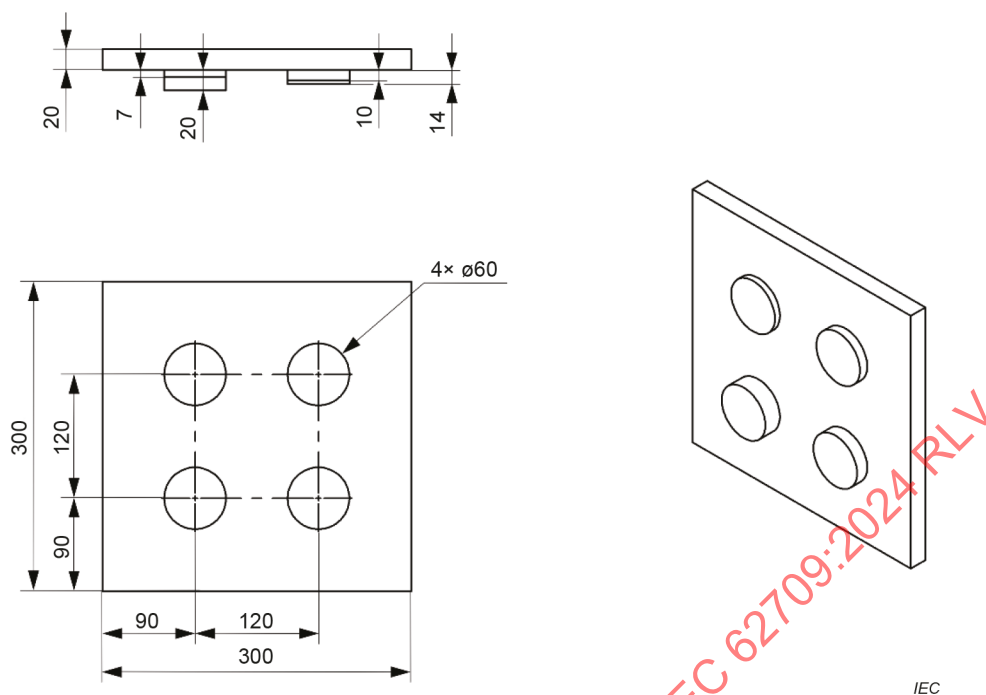


IEC

NOTE 1 This is fabricated from HDPE plastic .

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

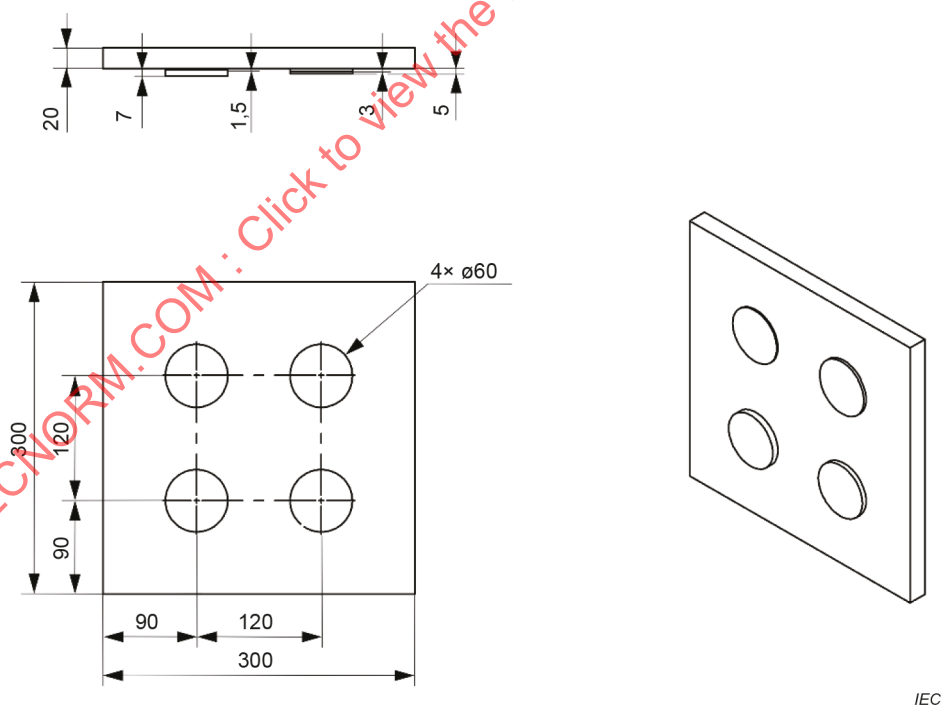
**Figure A.7 – Subassembly of the material detection in air phantom (Figure A.2), mounting sheet**



NOTE 1 This is fabricated from HDPE.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  mm.

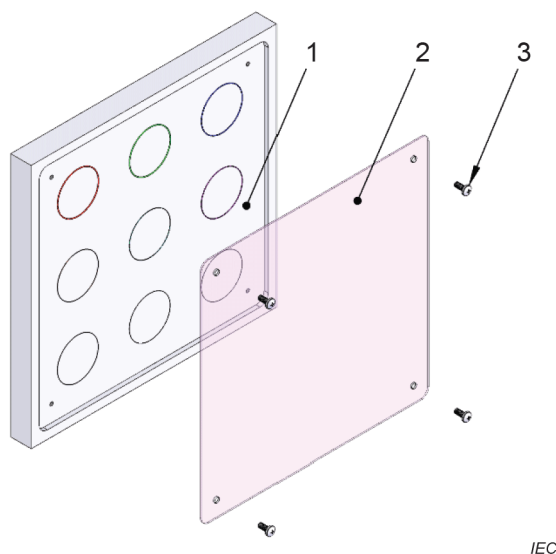
**Figure A.8 – Material detection on body 1**



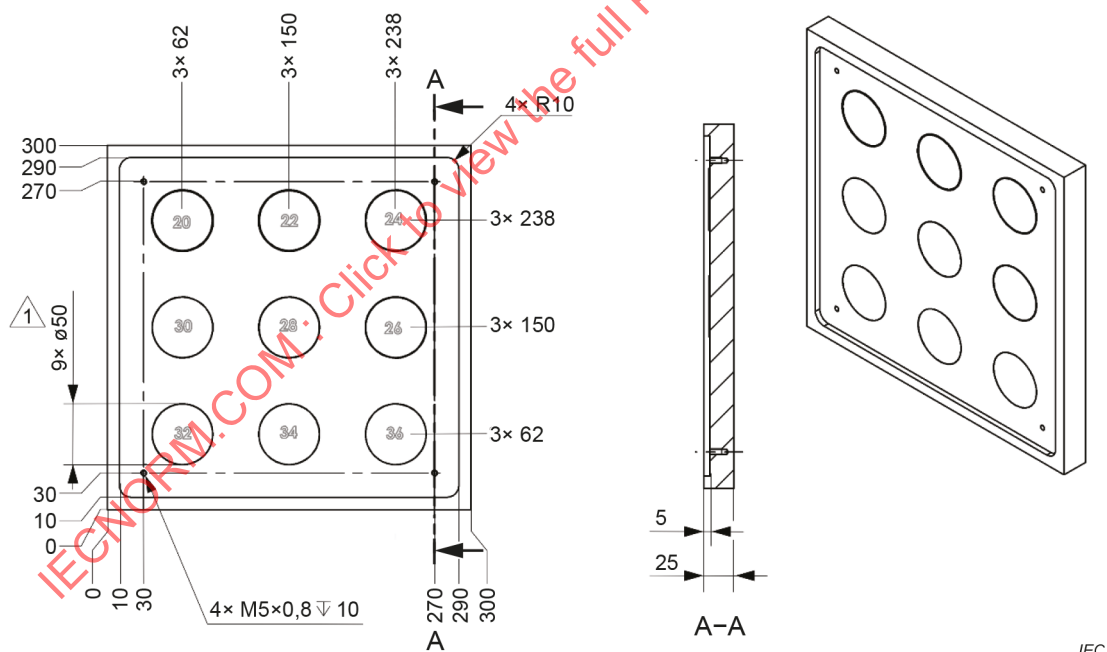
NOTE 1 This is fabricated from HDPE.

NOTE 2 All dimensions are in mm. Tolerances: angular:  $\pm 0,5^\circ$ ; X/.x  $\pm 0,3$  mm; 0, xx  $\pm 0,15$  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:  $\pm 0,5^\circ$ ;  $X/x \pm 0,3$ ; 0,  $xx \pm 0,15$ .

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