INTERNATIONAL STANDARD

IEC 61675-1

First edition
1998-02

Radionuclide imaging devices – Characteristics and test conditions –

Part 1: Positron emission tomographs

Dispositifs d'imagerie par radionucléides –
Caractéristiques et conditions d'essai –

Partie 1:
Tomographes à émission de positrons

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RADIONUCLIDE IMAGING DEVICES – CHARACTERISTICS AND TEST CONDITIONS –

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FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
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International Standard IEC 61675-1 has been prepared by subcommittee 62C: Equipment for radiotherapy, nuclear medicine and radiation dosimetry, of IEC technical committee 62: Electrical equipment in medical practice.

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

FDIS	Report on voting
62C/205/FDIS	62C/214/RVD

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

In this standard, the following print types are used:

– TERMS DEFINED IN CLAUSE 2 OF THIS STANDARD OR LISTED IN ANNEX A: SMALL CAPITALS.

The requirements are followed by specifications for the relevant tests.

Annex A is for information only.

A bilingual version of this standard may be issued at a later date.

RADIONUCLIDE IMAGING DEVICES – CHARACTERISTICS AND TEST CONDITIONS –

Part 1: Positron emission tomographs

1 General

1.1 Scope and object

This part of IEC 61675 specifies terminology and test methods for declaring the characteristics of POSITRON EMISSION TOMOGRAPHS. POSITRON EMISSION TOMOGRAPHS detect the ANNIHILATION RADIATION of positron emitting RADIONUCLIDES by COINCIDENCE DETECTION.

The test methods specified in this part of IEC 61675 have been selected to reflect as much as possible the clinical use of POSITRON EMISSION TOMOGRAPHS. It is intended that the test methods be carried out by manufacturers, thereby enabling them to declare the characteristics of POSITRON EMISSION TOMOGRAPHS. So, the specifications given in the ACCOMPANYING DOCUMENTS shall be in accordance with this standard. This standard does not imply which tests will be performed by the manufacturer on an individual tomograph.

No test has been specified to characterize the uniformity of reconstructed images, because all methods known so far will mostly reflect the noise in the image.

1.2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of IEC 61675. At the time of publication, the edition indicated was valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61675 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60788:1984, *Medical radiology – Terminology*

2 Terminology and definitions

For the purpose of this part of IEC 61675, the definitions given in IEC 60788 (see annex A) and the following definitions apply.

Defined terms are printed in small capitals.

2.1 TOMOGRAPHY (see annex A)

2.1.1

TRANSVERSE TOMOGRAPHY
in TRANSVERSE TOMOGRAPHY the three-dimensional object is sliced by physical methods, for example collimation, into a stack of OBJECT SLICES, which are considered as being two-dimensional and independent from each other. The transverse IMAGE PLANES are perpendicular to the SYSTEM AXIS.

2.1.2

EMISSION COMPUTED TOMOGRAPHY (ECT)

imaging method for the representation of the spatial distribution of incorporated RADIONUCLIDES in selected two-dimensional slices through the object

2.1.2.1

PROJECTION

transformation of a three-dimensional object into its two-dimensional image or of a two-dimensional object into its one-dimensional image, by integrating the physical property which determines the image along the direction of the PROJECTION BEAM

NOTE – This process is mathematically described by line integrals in the direction of projection (along the LINE OF RESPONSE) and called Radon-transform.

2.1.2.2

PROJECTION BEAM

determines the smallest possible volume in which the physical property which determines the image is integrated during the measurement process. Its shape is limited by SPATIAL RESOLUTION in all three dimensions.

NOTE – The PROJECTION BEAM mostly has the shape of a long thin cylinder or cone. In POSITRON EMISSION TOMOGRAPHY, it is the sensitive volume between two detector elements operated in coincidence.

2.1.2.3

PROJECTION ANGLE

angle at which the PROJECTION is measured or acquired

2.1.2.4

SINOGRAM

two-dimensional display of all one-dimensional PROJECTIONS of an OBJECT SLICE, as a function of the PROJECTION ANGLE. The PROJECTION ANGLE is displayed on the ordinate, the linear PROJECTION coordinate is displayed on the abscissa.

2.1.2.5

OBJECT SLICE

slice in the object. The physical property of this slice, that determines the measured information, is displayed in the tomographic image.

2.1.2.6

IMAGE PLANE

a plane assigned to a plane in the OBJECT SLICE

NOTE – Usually the IMAGE PLANE is the midplane of the corresponding OBJECT SLICE.

2.1.2.7

SYSTEM AXIS

axis of symmetry, characterized by geometrical and physical properties of the arrangement of the system

NOTE – For a circular POSITRON EMISSION TOMOGRAPH, the SYSTEM AXIS is the axis through the centre of the detector ring. For tomographs with rotating detectors it is the axis of rotation.

2.1.2.8

TOMOGRAPHIC VOLUME

juxtaposition of all volume elements which contribute to the measured PROJECTIONS for all PROJECTION ANGLES

2.1.2.8.1

TRANSVERSE FIELD OF VIEW

dimensions of a slice through the TOMOGRAPHIC VOLUME, perpendicular to the SYSTEM AXIS. For a circular TRANSVERSE FIELD OF VIEW, it is described by its diameter

NOTE – For non-cylindrical TOMOGRAPHIC VOLUMES the TRANSVERSE FIELD OF VIEW may depend on the axial position of the slice.

2.1.2.8.2

AXIAL FIELD OF VIEW

dimensions of a slice through the TOMOGRAPHIC VOLUME, parallel to and including the SYSTEM AXIS. In practice, it is specified only by its axial dimension, given by the distance between the centre of the outmost defined IMAGE PLANES plus the average of the measured AXIAL SLICE WIDTH

2.1.2.8.3

TOTAL FIELD OF VIEW

dimensions (three-dimensional) of the TOMOGRAPHIC VOLUME

2.1.3

POSITRON EMISSION TOMOGRAPHY (PET)

EMISSION COMPUTED TOMOGRAPHY utilizing the ANNIHILATION RADIATION of positron emitting RADIONUCLIDES by COINCIDENCE DETECTION

2.1.3.1

POSITRON EMISSION TOMOGRAPH

tomographic device, which detects the ANNIHILATION RADIATION of positron emitting RADIONUCLIDES by COINCIDENCE DETECTION

2.1.3.2

ANNIHILATION RADIATION

ionizing radiation that is produced when a particle and its antiparticle interact and cease to exist

2.1.3.3

COINCIDENCE DETECTION

a method which checks whether two opposing detectors have detected one photon each simultaneously. By this method the two photons are concatenated into one event.

NOTE – The COINCIDENCE DETECTION between two opposing detector elements serves as an electronic collimation to define the corresponding PROJECTION BEAM or LINE OF RESPONSE (LOR), respectively.

2.1.3.4

COINCIDENCE WINDOW

time interval during which two detected photons are considered being simultaneous

2.1.3.5

LINE OF RESPONSE (LOR)

the axis of the PROJECTION BEAM

NOTE – In PET, it is the line connecting the centres of two opposing detector elements operated in coincidence.

2.1.3.6

TOTAL COINCIDENCES

sum of all coincidences detected

2.1.3.6.1

TRUE COINCIDENCE

result of COINCIDENCE DETECTION of two gamma events originating from the same positron annihilation

2.1.3.6.2
SCATTERED TRUE COINCIDENCE

TRUE COINCIDENCE where at least one participating photon was scattered before the COINCIDENCE DETECTION

2.1.3.6.3
UNSCATTERED TRUE COINCIDENCE

the difference between TRUE COINCIDENCES and SCATTERED TRUE COINCIDENCES

2.1.3.6.4
RANDOM COINCIDENCE

result of COINCIDENCE DETECTION in which both participating photons emerge from different positron annihilations

2.1.3.7
SINGLES RATE

COUNT RATE measured without COINCIDENCE DETECTION, but with energy discrimination

2.1.4
Reconstruction

2.1.4.1
TWO-DIMENSIONAL RECONSTRUCTION

in TWO-DIMENSIONAL RECONSTRUCTION, the data are rebinned prior to reconstruction into SINOGRAMS, which are the PROJECTION data of transverse slices, which are considered being independent of each other and being perpendicular to the SYSTEM AXIS. So, each event will be assigned, in the axial direction, to that transverse slice passing the midpoint of the corresponding LINE OF RESPONSE. Any deviation from perpendicularity to the SYSTEM AXIS is neglected. The data are then reconstructed by two-dimensional methods, i.e. each slice is reconstructed from its associated SINOGRAM, independent of the rest of the data set.

NOTE – This is the standard method of reconstruction for POSITRON EMISSION TOMOGRAPHS using small axial acceptance angles, i.e. utilizing septa. For POSITRON EMISSION TOMOGRAPHS using large axial acceptance angles, i.e. without septa, this method is also called ‘single slice rebinning’.

2.1.4.2
THREE-DIMENSIONAL RECONSTRUCTION

in THREE-DIMENSIONAL RECONSTRUCTION, the LINES OF RESPONSE are not restricted to being perpendicular to the SYSTEM AXIS. So, a LINE OF RESPONSE may pass several transverse slices. Consequently, transverse slices cannot be reconstructed independent of each other. Each slice has to be reconstructed utilizing the full three-dimensional data set.

2.2
IMAGE MATRIX

arrangement of MATRIX ELEMENTS in a preferentially cartesian coordinate system

2.2.1
MATRIX ELEMENT

smallest unit of an IMAGE MATRIX, which is assigned in location and size to a certain volume element of the object (VOXEL)

2.2.1.1
PIXEL

matrix element in a two-dimensional IMAGE MATRIX

2.2.1.2
TRIXEL

matrix element in a three-dimensional IMAGE MATRIX

2.2.2

VOXEL

volume element in the object which is assigned to a MATRIX ELEMENT in the IMAGE MATRIX (two-dimensional or three-dimensional). The dimensions of the VOXEL are determined by the dimensions of the corresponding MATRIX ELEMENT via the appropriate scale factors and by the systems SPATIAL RESOLUTION in all three dimensions

2.3

POINT SPREAD FUNCTION (PSF)

scintigraphic image of a POINT SOURCE

2.3.1

PHYSICAL POINT SPREAD FUNCTION

for tomographs, a two-dimensional POINT SPREAD FUNCTION in planes perpendicular to the PROJECTION BEAM at specified distances from the detector

NOTE – The PHYSICAL POINT SPREAD FUNCTION characterizes the purely physical (intrinsic) imaging performance of the tomographic device and is independent of for example sampling, image reconstruction and image processing. A PROJECTION BEAM is characterized by the entirety of all PHYSICAL POINT SPREAD FUNCTIONS as a function of distance along its axis.

2.3.2

AXIAL POINT SPREAD FUNCTION

profile passing through the peak of the PHYSICAL POINT SPREAD FUNCTION in a plane parallel to the SYSTEM AXIS

2.3.3

TRANSVERSE POINT SPREAD FUNCTION

reconstructed two-dimensional POINT SPREAD FUNCTION in a tomographic IMAGE PLANE

NOTE – In TOMOGRAPHY, the TRANSVERSE POINT SPREAD FUNCTION can also be obtained from a LINE SOURCE located parallel to the SYSTEM AXIS.

2.4

SPATIAL RESOLUTION

ability to concentrate the count density distribution in the image of a POINT SOURCE to a point

2.4.1

TRANSVERSE RESOLUTION

SPATIAL RESOLUTION in a reconstructed plane perpendicular to the SYSTEM AXIS

2.4.1.1

RADIAL RESOLUTION

TRANSVERSE RESOLUTION along a line passing through the position of the source and the SYSTEM AXIS

2.4.1.2

TANGENTIAL RESOLUTION

TRANSVERSE RESOLUTION in the direction orthogonal to the direction of RADIAL RESOLUTION

2.4.2

AXIAL RESOLUTION

for tomographs with sufficiently fine axial sampling fulfilling the sampling theorem, SPATIAL RESOLUTION along a line parallel to the SYSTEM AXIS

2.4.3

AXIAL SLICE WIDTH

for tomographs, the width of the AXIAL POINT SPREAD FUNCTION

2.4.4

EQUIVALENT WIDTH (EW)

width of that rectangle, having the same area and the same height as the response function, for example the POINT SPREAD FUNCTION

2.4.5

FULL WIDTH AT HALF MAXIMUM (FWHM)

(see annex A)

2.5

RECOVERY COEFFICIENT

measured (image) ACTIVITY concentration of an active volume divided by the true ACTIVITY concentration of that volume, neglecting ACTIVITY calibration factors

NOTE – For the actual measurement, the true ACTIVITY concentration is replaced by the measured ACTIVITY concentration in a large volume.

2.6

Tomographic sensitivity

2.6.1

SLICE SENSITIVITY

ratio of COUNT RATE as measured on the SINOGRAM to the ACTIVITY concentration in the phantom

NOTE – In PET, the measured counts are numerically corrected for scatter by subtracting the SCATTER FRACTION.

2.6.1.1

NORMALIZED SLICE SENSITIVITY

SLICE SENSITIVITY divided by the AXIAL SLICE WIDTH (EW) for that slice

2.6.2

VOLUME SENSITIVITY

sum of the individual SLICE SENSITIVITIES

2.7

COUNT RATE CHARACTERISTIC (see annex A)

2.7.1

COUNT LOSS

difference between measured COUNT RATE and TRUE COUNT RATE, which is caused by the finite RESOLVING TIME of the instrument

2.7.2

COUNT RATE

number of counts per unit of time

2.7.3

TRUE COUNT RATE (see annex A)

2.7.4

ADDRESS PILE UP

for imaging devices false address calculation of an artificial event which passes the PULSE AMPLITUDE ANALYZER WINDOW, but is formed from two or more events by the PILE UP EFFECT

2.7.4.1

PILE UP EFFECT

false measurement of the pulse amplitude, due to the absorption of two or more gamma rays, reaching the same radiation detector within the RESOLVING TIME

2.8

SCATTER FRACTION (SF)

ratio between SCATTERED TRUE COINCIDENCES and the sum of SCATTERED plus UNSCATTERED TRUE COINCIDENCES for a given experimental set-up

2.9

POINT SOURCE

RADIOACTIVE SOURCE approximating a δ-function in all three dimensions

2.10

LINE SOURCE

straight RADIOACTIVE SOURCE approximating a δ-function in two dimensions and being constant (uniform) in the third dimension

3 Test methods

For all measurements, the tomograph shall be set up according to its normal mode of operation, i.e. it shall not be adjusted specially for the measurement of specific parameters. If the tomograph is specified to operate in different modes influencing the performance parameters, for example with different axial acceptance angles, with and without septa, with TWO-DIMENSIONAL RECONSTRUCTION and THREE-DIMENSIONAL RECONSTRUCTION, the test results shall be reported in addition. The tomographic configuration (e.g. energy thresholds, axial acceptance angle, reconstruction algorithm) shall be chosen according to the manufacturer's recommendation and clearly stated. If any test cannot be carried out exactly as specified in this standard, the reason for the deviation and the exact conditions under which the test was performed shall be stated clearly.

The test phantoms shall be centred within the tomographs' AXIAL FIELD OF VIEW, if not specified otherwise.

NOTE – For tomographs with an AXIAL FIELD OF VIEW greater than 16,5 cm, this centring will only produce performance estimates for the central part. However, if the phantoms were displaced axially in order to cover the entire AXIAL FIELD OF VIEW, false results could be obtained for the central planes, if the axial acceptance angle of the detectors is not fully covered with ACTIVITY.

3.1 SPATIAL RESOLUTION

3.1.1 General

SPATIAL RESOLUTION measurements describe partly the ability of a tomograph to reproduce the spatial distribution of a tracer in an object in a reconstructed image. The measurement is performed by imaging POINT (or LINE) SOURCES in air and reconstructing images, using a sharp reconstruction filter. Although this does not represent the condition of imaging a patient, where tissue scatter is present and limited statistics require the use of a smooth reconstruction filter, the measured SPATIAL RESOLUTION provides a best-case comparison between tomographs, indicating the highest achievable performance.

3.1.2 Purpose

The purpose of this measurement is to characterize the ability of the tomograph to recover small objects by characterizing the width of the reconstructed TRANSVERSE POINT SPREAD FUNCTIONS of radioactive POINT SOURCES or of extended LINE SOURCES placed perpendicular to the direction of measurement. The width of the spread function is measured by the FULL WIDTH AT HALF MAXIMUM (FWHM) and the EQUIVALENT WIDTH (EW).

To define how well objects can be reproduced in the axial direction, the AXIAL SLICE WIDTH (commonly referred to as the slice thickness) is used. It is measured with a POINT SOURCE which is stepped through the tomographs TRANSVERSE FIELD OF VIEW axially in small increments and is characterized by the EW and the FWHM of the AXIAL POINT SPREAD FUNCTION for each individual slice.