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Radionuclide imaging devices – Characteristics and test conditions –

Part 2: Single photon emission computed tomographs

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

RADIONUCLIDE IMAGING DEVICES – CHARACTERISTICS AND TEST CONDITIONS –

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FOREWORD

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International Standard IEC 61675-2 has been prepared by subcommittee 62C: Equipment for radiotherapy, nuclear medicine and radiation dosimetry, of IEC technical committee 62: Electrical equipment in medical practice.

This consolidated version of IEC 61675-2 consists of the first edition (1998) [documents 62C/206/FDIS and 62C/215/RVD] and its amendment 1 (2004) [documents 62C/378/FDIS and 62C/379/RVD].

The technical content is therefore identical to the base edition and its amendment and has been prepared for user convenience.

It bears the edition number 1.1.

A vertical line in the margin shows where the base publication has been modified by amendment 1.

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.

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

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- withdrawn,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

RADIONUCLIDE IMAGING DEVICES – CHARACTERISTICS AND TEST CONDITIONS –

Part 2: Single photon emission computed tomographs

1 General

1.1 Scope and object

This part of IEC 61675 specifies terminology and test methods for describing the characteristics of Anger type rotational GAMMA CAMERA SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHS (SPECT), equipped with parallel hole collimators. As these systems are based on Anger type GAMMA CAMERAS this part of IEC 61675 shall be used in conjunction with IEC 60789. These systems consist of a gantry system, single or multiple DETECTOR HEADS and a computer system together with acquisition, recording, and display devices.

This part of IEC 61675-2 also specifies test conditions for declaring the characteristics of single photon computer tomographs operated in coincidence mode as well as in single photon mode.

The test methods specified for coincidence mode are based on the test methods for dedicated PET tomographs as described in IEC 61675-1 to reflect as well as possible the clinical use of coincidence detection. Tests have been modified to reflect the limited sensitivity and COUNT RATE CHARACTERISTICS of the single photon computer tomographs operated in coincidence detection mode only when needed.

The test methods specified in this part of IEC 61675 have been selected to reflect as much as possible the clinical use of Anger type rotational GAMMA CAMERA SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHS (SPECT). It is intended that the test methods be carried out by manufacturers thereby enabling them to describe the characteristics of SPECT systems on a common basis.

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

1.2 Normative references

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

IEC 60788:1984, *Medical radiology – Terminology*

IEC 60789:1992, *Characteristics and test conditions of radionuclide imaging devices – Anger type gamma cameras*

IEC 61675-1, — *Radionuclide imaging devices – Characteristics and test conditions – Part 1: Positron emission tomographs*

2 Terminology and definitions

For the purposes of this part of IEC 61675 the definitions given in IEC 60788, IEC 60789 and IEC 61675-1 (some of which are repeated in this clause), and the following definitions apply.

Defined terms are printed in small capital letters.

2.1
SYSTEM AXIS
Axis of symmetry characterized by geometrical and physical properties of the arrangement of the system

NOTE The SYSTEM AXIS of a GAMMA CAMERA with rotating detectors is the axis of rotation.

2.1.1
COORDINATE SYSTEMS

2.1.2
FIXED COORDINATE SYSTEM
Cartesian system with axes X, Y, and Z, Z being the SYSTEM AXIS. The origin of the FIXED COORDINATE SYSTEM is defined by the centre of the TOMOGRAPHIC VOLUME (see Figure 1). The SYSTEM AXIS is orthogonal to all TRANSVERSE SLICES.

2.1.3
COORDINATE SYSTEM OF PROJECTION
Cartesian system of the IMAGE MATRIX of each two-dimensional projection with axes X_p and Y_p (defined by the axes of the IMAGE MATRIX). The Y_p axis and the projection of the system axis onto the detector front face have to be in parallel. The origin of the COORDINATE SYSTEM OF PROJECTION is the centre of the IMAGE MATRIX (see Figure 1).

2.1.4
CENTRE OF ROTATION (COR)
Origin of that COORDINATE SYSTEM, which describes the PROJECTIONS of a TRANSVERSE SLICE with respect to their orientation in space

NOTE The CENTRE OF ROTATION of a TRANSVERSE SLICE is given by the intersection of the SYSTEM AXIS with the mid-plane of the corresponding OBJECT SLICE.

2.1.5
OFFSET
Deviation of the position of the PROJECTION of the COR (X'_p) from $X_p = 0$. (See Figure 1)

2.2
TOMOGRAPHY (see annex A)

2.2.1
TRANSVERSE TOMOGRAPHY
In TRANSVERSE TOMOGRAPHY the three-dimensional object is sliced by physical methods, e.g. 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.

2.2.2
EMISSION COMPUTED TOMOGRAPHY (ECT)
Imaging method for the representation of the spatial distribution of incorporated RADIONUCLIDES in selected two-dimensional SLICES through the object

2.2.2.1
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 and called the Radon-transform.

2.2.2.2
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 the SPATIAL RESOLUTION in all three dimensions.

NOTE In SPECT the PROJECTION BEAM usually has the shape of a long thin diverging cone.

2.2.2.3
PROJECTION ANGLE
Angle at which the PROJECTION is measured or acquired

NOTE For illustration see Figure 1.

2.2.2.4
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.

2.2.2.5
OBJECT SLICE
A slice in the object. The physical property of this slice that determines the measured information is displayed in the tomographic image.

2.2.2.6
IMAGE PLANE
A plane assigned to a plane in the OBJECT SLICE

NOTE Usually the IMAGE PLANE is the mid-plane of the corresponding OBJECT SLICE.

2.2.2.7
TOMOGRAPHIC VOLUME
Ensemble of all volume elements which contribute to the measured PROJECTIONS for all PROJECTION ANGLES

NOTE For a rotating GAMMA CAMERA with a circular field of view the TOMOGRAPHIC VOLUME is a sphere provided that the radius of rotation is larger than the radius of the field of view. For a rectangular field of view, the TOMOGRAPHIC VOLUME is a cylinder.

2.2.2.7.1
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.

2.2.2.7.2
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 centres of the outermost defined IMAGE PLANES plus the average of the measured AXIAL SLICE WIDTH measured as EQUIVALENT WIDTH (EW).

2.2.2.7.3
TOTAL FIELD OF VIEW
Dimensions (three-dimensional) of the TOMOGRAPHIC VOLUME

2.3
IMAGE MATRIX
Arrangement of MATRIX ELEMENTS in a preferentially cartesian coordinate system

2.3.1
MATRIX ELEMENT
Smallest unit of an IMAGE MATRIX, which is assigned in location and size to a certain volume element of the object (VOXEL)

2.3.1.1
PIXEL
MATRIX ELEMENT in a two-dimensional IMAGE MATRIX

2.3.1.2
TRIXEL
MATRIX ELEMENT in a three-dimensional IMAGE MATRIX

2.3.2
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 system's SPATIAL RESOLUTION in all three dimensions.

2.4
POINT SPREAD FUNCTION (PSF)
Scintigraphic image of a POINT SOURCE

2.4.1
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 imaging performance of the tomographic device independent from, e.g. sampling, image reconstruction and image processing, but dependent on the COLLIMATOR. A PROJECTION BEAM is characterized by the entirety of all PHYSICAL POINT SPREAD FUNCTIONS as a function of distance along its axis.

2.4.2
AXIAL POINT SPREAD FUNCTION
Profile passing through the peak of the PHYSICAL POINT SPREAD FUNCTION in a plane parallel to the SYSTEM AXIS

2.4.3
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.

2.5
SPATIAL RESOLUTION
Ability to concentrate the count density distribution in the image of a POINT SOURCE to a point

2.5.1
TRANSVERSE RESOLUTION
SPATIAL RESOLUTION in a reconstructed plane perpendicular to the SYSTEM AXIS

2.5.1.1
RADIAL RESOLUTION
TRANSVERSE RESOLUTION along a line passing through the position of the source and the SYSTEM AXIS

2.5.1.2
TANGENTIAL RESOLUTION
TRANSVERSE RESOLUTION in the direction orthogonal to the direction of RADIAL RESOLUTION

2.5.2
AXIAL RESOLUTION
For tomographs with sufficiently fine axial sampling fulfilling the sampling theorem, SPATIAL RESOLUTION along a line parallel to the SYSTEM AXIS

2.5.3
EQUIVALENT WIDTH (EW)
Width of that rectangle having the same area and the same height as the response function, e.g. the POINT SPREAD FUNCTION

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 SPECT the measured counts are not numerically corrected for scatter by subtracting the SCATTER FRACTION.

2.6.2
VOLUME SENSITIVITY
Sum of the individual SLICE SENSITIVITIES

2.6.3
NORMALIZED VOLUME SENSITIVITY
VOLUME SENSITIVITY divided by the AXIAL FIELD OF VIEW of the tomograph or the phantom length, whichever is the smaller

2.7
SCATTER FRACTION (SF)
Ratio between the number of scattered photons and the sum of scattered plus unscattered photons for a given experimental set-up

2.8
SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)
EMISSION COMPUTED TOMOGRAPHY utilizing single photon detection of gamma-ray emitting RADIONUCLIDES

2.8.1
DETECTOR POSITIONING TIME
Fraction of the total time spent on an acquisition which is not used in collecting data

2.8.2
DETECTOR HEAD TILT
Deviation of the COLLIMATOR axis from orthogonality with the SYSTEM AXIS

2.8.3
RADIUS OF ROTATION
Distance between the SYSTEM AXIS and the COLLIMATOR front face

2.9
RADIOACTIVE SOURCE
See rm-20-02 of IEC 60788

2.9.1
POINT SOURCE
RADIOACTIVE SOURCE approximating a δ-function in all three dimensions

2.9.2
LINE SOURCE
Straight RADIOACTIVE SOURCE approximating a δ-function in two dimensions and being constant (uniform) in the third dimension

2.10
POSITRON EMISSION TOMOGRAPHY
PET
emission computed tomography utilizing the annihilation radiation of positron emitting radionuclides by coincidence detection

[IEC 61675-1, definition 2.1.3]

2.10.1
POSITRON EMISSION TOMOGRAPH
tomographic device, which detects the annihilation radiation of positron emitting radionuclides by coincidence detection

[IEC 61675-1, definition 2.1.3.1]

2.10.2
ANNIHILATION RADIATION
IONIZING RADIATION that is produced when a particle and its antiparticle interact and cease to exist

[IEC 61675-1, definition 2.1.3.2]

2.10.3
LINE OF RESPONSE
LOR
axis of the PROJECTION BEAM

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

[IEC 61675-1, definition 2.1.3.5]

2.10.4
TOTAL COINCIDENCES
sum of all coincidences detected

[IEC 61675-1, definition 2.1.3.6]

2.10.4.1
TRUE COINCIDENCE
result of COINCIDENCE DETECTION of two gamma events originating from the same positron annihilation

[IEC 61675-1, definition 2.1.3.6.1]

2.10.4.2
SCATTERED TRUE COINCIDENCE
TRUE COINCIDENCE where at least one participating PHOTON was scattered before the COINCIDENCE DETECTION

[IEC 61675-1, definition 2.1.3.6.2]

2.10.4.3
UNSCATTERED TRUE COINCIDENCES
difference between true coincidences and scattered true coincidences

[IEC 61675-1, definition 2.1.3.6.3]

2.10.4.4
RANDOM COINCIDENCE
result of COINCIDENCE DETECTION in which both participating PHOTONS emerge from different positron annihilations

[IEC 61675-1, definition 2.1.3.6.4]

2.10.5
SINGLES RATE
COUNT RATE measured without COINCIDENCE DETECTION, but with energy discrimination

[IEC 61675-1, definition 2.1.3.7]

2.10.6
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 perpendicular 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”.

[IEC 61675-1, definition 2.1.4.1]

2.10.7
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

[IEC 61675-1, definition 2.1.4.2]

2.11
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.

[IEC 61675-1, definition 2.5]

2.12
NORMALIZED SLICE SENSITIVITY
slice sensitivity divided by the axial slice width (EW) for that slice

[IEC 61675-1, definition 2.6.1.1]

2.12.1
COUNT RATE CHARACTERISTIC
function giving the relationship between observed COUNT RATE and TRUE COUNT RATE

[IEC 60788, definition rm-34-21]

2.12.2
COUNT LOSS
difference between measured COUNT RATE and TRUE COUNT RATE, which is caused by the finite RESOLVING TIME of the instrument

[IEC 61675-1, definition 2.7.1]

2.12.3
ADDRESS PILE UP
<GAMMA CAMERA> false address calculation of an artificial event which passes the ENERGY WINDOW, but is formed from two or more events by the PILE UP EFFECT

[IEC 61675-1, definition 2.7.4, modified]

2.12.4
RADIOACTIVE SOURCE
quantity of radioactive material having both an ACTIVITY and a specific ACTIVITY above specific levels

[IEC 60788, definition rm-20-02]

3 Test methods

All measurements shall be performed with the PULSE AMPLITUDE ANALYZER WINDOW as specified in Table 1 of IEC 60789. Additional measurements with other settings as specified by the manufacturer can be performed. Before the measurements are performed, the tomographic system shall be adjusted by the procedure normally used by the manufacturer for an installed unit and shall not be adjusted specially for the measurement of specific parameters. If any test cannot be carried out exactly as specified in the standard, the reason for the deviation and the exact conditions under which the test was performed shall be stated clearly.

Unless otherwise specified, each DETECTOR HEAD in the system shall be characterized by a full data set covering an angular range of 360°. For multiheaded systems, characterization shall also be provided for an acquisition covering the minimal rotation required to obtain a complete set of data (e.g. 120° for a three-headed system). If the tomograph is specified to operate in a non-circular orbiting mode influencing the performance parameters, test results shall be reported in addition.

Unless otherwise specified, measurements shall be carried out at COUNT RATES not exceeding 20 000 counts per second.

Measurements of performance parameters in the planar mode of operation are a prerequisite. A complete set of performance parameters shall be measured as specified in IEC 60789.

3.1 Calibration measurements

3.1.1 Measurement of the CENTRE OF ROTATION (COR)

An error-free reconstruction requires the knowledge of the position of the PROJECTION of the COR into the coordinate system X_p, Y_p for each PROJECTION (i.e. for each PROJECTION angle) of that slice. For a circular rotation of the DETECTOR and for an ideal system, the PROJECTION of a POINT SOURCE at the COR will be at the same position X'_p in the projection matrix for all angles of PROJECTION (see Figure 1).

To determine the CENTRE OF ROTATION, the OFFSET X'_p has to be measured. POINT SOURCE(S) are used. A minimum of 32 projections equally spaced over 360° are acquired and displayed as a SINOGRAM. The RADIUS OF ROTATION shall be set to 20 cm. The source(s) shall be positioned radially at least 5 cm from the system axis to get SINOGRAMS with a discernible shape of a sine function. The OFFSET shall be determined for a minimum of three slices with axial positions, (Z direction), one at the centre of the FIELD OF VIEW and the other two, ±1/3 of the AXIAL FIELD OF VIEW from the centre.

At least 10 000 counts per view shall be acquired. The length of PIXEL side shall be less than 4 mm. For the calculation of the centroid (centre of gravity) $X_p(\theta)$ of the source in the X_p direction, 50 mm wide strips in the Y direction centred around the Y_p position of each source shall be used. This shall be done for each projection angle θ. Then the OFFSET is determined by fitting a sine function to the $X_p(\theta)$ values of each source, where

$$X_p(\theta) = A \sin(\theta + \varphi) + X'$$

where

θ is the angle of projection;

A is the amplitude;

φ is the phase shift of the sine function;

X' is the average OFFSET to be reported for the three different axial positions.

NOTE If there is a DETECTOR HEAD TILT the position of the image of the POINT SOURCE will move not only in the x_p direction, but also in the Y_p direction. To determine the X_p movement not influenced by the Y_p movement (for a reasonable amount of head tilt), the centroid is calculated using the 50 mm wide strip. The subscript p refers to the projection space (see Figure 1).

NOTE If a system uses an automatic OFFSET correction which cannot be switched off, then X' shall be zero.

In addition, the difference between fit and data shall be plotted (showing the error) as a function of θ. The maximum difference for each axial position shall be reported. The values are valid only for the COLLIMATOR used and shall be stated in millimetres.

NOTE Systematic deviations (trends) are indicative of varying OFFSET during rotation of the detector.

3.1.2 DETECTOR HEAD TILT

An error-free reconstruction requires that the direction of the COLLIMATOR holes is orthogonal to the SYSTEM AXIS for each angle of projection. Deviations from this requirement are called DETECTOR HEAD TILT.

Using the measurements according to 3.1.1 the DETECTOR HEAD TILT can be determined by calculating the centroid $Y_p(\theta)$ of the image of the POINT SOURCE in the Y_p direction, using strips over the full field-of-view in the X_p direction. This calculation shall be done for each angle of projection. A sine function is fitted to all those values,

$$Y_p(\theta) = B \sin(\theta + \varphi) + D$$

where

θ is the angle of projection;

B is the amplitude;

φ is the phase shift of the sine function.

Report the head tilt angle value a = arcsin B/A, where A is the amplitude resulting from the COR measurement (3.1.1).

NOTE If there is no DETECTOR HEAD TILT, B must be zero and D must be the Y_p position of the source.

In addition the difference between fit and data shall be plotted (showing the error) as a function of θ.

3.2 Measurement of COLLIMATOR hole misalignment

If all holes of a parallel hole COLLIMATOR are parallel, the OFFSET is constant for all source positions within the measuring volume, assuming linearity of the positioning electronics. To detect possible misalignments of the collimator holes, the OFFSET shall be determined using a point source placed at all intersections of an orthogonal positioning grid, lying in the X, Z plane, covering the field of view. The grid lines shall be 10 cm apart. The radius of rotation shall be at least 20 cm. The mean value of all measured OFFSETs shall be calculated and the maximum deviation from that value stated.

3.3 Measurement of SPECT system SENSITIVITY

3.3.1 DETECTOR POSITIONING TIME

In combination with the acquisition time chosen, the DETECTOR POSITIONING TIME determines that fraction of the total time spent on an acquisition which is not useful in collecting data. Therefore it will influence the sensitivity of a tomographic device. This is especially true for a rotating detector working in "step and shoot" mode.

A POINT SOURCE of ^{99m}Tc shall be placed at the CENTRE OF ROTATION in air. The COUNT RATE shall be greater than 1 000 cps. Two 360° tomographic acquisitions of a stated number, P_j, PROJECTIONS (one with at least 60, the other with at least 120 PROJECTIONS) shall be performed using an acquisition time ΔT_{acq} per PROJECTION of 10 s. The subscript j is either "low" or "high" corresponding to the range of approximately 60 or 120 projections. The time T_j from the start of acquisition of the first projection to the end of the acquisition of the last projection shall be measured. A corresponding static acquisition of duration T_j shall also be performed directly after the tomographic acquisition. The data shall be decay corrected for the different starting times.

The total DETECTOR POSITIONING TIME T_{pos} shall be calculated according to:

$$T_{pos,j} = \frac{\left(N_{static,j} - N_{total,j}\right)T_j}{N_{static,j}}$$

where

N_{total} is the sum of the counts in all PROJECTIONS;

N_{static} is the number of counts in the static acquisition.

The mean positioning time per PROJECTION ΔT_{pos} is then calculated by dividing T_{pos} by the number of transitions between PROJECTION steps actually used.

$$\Delta T_{pos,j} = \frac{T_{pos,j}}{\left(P_j - 1\right)}$$

The correction factor c_j for the calculation of the VOLUME SENSITIVITY is then given by

$$c_j = \frac{\Delta T_{acq,j}}{\Delta T_{acq,j} + \Delta T_{pos,j}}$$

The correction factor c_j shall be calculated and reported for the subscript j with corresponding acquisition times per PROJECTION $\Delta T_{acq,j}$ of 30 s (low) and 15 s (high), respectively. This corresponds to a typical clinical situation of total acquisition time of 30 min.

3.3.2 NORMALIZED VOLUME SENSITIVITY

The measurement shall be carried out using a cylindrical phantom of 200 mm ± 3 mm outside diameter, of wall thickness 3 mm ± 1 mm, and 190 mm ±3 mm inside length (see Figure 2), filled homogeneously with a water solution of ^{99m}Tc.

The ACTIVITY concentration a_{ave} (kBq/cm^3) shall be accurately determined by counting at least two samples from that solution in a calibrated well counter and correcting the result for radioactive decay to the time of measurement (midpoint of acquisition interval).

NOTE The test is critically dependent upon accurate assays of radioactivity as measured in a dose calibrator or well counter. It is difficult to maintain an absolute calibration with such devices to accuracies better than 10 %. Absolute reference standards using appropriate (γ-emitters should be considered if higher degrees of accuracy are required.

The phantom shall be positioned so that its long axis coincides with the SYSTEM AXIS (parallel to and as close as possible to the SYSTEM AXIS). The radius of rotation R shall be 20 cm. For each COLLIMATOR used routinely for SPECT imaging at least one million counts shall be acquired in static imaging mode and the acquisition time T_a [sec] recorded. For a rectangular region of interest (ROI) centred on the image of the phantom the number of counts N_{ROI} shall be determined. The width of the ROI shall be at most 240 mm to cover the cylinder diameter, and the length l shall be at least 150 mm in the axial direction and centred to the phantom. The NORMALIZED VOLUME SENSITIVITY S_{norm} is then calculated by dividing the number of counts N_{ROI} registered from the ROI by the activity concentration a_{ave}, the acquisition time T_a, the axial length l of the ROI, and by multiplying by the correction factor c_j (see 3.3.1) according to the following equation:

$$S_{norm} = \frac{N_{ROI}}{a_{ave} T_a l} c_j \qquad \left[\text{cps} / \left(\text{kBq} / \text{cm}^2 \right) \right]$$

The values shall be specified and stated for the subscript *j* of low and high respectively.

NOTE For a given phantom set-up and parallel hole COLLIMATOR, the NORMALIZED VOLUME SENSITIVITY and the SYSTEM SENSITIVITY measured according to 3.1 of IEC 60789 are related by a fixed ratio and the correction factor c_j

3.4 Scatter

The scattering of primary gamma rays results in events with false information for radiation source localization. Variations in design and implementation cause emission tomographs to have different sensitivities to scattered radiation. The purpose of this procedure is to measure the relative system sensitivity to scattered radiation, expressed by the SCATTER FRACTION (SF), as well as the values of the SCATTER FRACTION in each slice(SFI).

3.4.1 Scatter measurement

The measurements shall be performed by imaging a single line source at three different radial positions within a water-filled test phantom, using the COLLIMATOR used for SPECT imaging, a circular orbit and a 20 cm radius of rotation.

Unscattered events are assumed to lie within a 2 × FWHM wide strip centred on the image of the line source in each SINOGRAM. This width region is chosen because the scatter value is insensitive to the exact width of the region, and a negligible number of unscattered events lie more than one FWHM from the line image.

The width of the scatter response function allows a simplified analysis method. A linear interpolation across the strip from the points of intersection of the scatter tails and the edges of the 2 × FWHM wide strip is used to estimate the amount of scatter present in the strip. The area under the line of interpolation plus the contributions outside the strip constitute the estimated scatter.

Estimates of the SCATTER FRACTION for uniform source distributions are made under the assumption of slow radial dependence. In this assumption, the measure of SCATTER FRACTION for a line source on-axis is applied to a cross-sectional area out to a radius of 22,5 mm. The SCATTER FRACTION for a line source of 45 mm off-axis is applied to an annulus between 22,5 mm and 67,5 mm. Likewise, the SCATTER FRACTION for a line source 90 mm off-axis is applied to an annulus between 67,5 mm and 100 mm (see Figure 3). The three values for SCATTER FRACTION are weighted by the areas to which they are applied, yielding a weighted average. The annular areas are in the ratios of 1:8:10,75 respectively.

3.4.1.1 RADIONUCLIDE

The RADIONUCLIDE for the measurement shall be ^{99m}Tc, with an ACTIVITY less than that at which the percent dead-time losses exceed 5 % (see IEC 60789).

3.4.1.2 Source distribution

The test phantom shall be filled with non-radioactive water as a scatter medium. The test phantom line source shall be inserted, parallel to the axis of the cylinder, sequentially at radii of 0 mm, 45 mm, and 90 mm. The phantom shall be centred axially. For tomographs with an AXIAL FIELD OF VIEW greater than 165 mm, the phantom shall be centred within the AXIAL FIELD OF VIEW.

3.4.1.3 Data collection

Data shall be taken with the source at the specified radii from the long axis of the tomograph. SINOGRAM data shall be acquired for each of the radial locations of the line source. At least 200 000 counts per slice shall be acquired for each slice within:

a) the AXIAL FIELD OF VIEW;

b) the central 165 mm;

where the phantom was placed, whichever is the smaller.

3.4.1.4 Data processing

Data shall not be corrected for scatter or ATTENUATION.

3.4.2 Analysis

All SINOGRAMS corresponding to slices at least 1 cm from either end of the phantom shall be processed. Thus for tomographs with an AXIAL FIELD OF VIEW less than 165 mm, all slices shall be processed.

All PIXELS in each SINOGRAM which correspond to points which are located further than 12 cm from the centre shall be set to zero. For each projection angle within the SINOGRAM, the location of the centre of the line source shall be determined by finding the PIXEL with the largest value. Each PROJECTION shall be shifted so that the PIXEL containing the maximum value aligns with the central PIXEL row of the SINOGRAM. After realignment, a sum projection shall be produced. The counts in the PIXELS at the left and right edges of the 2 × FWHM wide strip $C_{L,i,k}$ and $C_{R,i,k}$, respectively shall be obtained from the sum projection (see Figure 4). Linear interpolation shall be used to find the count levels at ±1 × FWHM from the central PIXEL of the projection. The average of the two count levels $C_{L,i,k}$ and $C_{R,i,k}$ shall be multiplied by the fractional number of PIXELS between the edges of the 2 × FWHM wide strip, with the product added to the counts in the PIXELS outside the strip, to yield the number of scattered counts $C_{s,i,k}$, for the slice i and the source position k. The total counts (scattered plus unscattered) $C_{\text{tot},i,k}$ is the sum of the counts in all PIXELS in the sum projection.

The average ACTIVITY $A_{\text{ave},k}$ during data acquisition over the time interval $T_{\text{acq},k}$ for the line source at position k, shall be calculated by correcting for decay (each midpoint of the time intervals $T_{\text{acq},k}$ is related to a common starting time).

The SCATTER FRACTION SF_i for each slice, i, due to a uniform source distribution shall be calculated as follows:

$$SF_i = \frac{\left[\dfrac{C_{\text{s},i,1}}{A_{\text{ave},1}}\right] + 8\left[\dfrac{C_{\text{s},i,2}}{A_{\text{ave},2}}\right] + 10{,}75\left[\dfrac{C_{\text{s},i,3}}{A_{\text{ave},3}}\right]}{\left[\dfrac{C_{\text{tot},i,1}}{A_{\text{ave},1}}\right] + 8\left[\dfrac{C_{\text{tot},i,2}}{A_{\text{ave},2}}\right] + 10{,}75\left[\dfrac{C_{\text{tot},i,3}}{A_{\text{ave},3}}\right]}$$

where the subscripts 1, 2 and 3 refer to line sources at radii 0 mm, 45 mm and 90 mm, respectively.

3.4.3 Report

For each slice, i, that was processed, the value of SF_i shall be tabulated. The average SF of the set of values of SF_i shall also be reported as the system SCATTER FRACTION for uniform sources.

3.5 Measurement of SPECT non-uniformity of response

At this time there is no suitable method to measure reconstructed non-uniformity of response.

3.6 SPECT system SPATIAL RESOLUTION

3.6.1 Phantom

The IEC phantom shall be adopted (see Figures 2 and 3).

3.6.2 Source

Three POINT SOURCES, prepared from a RADIONUCLIDE selected from Table 1 of IEC 60789 and stated, of dimensions not to exceed 2 mm in any direction, shall be placed within the water-filled cylinder. The axis of the cylinder shall coincide with the SYSTEM AXIS. The first POINT SOURCE shall be placed on the axis of the cylinder (see Figure 3) and at the central plane in the *Z* direction (see Figure 1).

The second POINT SOURCE shall be placed at the radial position of 45 mm and –50 mm from the central plane in the *Z* direction. The third POINT SOURCE shall be placed at the radial position of 90 mm and +50 mm from the central plane in the *Z* direction.

3.6.3 Measurements

To measure the SPECT system SPATIAL RESOLUTION the axis of the phantom shall be aligned with the SYSTEM AXIS and oriented such that the two off-centre POINT SOURCES will intercept either the *X* or *Y* axis of the reconstructed transverse slice. Measurements shall be carried out with a 200 mm radius of rotation unless otherwise specified. For those systems that cannot achieve 200 mm, the maximum possible radius of rotation shall be set and stated. Data shall be acquired with a PIXEL size equal to or less than 30 % of the system FWHM at 200 mm from the face of the COLLIMATOR using at least 120 equally spaced projection angles over 360° acquisition. The PIXEL size and the number of projections shall be stated. Three transverse slices, 10 mm ± 3 mm thick shall be reconstructed using a ramp filter with a cut-off at the Nyquist frequency as determined by the acquisition PIXEL size. A minimum of 250 000 counts shall be acquired into each reconstructed slice.

The three slices to be analysed shall be positioned so as to include the centre of the phantom, and the points ±50 mm distant along the axis of the phantom. Profiles of the TRANSVERSE POINT SPREAD FUNCTIONS of each reconstructed transverse slice shall be obtained both in the *X* and *Y* direction (see Figure 5) to yield PIXEL size, RADIAL and TANGENTIAL RESOLUTION. From the coronal or sagittal slice containing the three POINT SOURCES, profiles of the POINT SPREAD FUNCTIONS shall be obtained in the *Z* direction to yield PIXEL size and AXIAL RESOLUTION.

3.6.4 Evaluation and report

From the measured POINT SPREAD FUNCTIONS (see 3.6.3), the following data shall be obtained and reported:

a) the RADIAL RESOLUTION (FWHM and EW) for each position in the radial direction from the measurements described in 3.6.3 (see Figures 3, 5, 6 and 7);

b) the TANGENTIAL RESOLUTION (FWHM and EW) in the tangential direction from the measurements for each position described in 3.6.3 (see Figures 3, 5, 6 and 7);

c) the AXIAL RESOLUTION (FWHM and EW) in the axial direction from the measurements for each position described in 3.6.3 (see Figures 3, 6 and 7).

3.7 Test methods for single photon computer tomographs perated in coincidence detection mode

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 energy windows, 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, radius of rotation, configuration of heads) 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 tomograph's AXIAL FIELD OF VIEW, if not specified otherwise.

Single photon computer tomographs operated in coincidence mode must also conform to all planar and SPECT tests (e.g. 3.1 to 3.6).

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 was not fully covered with ACTIVITY.

3.7.1 SPATIAL RESOLUTION

3.7.1.1 General

SPATIAL RESOLUTION measurements are used to estimate 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.

3.7.1.2 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 tomograph's 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.

The AXIAL RESOLUTION is defined for tomographs with sufficiently fine axial sampling (volume detectors) and could be measured with a stationary POINT SOURCE. For these systems the AXIAL RESOLUTION (EW and FWHM) is equivalent to the AXIAL SLICE WIDTH. These systems (fulfilling the sampling theorem in the axial direction) are characterized by the fact that the AXIAL POINT SPREAD FUNCTION of a stationary POINT SOURCE would not vary if the position of the source were varied in the axial direction for half the axial sampling distance.

3.7.1.3 Method

3.7.1.3.1 General

For all systems, the SPATIAL RESOLUTION shall be measured in the transverse IMAGE PLANE in two directions (i.e. radially and tangentially). In addition, for those systems having sufficiently fine axial sampling, an AXIAL RESOLUTION also shall be measured.

The TRANSVERSE FIELD OF VIEW and the IMAGE MATRIX size determine the PIXEL size in the transverse IMAGE PLANE. In order to measure accurately the width of the spread function, its FWHM should span at least ten PIXELS. A typical imaging study of a brain, however, requires a 260 mm TRANSVERSE FIELD OF VIEW, which together with a 128 x 128 IMAGE MATRIX and 6 mm SPATIAL RESOLUTION, results in a FWHM of only three PIXELS. The width of the response may be incorrect if there are fewer than ten PIXELS in the FWHM. Therefore, if possible, the PIXEL size should be made close to one-tenth of the expected FWHM during reconstruction and should be indicated as ancillary data for the TRANSVERSE RESOLUTION measurement. For volume imaging systems, the TRIXEL size, in both the transverse and axial dimensions, should be made close to one-tenth the expected FWHM, and should be indicated as ancillary data for the SPATIAL RESOLUTION measurement. For all systems, the AXIAL SLICE WIDTH is measured by moving the source in fine steps to sample the response function adequately. For the AXIAL SLICE WIDTH measurement, the step size should be close to one-tenth the expected EW. It is assumed that a computer-controlled bed will be used for accurate positioning of the RADIOACTIVE SOURCE.

3.7.1.3.2 RADIONUCLIDE

The RADIONUCLIDE for the measurement shall be ^{18}F, with an ACTIVITY such that the percent COUNT LOSS is less than 5 % and the RANDOM COINCIDENCE rate is less than 5 % of the TOTAL COINCIDENCE rate.

3.7.1.3.3 RADIOACTIVE SOURCE distribution

3.7.1.3.3.1 General

POINT SOURCES or LINE SOURCES, respectively, shall be used as described in 3.7.1.3.3.2 to 3.7.1.3.3.4.

3.7.1.3.3.2 TRANSVERSE RESOLUTION

Tomographs shall use LINE SOURCES, suspended in air to minimize scatter, for measurements of TRANSVERSE RESOLUTION. The sources shall be kept parallel to the long axis of the tomograph and shall be positioned radially at 100 mm intervals along Cartesian axes in a plane perpendicular to the long axis of the tomograph i.e. *r* = 10 mm, 100 mm, 200 mm ... up to the edge of the TRANSVERSE FIELD OF VIEW. The last position shall be not more than 20 mm from the edge and shall be stated. Each of these positions yields two measurements of TRANSVERSE RESOLUTION, which shall be distinguished by being in the radial or tangential direction.

NOTE The SPATIAL RESOLUTION at *r* = 0 mm may yield artificial values due to sampling, so this measurement is done at the position *r* = 10 mm.

3.7.1.3.3.3 AXIAL SLICE WIDTH

The AXIAL POINT SPREAD FUNCTION for POINT SOURCES suspended in air shall be measured for all systems. The POINT SOURCES shall be moved in fine increments along the axial direction over the length of the tomograph, at radial positions of *r* = 0 mm, 100 mm, ... in 100 mm steps up to the edge of the TRANSVERSE FIELD OF VIEW. The last position shall be not more than 20 mm from the edge and shall be stated. The source is stepped in the axial direction by one-tenth of the expected EW of the axial response function. For each radial position, the measured values shall be corrected for decay. This measurement does not apply to THREE-DIMENSIONAL RECONSTRUCTION.

3.7.1.3.3.4 AXIAL RESOLUTION

For systems having axial sampling at least three times smaller than the FWHM of the AXIAL POINT SPREAD FUNCTION the measurement of AXIAL RESOLUTION can be made with stationary POINT SOURCES. POINT SOURCES suspended in air are positioned at radial intervals of 100 mm, starting at the centre and extending to a distance which depends on the TRANSVERSE FIELD OF VIEW, as described in the measurement of AXIAL SLICE WIDTH (3.7.1.3.3.3). Each POINT SOURCE shall be imaged at axial intervals of ±80 mm, starting at the centre of the tomograph and extending to within 20 mm from the edge of the AXIAL FIELD OF VIEW.

3.7.1.3.4 Data collection

Data shall be collected for all sources in all of the positions specified above, either singly or in groups of multiple sources, to minimize the data acquisition time. At least 50 000 counts shall be acquired in each response function, as defined below.

3.7.1.3.5 Data processing

Reconstruction using a ramp filter with the cut-off at the Nyquist frequency of the PROJECTION data shall be employed for all SPATIAL RESOLUTION data.

3.7.1.4 Analysis

The RADIAL RESOLUTION and the TANGENTIAL RESOLUTION shall be determined by forming one-dimensional response functions, which result from taking profiles through the TRANSVERSE POINT SPREAD FUNCTION in radial and tangential directions, passing through the peak of the distribution.

The AXIAL RESOLUTION of the POINT SOURCE measurements is determined by forming one-dimensional response functions (AXIAL POINT SPREAD FUNCTIONS), which result from taking profiles through the volume image in the axial direction, passing through the peak of the distribution in the slice nearest the source.

The AXIAL SLICE WIDTH is determined by forming one-dimensional response functions (AXIAL POINT SPREAD FUNCTIONS), which result from summing the counts per slice collected for each slice at each axial location of each radial source location.

Each FWHM shall be determined by linear interpolation between adjacent PIXELS at half the maximum PIXEL value, which is the peak of the response function (see Figure 6). Values shall be converted to millimetre units by multiplication with the appropriate PIXEL size.

Each EQUIVALENT WIDTH (EW) shall be measured from the corresponding response function.

EW is calculated from the formula

$$EW = \sum_i \frac{C_i \times PW}{C_\mathrm{m}}$$

where

ΣC_i is the sum of the counts in the profile between the limits defined by 1/20 cm on either side of the peak;

C_m is the maximum PIXEL value;

PW is the PIXEL width (or axial increment in the case of the AXIAL SLICE WIDTH) in millimetres (see Figure 7).

3.7.1.5 Report

RADIAL and TANGENTIAL RESOLUTIONS (FWHM and EW) for each radius, averaged over all slices, shall be calculated and reported as TRANSVERSE RESOLUTION values. AXIAL SLICE WIDTHS (EW and FWHM) for each radius, averaged over all slices for each type (e.g. odd, even) shall be reported. Transverse PIXEL dimensions and axial step size shall also be reported.

For systems where AXIAL RESOLUTION is to be measured, AXIAL RESOLUTION (FWHM and EW), averaged over all slices, shall be reported. For these systems, the axial PIXEL dimension in millimetres shall also be reported.

For systems utilizing THREE-DIMENSIONAL RECONSTRUCTION, RESOLUTION data as listed above shall not be averaged. Graphs of TRANSVERSE RESOLUTION and AXIAL RESOLUTION shall be reported, showing the RESOLUTION values (RADIAL RESOLUTION, TANGENTIAL RESOLUTION, and AXIAL RESOLUTION) for each radius as a function of slice number.

3.7.2 RECOVERY COEFFICIENT

3.7.2.1 General

The finite RESOLUTION of a tomograph leads to a spreading of image counts beyond the geometrical boundaries of the object. This effect becomes more important as the object size decreases. The RECOVERY COEFFICIENT provides an assessment of the ability of the tomograph to quantify the ACTIVITY concentration as a function of the object size.

3.7.2.2 Purpose

The objective of the following procedures is to quantify the apparent decrease in tracer concentration in a region of interest (ROI) of an image of spherical sources of different diameters.

3.7.2.3 Method

A number of hollow spheres, filled with an ACTIVITY concentration of ^{18}F from a stock solution, are placed in the water-filled head phantom (see Figures 2 and 8), which is in turn placed in the centre of the TRANSVERSE FIELD OF VIEW. The phantom shall be held in position without introducing additional attenuating material. At least two samples from this solution are counted in a well counter. The spheres are arranged to be coplanar.

For systems utilizing THREE-DIMENSIONAL RECONSTRUCTION, the measurements shall be done at the axial centre of the tomograph and halfway between the axial centre and the edge of the AXIAL FIELD OF VIEW.

After data acquisition, the spheres are removed and the cylinder filled with a uniform solution of ^{18}F from which at least two samples are taken for well counting.

3.7.2.4 Data collection

The data collection shall be carried out at low COUNT RATES such that the COUNT LOSS is less than 5 % and the RANDOM COINCIDENCE rate is less than 5 % of the TOTAL COINCIDENCE rate.

Care should be taken to acquire sufficient counts so that statistical variations do not significantly affect the result. So, for the slice containing the spheres, at least 500 000 counts shall be acquired. COUNT RATES and scanning times shall be stated.

3.7.2.5 Data processing and analysis

Reconstruction shall be performed using a ramp filter with a cut-off at the Nyquist frequency and with all corrections applied. The method of ATTENUATION correction shall be by an analytical calculation. The ATTENUATION coefficient used shall be reported. The scatter correction method used shall be clearly described.

Circular ROIs of diameter as close as possible to the FWHM as measured in 3.7.1.3.3.3 are defined centrally on the image of each sphere. The precise ROI diameter should be stated.

A large ROI (diameter: 150 mm) is centred on the image of the uniform cylinder. Calculation of the RECOVERY COEFFICIENT (RC_{si}) for each sphere is obtained from the equation:

$$RC_{si} = \left(\frac{\dfrac{C_{si}}{SM_s}}{\dfrac{C_u}{SM_u}} \right)$$

where

C_{si} are the ROI counts/pixel/s for sphere i;

SM_s *are* the sample counts/s/cm^3 (stock solution spheres);

C_u are the ROI counts/pixel/s (head phantom);

SM_u are the sample counts/s/cm^3 (head phantom);

C_u/SM_u represents a calibration factor for a large reference object.

Care shall be taken to correct for any dead-time and sample volume effects in the well counter. RC_{si} is then plotted against sphere diameter to give recovery curves.

3.7.2.6 Report

Graphs of RECOVERY COEFFICIENTS for each axial position described in 3.7.2.3 shall be reported.

The scatter correction method used shall be clearly described, as well as the ATTENUATION coefficient used.

3.7.3 Tomographic sensitivity

3.7.3.1 General

Tomographic sensitivity is a parameter that characterizes the rate at which coincidence events are detected in the presence of a RADIOACTIVE SOURCE in the limit of low ACTIVITY where COUNT LOSSES and RANDOM COINCIDENCES are negligible. The measured rate of TRUE COINCIDENCE EVENTS for a given distribution of the RADIOACTIVE SOURCE depends upon many factors, including the detector material, size, and packing fraction, axial acceptance window and septa geometry, ATTENUATION, scatter, dead-time, and energy thresholds, radius of rotation and detector head geometry.

3.7.3.2 Purpose

The purpose of this measurement is to determine the detected rate of TRUE COINCIDENCE EVENTS per unit of ACTIVITY concentration for a standard volume source, i.e. a cylindrical phantom of given dimensions.

3.7.3.3 Method

The tomographic sensitivity test places a specified volume of radioactive solution of known ACTIVITY concentration in the TOTAL FIELD OF VIEW of the single photon computer tomograph operated in coincidence detection mode and observes the resulting COUNT RATE. The systems sensitivity is calculated from these values.

The test is critically dependent upon accurate assays of radioactivity as measured in a dose calibrator or well counter. It is difficult to maintain an absolute calibration with such devices to accuracies finer than 10 %. Absolute reference standards using positron emitters should be considered if higher degrees of accuracy are required.

3.7.3.3.1 RADIONUCLIDE

The RADIONUCLIDE used for these measurements shall be ^{18}F or ^{68}Ge. The amount of ACTIVITY used shall be such that the percentage of COUNT LOSSES is less than 5 % and the RANDOM COINCIDENCE rate is less than 5 % of the TOTAL COINCIDENCE rate.

3.7.3.3.2 RADIOACTIVE SOURCE distribution

The head phantom (Figure 2) shall be filled with a homogeneous solution of known ACTIVITY concentration. The phantom shall be held in position without introducing additional attenuating material. It shall be centred both axially and transaxially in the TOTAL FIELD OF VIEW.

3.7.3.3.3 Data collection

Each coincident event between individual detectors shall be taken into account only once. Data shall be assembled into SINOGRAMS. All events will be assigned to the transverse slice passing the midpoint of the corresponding LINE OF RESPONSE.

At least 20 000 counts shall be acquired for each slice within the lesser of the AXIAL FIELD OF VIEW or the central 16,5 cm where the phantom was placed.

3.7.3.3.4 Data processing

The ACTIVITY concentration in the phantom shall be corrected for decay to determine the average ACTIVITY concentration, a_{ave}, during the data acquisition time interval, T_{acq}, by the following equation:

$$a_{ave} = \frac{A_{cal}}{V} \frac{1}{\ln 2} \frac{T_{1/2}}{T_{acq}} \exp\left[\frac{T_{cal} - T_0}{T_{1/2}} \ln 2\right]\left[1 - \exp\left(-\frac{T_{acq}}{T_{1/2}} \ln 2\right)\right]$$

where

V is the volume of the phantom;

A_{cal} is the ACTIVITY times branching ratio ("positron activity") measured at time T_{cal};

T_0 is the acquisition start time;

$T_{1/2}$ is the half life of the RADIONUCLIDE.

It is not necessary to reconstruct these data. No corrections for detector normalization, COUNT LOSS, scatter, and ATTENUATION shall be applied. The data shall be corrected for RANDOM COINCIDENCES.

3.7.3.4 Analysis

The total counts, $C_{i,\text{tot},120\text{mm}}$, on each slice i shall be obtained by summing all PIXELS in the corresponding SINOGRAM within a radius of 120 mm. The SLICE SENSITIVITY S_i for unscattered events shall be found by the following, taking into account that the acquisition time T_{acq} shall include the time required to move the detectors to collect a complete set of PROJECTIONS:

$$S_i = \frac{C_{i,\text{tot},120\text{mm}}}{T_{\text{acq}}} \frac{1 - SF_i}{a_{\text{ave}}}$$

where SF_i is the corresponding SCATTER FRACTION (see 3.7.6).

The NORMALIZED SLICE SENSITIVITY for each slice nS_i shall be calculated as follows:

$$nS_i = \frac{S_i}{EW_{a,i}}$$

where $EW_{a,i}$ is the AXIAL SLICE WIDTH expressed as EW for slice i (see 3.7.1.4).

NOTE 1 The NORMALIZED SLICE SENSITIVITY allows for comparison of tomographs with different AXIAL SLICE WIDTH.

The VOLUME SENSITIVITY, S_{tot}, shall be the sum of S_i over all slices of the tomograph within the central 16,5 cm or the AXIAL FIELD OF VIEW, whichever is smaller.

NOTE 2 This will yield only the VOLUME SENSITIVITY for the central part of the tomograph, if the AXIAL FIELD OF VIEW is greater than 16,5 cm.

3.7.3.5 Report

For each slice i, tabulate the values of S_i and nS_i. The VOLUME SENSITIVITY S_{tot} shall also be reported.

3.7.4 Uniformity

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.

3.7.5 COUNT RATE CHARACTERISTIC

3.7.5.1 General

Coincidence COUNT RATE performance depends in a complex manner on the spatial distribution of ACTIVITY and scattering materials, which will be referred to as the different scatter conditions (see 3.7.5.3.1). The COUNT RATE CHARACTERISTIC of the TRUE COINCIDENCE COUNT RATE is highly dependent on the trues-to-singles ratio and on the COUNT RATE CHARACTERISTIC of the SINGLES RATE and consequently on the set-up of the measurement conditions, which therefore should simulate the range of clinical imaging situations. In addition, COUNT RATE performance is strongly influenced by the amount of RANDOM COINCIDENCES and by the accuracy of the subtraction of these events.

NOTE As the TRUE COINCIDENCE COUNT RATE includes scattered events, the relative SCATTER FRACTION must be considered when comparing tomographs with different design.

3.7.5.2 Purpose

The procedure described here is designed to evaluate deviations from the linear relationship between TRUE COINCIDENCE COUNT RATE and ACTIVITY, caused by COUNT LOSSES, and the evaluation of image distortions at high COUNT RATES, especially those leading to spatially misplaced events by ADDRESS PILE UP. As modern coincidence detection devices are operated with COUNT LOSS correction schemes, the accuracy of these correction algorithms is tested.

Coincidence COUNT RATE performance means:

a) the relationship between measured TRUE COINCIDENCES (UNSCATTERED plus SCATTERED TRUE COINCIDENCES) and ACTIVITY, i.e. the COUNT RATE CHARACTERISTIC of TRUE COINCIDENCE COUNT RATE;
b) a test to determine address errors caused by ADDRESS PILE UP;
c) the evaluation of the accuracy of the COUNT LOSS correction scheme.

3.7.5.3 Method

For dedicated brain tomographs, only the scatter condition described in 3.7.5.3.1.1 applies, whereas for all other tomographs the scatter conditions described in 3.7.5.3.1.1 to 3.7.5.3.1.3 apply. For all tests the only correction to be applied is the subtraction of the multiple and the RANDOM COINCIDENCES (to calculate TRUE COINCIDENCE counts). No correction is made for COUNT LOSSES, ATTENUATION, and scatter, unless otherwise stated. The ACTIVITY shall generally be specified as the total amount of ACTIVITY within the phantom as specified in 3.7.5.3.1. As the variation of ACTIVITY is normally achieved by radioactive decay, care should be taken with respect to the radiochemical purity of the ACTIVITY used.

3.7.5.3.1 RADIOACTIVE SOURCE distribution

To describe various scatter conditions, three different experimental set-ups are to be used.

3.7.5.3.1.1 Head imaging

The head phantom (Figure 2) shall be filled homogeneously with ACTIVITY.

3.7.5.3.1.2 Cardiac imaging

The centre of the body phantom, Figure 9, (head phantom inserted) with outer section and arms (Figure 10) of the phantom filled with water, inner section (head phantom, Figure 2) filled with air, and a rod source (130 mm inside length x 21 mm inside diameter) containing the ACTIVITY and placed eccentrically as indicated in Figure 11 shall be centred to the SYSTEM AXIS, see Figures 9 and 11.

3.7.5.3.1.3 Abdominal imaging

The procedure described in 3.7.5.3.1.2 is followed but the head phantom is also filled with water. This configuration is used to mimic the worst-case scattering condition encountered in positron emission imaging.

3.7.5.4 Data acquisition and analysis

Each coincident event between individual detectors shall be taken into account only once.

3.7.5.4.1 Test of the TRUE COINCIDENCE COUNT RATE CHARACTERISTIC

For all scatter conditions, a COUNT RATE CHARACTERISTIC (measured TRUE COINCIDENCE COUNT RATE versus incident TRUE COINCIDENCE COUNT RATE or ACTIVITY within the TOTAL FIELD OF VIEW of the tomograph) shall be measured. The variation of ACTIVITY shall be accomplished by radioactive decay; ^{18}F or ^{11}C with continuous measurements over approximately 10 half lifes can be used. The time per frame shall be less than one-half of the half life with the exception of the last three frames, which can be longer. The initial amount of ACTIVITY shall be chosen so that COUNT RATE saturation is exceeded, and the last frame shall be acquired with a COUNT LOSS of less than 1 %.

Data shall be assembled into SINOGRAMS. All events will be assigned to the transverse slice passing the midpoint of the corresponding LINE OF RESPONSE. The data to be inspected are for the TRANSVERSE FIELD OF VIEW restricted to 520 mm in diameter and without COUNT LOSS correction. For the sake of comparison with data published elsewhere, a second scale (kBq/cm^3) shall be added to the abscissa for the scatter condition of 3.7.5.3.1.1.

The average of the decaying ACTIVITY, $A_{\text{ave},i}$, during the data acquisition interval for time frame i, $T_{\text{acq},i}$, shall be determined by the following equation, taking into account that $T_{\text{acq},i}$ shall include the time required to rotate the detectors for a complete set of PROJECTIONS:

$$A_{\text{ave},i} = A_{\text{cal}} \frac{1}{\ln 2} \frac{T_{1/2}}{T_{\text{acq},i}} \exp\left[\frac{T_{\text{cal}} - T_{0,i}}{T_{1/2}} \ln 2\right]\left[1 - \exp\left(-\frac{T_{\text{acq},i}}{T_{1/2}} \ln 2\right)\right]$$

where

A_{cal} is the ACTIVITY measured at time T_{cal}, corrected for branching ratio (see 3.7.3.3.4);

T_{0i} is the acquisition start-time of the time frame i;

$T_{1/2}$ is the half life of ^{18}F or ^{11}C, respectively.

From the above measurements, plot the COUNT RATE CHARACTERISTIC (e.g. measured TRUE COINCIDENCE COUNT RATE versus ACTIVITY) and the characteristic of the RANDOM COINCIDENCE rate (all data without ATTENUATION correction and normalization) for the total system (data for the TOTAL FIELD OF VIEW).

For the head phantom, the random rate shall be evaluated only for a circular region, with diameter of 24 cm, centred at the position of the phantom.

The conversion factor between ACTIVITY and TRUE COINCIDENCE COUNT RATE without COUNT LOSS shall be determined from each of the three frames with lowest ACTIVITY and averaged.

Care shall be taken to acquire enough counts in these frames to ensure sufficient statistical precision.

From the data set, for each slice and for the total system, determine the ACTIVITY at which the measured TRUE COINCIDENCE COUNT RATE reaches 20 % COUNT LOSS and plot these ACTIVITY levels versus slice number. Repeat this evaluation for 50 % COUNT LOSS. For the total system specify the measured TRUE COINCIDENCE COUNT RATE for 20 % COUNT LOSS and for 50 % COUNT LOSS.

From the data set measured (from the SINOGRAMS as described above when using TWO-DIMENSIONAL RECONSTRUCTION, from the full data set when using THREE-DIMENSIONAL RECONSTRUCTION) reconstruct a full set of slices for all time frames. For a region containing the ACTIVITY (21 mm in diameter for the rod source, 194 mm in diameter for the cylinder), plot ROI counts divided by measured TRUE COINCIDENCES for the whole slice versus ACTIVITY, as an indicator of image distortion at high COUNT RATES (ideally, this plot should yield a constant value).

3.7.5.4.2 Test of ADDRESS PILE UP

The ADDRESS PILE UP in the axial direction shall be checked from the set of reconstructed images according to 3.7.5.4.1. For a region just containing the source, calculate the ratio of ROI counts per slice at each COUNT RATE, normalized to the corresponding value at the lowest rate.

$$R_{i,j} = \frac{C_{i,j}}{C_{i,\mathrm{low}}}$$

where

$R_{i,j}$ is the ratio of ROI counts for slice i and time frame j.

$C_{i,j}$ are the ROI counts for slice i at time frame j.

$C_{i,\mathrm{low}}$ are the average ROI counts for slice i at the three time frames with lowest ACTIVITY, see 3.7.5.4.1.

By the above division, all normalizing factors with respect to different efficiencies per slice cancel out. Plot this ratio versus the slice number. In this graph, all deviations from a line parallel to the abscissa and positioned at the mean value are a measure of ADDRESS PILE UP in the axial direction. Determine the ACTIVITY in the phantom within the TOTAL FIELD OF VIEW corresponding to a 5 % deviation for any slice.

NOTE Axial variations at high COUNT RATES are most often caused by ADDRESS PILE UP, but may also result from other factors depending on the design of the tomograph.

For systems utilizing THREE-DIMENSIONAL RECONSTRUCTION, this test does not apply, because the complex relationship between a reconstructed slice and an axial crystal location obscures meaningful results from this test.

3.7.5.4.3 Test of COUNT LOSS correction scheme

From the set of reconstructed images according to 3.7.5.4.1 (and for each slice) plot a graph (see Figure 12) of:

a) TRUE COINCIDENCE counts measured;

b) TRUE COINCIDENCE counts corrected for COUNT LOSS;

c) TRUE COINCIDENCE counts corrected for COUNT LOSS and decay.

The decay correction shall be done with the same half life according to Table 1 for all slices and for all scatter conditions. This half life should yield, in the low COUNT LOSS range (low COUNT LOSSES but high decay correction factor), a line parallel to the abscissa. All deviations from this parallel line are indicative of errors in the COUNT LOSS correction.

3.7.5.5 Report

3.7.5.5.1 TRUE COINCIDENCE COUNT RATE CHARACTERISTIC (see 3.7.5.4.1)

From the measurements according to 3.7.5.4.1, report the graphs showing the COUNT RATE CHARACTERISTIC (including the characteristic of the RANDOM COINCIDENCE rate) for the total system and the ACTIVITY levels at 20 % COUNT LOSS and at 50 % COUNT LOSS (without ATTENUATION correction and normalization) for each slice. For the total system, report the measured TRUE COINCIDENCE COUNT RATE at 20 % COUNT LOSS and at 50 % COUNT LOSS.

Report a plot of ROI counts (21 mm in diameter for the rod source, 194 mm in diameter for the cylinder) divided by measured TRUE COINCIDENCES for the whole slice versus ACTIVITY for each slice.

3.7.5.5.2 ADDRESS PILE UP (see 3.7.5.4.2)

Report a plot of normalized ROI counts according to 3.7.5.4.2. Report the observed ACTIVITY in the phantom within the TOTAL FIELD OF VIEW causing a 5 % deviation in the axial profile according to 3.7.5.4.2.

3.7.5.5.3 Accuracy of COUNT LOSS correction (see 3.7.5.4.3)

Report the plots according to 3.7.5.4.3. Report the maximum deviation from linearity up to the saturation point and the corresponding ACTIVITY for any slice for the three scatter conditions described in 3.7.5.3.1.1 to 3.7.5.3.1.3.

3.7.6 Scatter measurement

3.7.6.1 General

The scattering of primary gamma rays created in the annihilation of positrons results in coincidence events with false information for radiation source localization. Variations in design and implementation cause single photon computer tomographs operated in coincidence detection mode to have different sensitivities to scattered radiation.

3.7.6.2 Purpose

The purpose of this procedure is to measure the relative system sensitivity to scattered radiation, expressed by the SCATTER FRACTION (SF) as well as the values of the SCATTER FRACTION in each slice.

3.7.6.3 Method

The measurement shall be performed by imaging a single LINE SOURCE at three different radial positions within the water-filled head phantom (see Figures 2 and 3).

Unscattered events are assumed to lie within a 4 × FWHM wide strip centred on the image of the LINE SOURCE in each SINOGRAM. This width region is chosen because the scatter value is insensitive to the exact width of the region, and negligible unscattered events lie more than 2 × FWHM from the line image in SINGLE PHOTON COMPUTER TOMOGRAPHS operated in coincidence detection modes (see Figure 4).

The width of the scatter response function allows a simplified method of analysis. A linear interpolation across the strip from the points of intersection of the scatter tails and the edges of the 4 × FWHM wide strip is used to estimate the amount of scatter present in the strip. The area under the line of interpolation, plus the contributions outside of the strip constitute the estimated scatter.

Estimates of SCATTER FRACTION for uniform source distributions are made under the assumption of slow radial dependence. The SCATTER FRACTION for a LINE SOURCE on-axis is assumed to be constant over a cross-sectional area out to a radius of 22,5 mm, the SCATTER FRACTION for a LINE SOURCE 45 mm off-axis is assumed to be constant within an annulus between 22,5 mm and 67,5 mm, and the SCATTER FRACTION for a LINE SOURCE 90 mm off-axis is assumed to be constant within an annulus between 67,5 mm and 100 mm (see Figure 3). The three values for SCATTER FRACTION are weighted by the areas to which they are applied, yielding a weighted average. The annular areas are in the ratios of 1:8:10,75, respectively.

3.7.6.3.1 RADIONUCLIDE

The RADIONUCLIDE for the measurement shall be ^{18}F, with an ACTIVITY such that the percentage of COUNT LOSSES is less than 10 % and the RANDOM COINCIDENCE rate is less than 10 % of the TOTAL COINCIDENCE rate.

3.7.6.3.2 RADIOACTIVE SOURCE distribution

The head phantom (Figure 2) shall be filled with non-radioactive water as a scatter medium.

The test phantom LINE SOURCE shall be inserted parallel to the axis of the cylinder sequentially at radii of 0 mm, 45 mm, and 90 mm, see Figure 3. The phantom shall be centred transaxially and axially in the field of view.

3.7.6.3.3 Data collection

Each coincident event between individual detectors shall be taken into account only once. Data shall be assembled into SINOGRAMS. All events will be assigned to the slice at the midpoint of the corresponding LINE OF RESPONSE. With the source at the specified positions, at least 10 000 counts shall be acquired for each slice within the central 16,5 cm or the AXIAL FIELD OF VIEW, whichever is the smaller.

3.7.6.3.4 Data processing

Data shall be corrected for RANDOM COINCIDENCES and COUNT LOSSES, but not for scatter or ATTENUATION.

3.7.6.4 Analysis

All SINOGRAMS corresponding to slices at least 1 cm from either end of the phantom shall be processed. Thus for tomographs with an AXIAL FIELD OF VIEW less than 16,5 cm, all slices shall be processed.

All PIXELS in each SINOGRAM *i* which are located further than 12 cm from the centre shall be set to zero. For each PROJECTION ANGLE within the SINOGRAM, the location of the centre of the LINE SOURCE shall be determined by finding the PIXEL with the largest value. Each PROJECTION shall be shifted so that the PIXEL containing the maximum value aligns with the central PIXEL column of the SINOGRAM. After realignment, a sum PROJECTION shall be produced.

The FWHM to be used for the analysis is the average of the RADIAL RESOLUTION and the TANGENTIAL RESOLUTION at radial position 10 cm off centre (see 3.7.1.5). The counts in the PIXELS at the left and right edges of the 4 x FWHM wide strip, $C_{L,i,k}$ and $C_{R,i,k}$ respectively, shall be obtained from the sum PROJECTION (see Figure 4). Linear interpolation shall be used to find the PIXEL intensities at ±2 x FWHM from the central PIXEL of the PROJECTION. The average of the two count levels $C_{L,i,k}$ and $C_{R,i,k}$ shall be multiplied by the fractional number of PIXELS between the edges of the 4 x FWHM wide strip, with the product added to the counts in the PIXELS outside the strip, to yield the number of SCATTERED TRUE COINCIDENCE counts $C_{s,i,k}$ for the slice *i* and the source position *k*. The TRUE COINCIDENCE counts (scattered plus unscattered) $C_{tot,i,k}$ is the sum of all PIXELS in the sum PROJECTION.

The average ACTIVITY $A_{ave,k}$ during data acquisition over the time interval $T_{acq,k}$ (includes the time required to rotate the detectors for a complete set of PROJECTIONS) for the LINE SOURCE at position *k*, shall be calculated (see 3.7.3.3.4).

The SCATTER FRACTION SF_i for each slice (moving average over 10 slices), due to a uniform source distribution is calculated as follows:

$$SF_i = \frac{\frac{C_{s,i,1}}{A_{ave,1}} + 8\frac{C_{s,i,2}}{A_{ave,2}} + 10{,}75\frac{C_{s,i,3}}{A_{ave,3}}}{\frac{C_{tot,i,1}}{A_{ave,1}} + 8\frac{C_{tot,i,2}}{A_{ave,2}} + 10{,}75\frac{C_{tot,i,3}}{A_{ave,3}}}$$

where the subscripts 1, 2 and 3 refer to LINE SOURCES at radius 0 mm, 45 mm and 90 mm, respectively.

3.7.6.5 Report

For each slice that was processed, tabulate the value of SF_i. The average SF of the SF_i shall also be reported as the system SCATTER FRACTION.

3.7.7 ATTENUATION correction

3.7.7.1 General

POSITRON EMISSION TOMOGRAPHY has a valid theoretical basis for ATTENUATION correction for arbitrary attenuating media within the TOMOGRAPHIC VOLUME of a tomograph. The basis for the correction is a measurement of the transmission of ANNIHILATION RADIATION through the object within the TOTAL FIELD OF VIEW. The accuracy with which this is achieved in practice is an important measure of its quantitative ability.

3.7.7.2 Purpose

The purpose of this procedure is to measure the accuracy of the transmission method of ATTENUATION correction.

NOTE The outcome of this test is influenced also by scatter.

3.7.7.3 Method

Transmission of external radiation through a non-uniform attenuating medium is processed to give ATTENUATION correction matrices, which are applied to emission PROJECTION data as a part of the reconstruction process. Conformity of reconstructed emission values with true values is an indicator of the accuracy of ATTENUATION correction.

3.7.7.3.1 RADIONUCLIDE

The RADIONUCLIDE for the emission measurement shall be ^{18}F, with an ACTIVITY such that the percentage of COUNT LOSSES is less than 5 % and the RANDOM COINCIDENCE rate is less than 5 % of the TOTAL COINCIDENCE rate.

3.7.7.3.2 RADIOACTIVE SOURCE distribution

The head phantom (Figure 2) shall be centred in the AXIAL FIELD OF VIEW but (vertically) displaced 25 mm off-axis. It shall be used with the three 50 mm diameter cylinder inserts placed 60 mm from the axis of the phantom at 120° angular increments, arranged as in Figure 13. For the transmission measurement, the phantom shall be filled with non-radioactive water. One of the hollow inserts shall be filled with non-radioactive air and the other with non-radioactive water. The third insert is solid and made of polytetrafluoroethylene. For the emission measurement, a measured amount of ACTIVITY shall be added to the background of the test phantom and thoroughly mixed with the water.

3.7.7.3.3 Data collection

Transmission measurement of the head phantom shall be carried out by the method recommended by the manufacturer of the tomograph and shall be stated. For the emission measurement, the ACTIVITY shall be added to the head phantom and a standard image acquisition shall be performed.

The transmission and emission measurements can be performed in either order provided proper procedures are followed. If the head phantom must be removed between measurements, it should be precisely repositioned as before. If the emission scan is performed first, then at least ten half lifes shall elapse before transmission data are acquired. Because the images are summed over slices in the analysis, it is important that the phantom axis be parallel to the axial direction (SYSTEM AXIS) of the tomograph.

3.7.7.3.4 Data processing

For tomographs with an AXIAL FIELD OF VIEW of 16,5 cm or less, all slices shall be reconstructed. For tomographs with an AXIAL FIELD OF VIEW greater than 16,5 cm, only slices in that part of the AXIAL FIELD OF VIEW where the phantom was placed, shall be reconstructed.

Images shall be reconstructed using the standard IMAGE MATRIX and TRIXEL size and using a ramp filter with cut-off at the Nyquist frequency of the PROJECTION data. The emission data shall be reconstructed applying all corrections including ATTENUATION correction as obtained from the transmission measurement. Transmission processing shall be done according to the method recommended by the manufacturer and shall be stated.

3.7.7.4 Analysis

For each insert a 10 mm wide profile shall be drawn in the image, passing through the centre of the head phantom and through the centre of the insert.

3.7.7.5 Report

Graphs of the profiles through the three inserts shall also be reported.

4 ACCOMPANYING DOCUMENTS

A document shall accompany each SINGLE PHOTON EMISSION COMPUTED TOMOGRAPH and shall include the following information.

4.1 All items specified in

– Clause 4 of IEC 60789

– Calibration measurements of COR as specified in 3.1.1

– Measurement of head tilt as specified in 3.1.2

– Measurement of COLLIMATOR head misalignment as specified in 3.2

4.2 SPECT system SPATIAL RESOLUTION

– TRANSVERSE RESOLUTION (RADIAL and TANGENTIAL) as specified in 3.6.4

– AXIAL RESOLUTION as specified in 3.6.4

– axial PIXEL size as specified in 3.6.3

– transaxial PIXEL size as specified in 3.6.3

4.3 SENSITIVITY

– DETECTOR POSITIONING TIME as specified in 3.3.1
– NORMALIZED VOLUME SENSITIVITY as specified in 3.3.2

4.4 SCATTER FRACTION

– SCATTER FRACTIONS SF_i and SF as specified in 3.4.3

4.5 Parameters describing a single photon computer tomograph operated in coincidence detection mode

4.5.1 Design parameters

– detector element dimensions and number of elements
– detector orientation
– detector material
– number and configuration of detector elements per block, if applicable
– number of detector blocks per ring, if applicable
– COINCIDENCE WINDOW
– detector ring diameter or detector separation (radius of rotation)
– patient port diameter
– TRANSVERSE FIELD OF VIEW
– AXIAL FIELD OF VIEW
– SINOGRAM sampling (linear and angular)
– axial sampling
– septal length
– septal thickness
– septa design
– graded absorbers
– length of side shields
– type of transmission source and source ACTIVITY (nominal and recommended range)
– detector movement (e.g. rotational speed, angular range), if any

4.5.2 Configuration of the tomograph

– energy windows used
– axial acceptance angle (2D-mode, 3D-mode)
– reconstruction algorithm
– method of RANDOM COINCIDENCE estimation
– any additional information being considered essential by the manufacturer to characterize normal operation

4.5.3 SPATIAL RESOLUTION

- TRANSVERSE RESOLUTION (radial and tangential) according to 3.7.1.5
- AXIAL SLICE WIDTH according to 3.7.1.5
- AXIAL RESOLUTION according to 3.7.1.5
- axial PIXEL dimension according to 3.7.1.5
- transverse PIXEL dimensions according to 3.7.1.5
- axial step size according to 3.7.1.5

4.5.4 RECOVERY COEFFICIENT

- graphs of RECOVERY COEFFICIENT according to 3.7.2.6

4.5.5 Sensitivity

- SLICE SENSITIVITY according to 3.7.3.5
- NORMALIZED SLICE SENSITIVITY according to 3.7.3.5
- VOLUME SENSITIVITY according to 3.7.3.5

4.5.6 COUNT RATE performance

- COUNT RATE CHARACTERISTIC according to 3.7.5.5
- ACTIVITY levels at 20 % and 50 % COUNT LOSS according to 3.7.5.5
- measured TRUE COINCIDENCE COUNT RATE at 20 % COUNT LOSS and 50 % COUNT LOSS according to 3.7.5.5
- plots of normalized ROI counts versus ACTIVITY according to 3.7.5.5
- ADDRESS PILE UP according to 3.7.5.5
- accuracy of COUNT LOSS correction and associated plots according to 3.7.5.5

4.5.7 SCATTER FRACTION

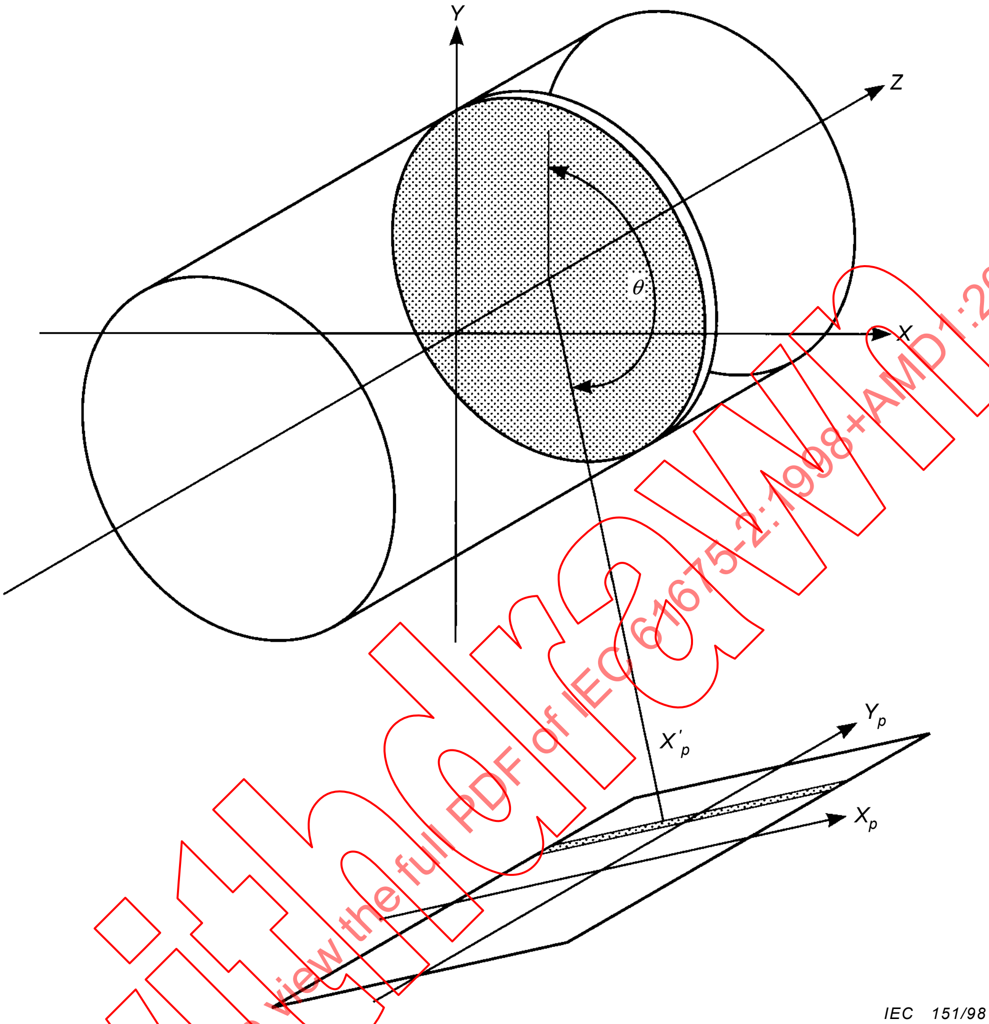
- SCATTER FRACTIONS SF_i and SF according to 3.7.6.5

4.5.8 Accuracy of ATTENUATION correction

- profiles across inserts according to 3.7.7.5

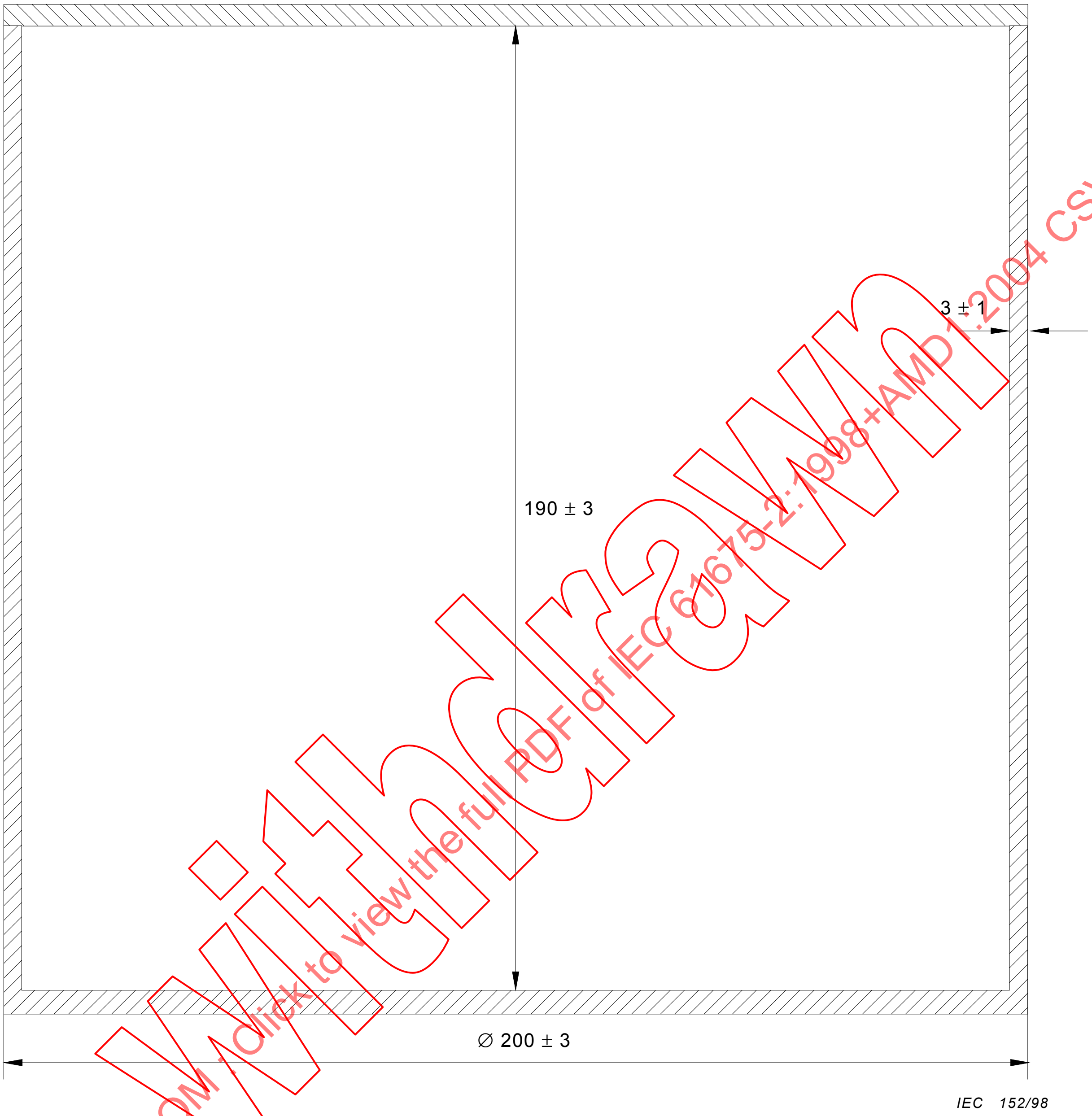
Table 1 – RADIONUCLIDES to be used in performance measurements

RADIONUCLIDE	Half life	Branching ratio
^{18}F	109,70 ± 0,11 min	0,971± 0,002
^{11}C	20,375 min	0,998
$^{68}Ge/^{68}Ga$	270,82 d	0,89



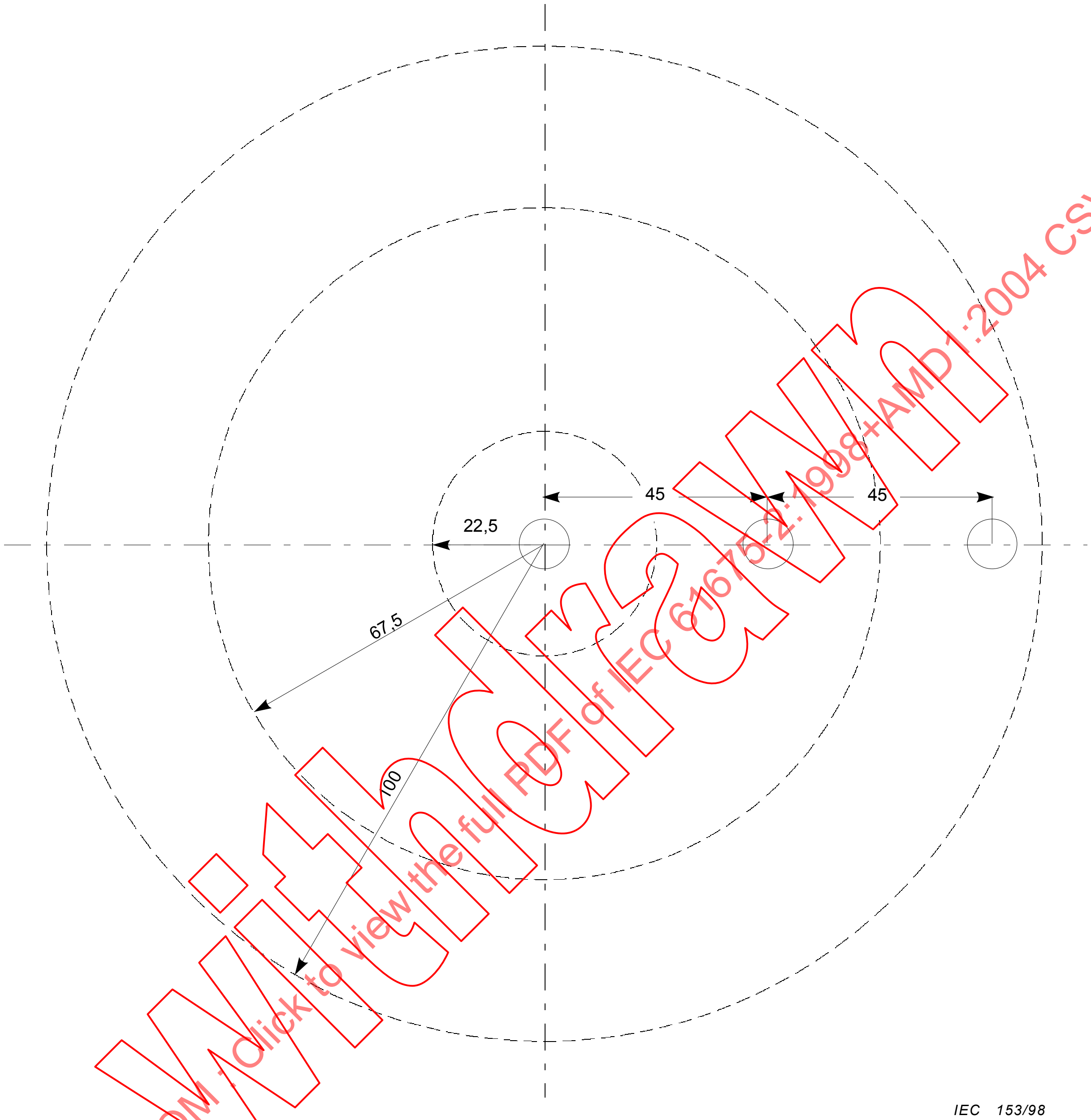
NOTE The fixed coordinate system X, Y, Z has its origin at the centre of the TOMOGRAPHIC VOLUME (shown as a cylinder), the Z-axis being the SYSTEM AXIS. The coordinate system of projection X_p Y_p is shown for a PROJECTION ANGLE θ. For each θ, the one-dimensional PROJECTION of the marked OBJECT SLICE has the address range shown (hatched). Within this range the CENTRE OF ROTATION is projected onto the address X_p (offset).

Figure 1 – Geometry of PROJECTIONS



Dimensions in millimetres *Material: polymethylmethacrylate*

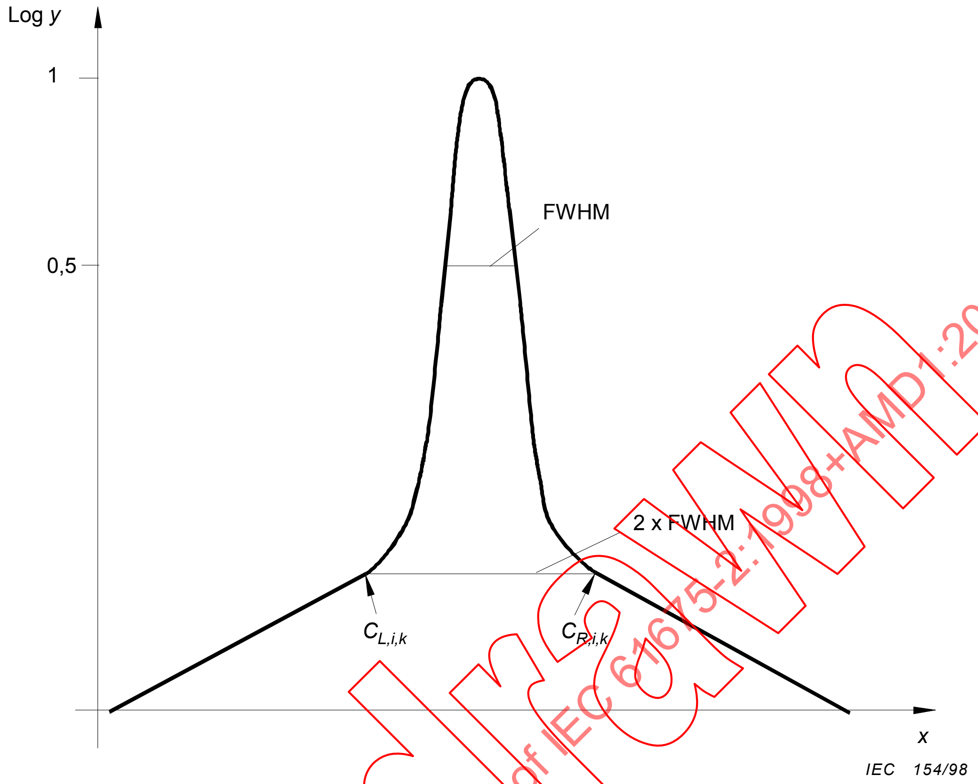
Figure 2 – Cylindrical head phantom



Dimensions in millimetres *Material: polymethylmethacrylate*

NOTE The mounting plate replaces the cover of the head phantom.
The source holders consist of tubes of lengths sufficient to fill the inside length of the head phantom.
In addition, the drawing shows the weighting areas (bounded by the dashed lines) for the scatter measurement.

Figure 3 – Phantom insert with holders for the scatter source



NOTE In the summed projection the scatter is estimated by the counts outside the 2 × FWHM wide strip plus the area of the LSF below the line $C_{L,i,k} - C_{R,i.k}$.

Figure 4 – Evaluation of SCATTER FRACTION