TECHNICAL REPORT

IEC TR 61948-2

First edition
2001-02

**Nuclear medicine instrumentation –
Routine tests –**

**Part 2:
Scintillation cameras and single photon emission computed tomography imaging**

*Instrumentation en médecine nucléaire –
Essais de routine –*

*Partie 2:
Imagerie par caméras à scintillation et systèmes de tomographie d'émission à photon unique*

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR MEDICINE INSTRUMENTATION – ROUTINE TESTS –

Part 2: Scintillation cameras and single photon emission computed tomography imaging

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 specifications, technical reports or guides and they are accepted by the National Committees in that sense.
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IEC 61948-2, which is a technical report, 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 technical report is based on the following documents:

Enquiry draft	Report on voting
62C/256/CDV	62C/266A/RVC

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

In this technical report the following print types are used:

– requirements, compliance with which can be tested, and definitions: in roman type;

– notes, explanations, advice, introductions, general statements, exceptions and references: in smaller roman type;

– *test specifications: in italic type;*

– TERMS DEFINED IN CLAUSE 3 OF THIS TECHNICAL REPORT OR LISTED IN ANNEX A: SMALL CAPITALS.

The requirements are followed by specifications for the relevant tests.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

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- withdrawn;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

This document, which is purely informative, is not to be regarded as an International Standard.

NUCLEAR MEDICINE INSTRUMENTATION – ROUTINE TESTS –

Part 2: Scintillation cameras and single photon emission computed tomography imaging

1 Scope and object

This technical report is valid for single photon SCINTILLATION CAMERAS with parallel hole collimators used in planar scintigraphy and tomography. The objective is to specify ROUTINE TESTS for QUALITY CONTROL. Methods for the ACCEPTANCE TEST are described in IEC 60789 and IEC 61675-2.

2 Reference documents

IEC 60788:1984, *Medical radiology – Terminology*

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

IEC 61675-2:1998, *Radionuclide imaging devices – Characteristics and test conditions – Part 2: Single photon emission computed tomographs*

IEC 61675-3:1998, *Radionuclide imaging devices – Characteristics and test conditions – Part 3: Gamma camera based wholebody imaging systems*

3 Terminology and definitions

For the purposes of this technical report the definitions given in IEC 60788, IEC 60789, IEC 61675-2 and IEC 61675-3 and the following definitions apply (see annex A). Defined terms are printed in small capital letters.

3.1
QUALITY CONTROL
part of the quality assurance in nuclear medicine including tests of instruments with appropriate test methods

NOTE Includes both the ACCEPTANCE TEST and the ROUTINE TEST.

3.2 Methodology

3.2.1
ACCEPTANCE TEST
test carried out at the request and with the participation of the user or his representative to ascertain by determination of proper performance parameters that the instrument meets the specifications claimed by the vendor

NOTE An ACCEPTANCE TEST should be carried out at the time of installation and when appropriate after major service. During or immediately after ACCEPTANCE TESTING, REFERENCE DATA are collected to be used as a standard for comparison in future ROUTINE TESTS.

3.2.2
ROUTINE TEST
test of a piece of equipment or its components which is repeated at specified intervals, to establish and document changes from the initial status described by REFERENCE DATA

NOTE A ROUTINE TEST could be carried out by the user with simple methods and equipment.

3.2.3
REFERENCE DATA
a set of data measured immediately after ACCEPTANCE TESTING using test methods designed for ROUTINE TESTING

3.3
DETECTOR HEAD
consists of the radiation detector, the collimator and the radiation shield

3.3.1
DETECTOR HEAD TILT
deviation of the COLLIMATOR AXIS from orthogonality with the SYSTEM AXIS

3.3.2
DETECTOR FIELD OF VIEW
region of the detector within which events are included in the displayed image. This region has to be specified by the manufacturer.

3.4
WHOLEBODY IMAGING DEVICE
equipment for scintigraphy, employing one or two DETECTOR HEAD(S), in which the image is formed by linear motion of the DETECTOR HEAD(S) and the object relative to each other

3.5
SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)
emission computed tomography utilizing single photon detection of gamma-ray emitting RADIONUCLIDES

3.6
NON-UNIFORMITY OF RESPONSE
in a RADIONUCLIDE imaging device, difference in count rate between small areas of specified dimensions within the DETECTOR FIELD OF VIEW when a uniform plane source parallel to the detector face and of dimensions larger than its entrance field is used

3.6.1
INTRINSIC NON-UNIFORMITY OF RESPONSE
the NON-UNIFORMITY OF RESPONSE of the DETECTOR HEAD without collimator

3.6.2
SYSTEM NON-UNIFORMITY OF RESPONSE
the NON-UNIFORMITY OF RESPONSE of the DETECTOR HEAD with collimator

3.7
SYSTEM SENSITIVITY
with a specified collimator and PULSE AMPLITUDE ANALYZER WINDOW, the ratio of the count rate of the DETECTOR HEAD to the ACTIVITY of a plane source of specific dimensions and containing a specified RADIONUCLIDE placed perpendicular to and centered on the COLLIMATOR AXIS under specified conditions

3.8
IMAGE MATRIX
arrangement of MATRIX ELEMENTS in a preferentially Cartesian coordinate system

3.9
OFFSET
deviation of the position of the PROJECTION of the COR (X'_p) from $X_p = 0$

3.10
SINOGRAM
the 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

3.11
RADIONUCLIDE
radioactive nuclide

3.12
ACTIVITY
letter symbol: A

quantitative indication of the radioactivity of an amount of RADIONUCLIDE in a particular energy state at a given time. ACTIVITY is determined as the quotient of dN by dt, where dN is the expectation value of the number of spontaneous nuclear transitions from that energy state in the time interval dt:

$$A = \frac{\mathrm{d}N}{\mathrm{d}t}$$

The unit of ACTIVITY is the reciprocal second (s^{-1}). The special name of the unit of ACTIVITY is the becquerel (Bq), 1 Bq being equal to one transition per second. The earlier unit of ACTIVITY was the curie (Ci), 1 Ci being equal to $3{,}7 \times 10^{10}$ transitions per second.

3.13
COLLIMATOR AXIS
straight line which passes through the geometrical centre of the exit and ENTRANCE FIELDS of the collimator

3.14
MATRIX ELEMENT
smallest unit of an IMAGE MATRIX, which is assigned in location and size to a certain volume element of the object (VOXEL)

3.15
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.

3.16
OBJECT SLICE
a slice in the object. The physical property of this slice that determines the measured information is displayed in the tomographic image

3.17
PROJECTION ANGLE
angle at which the PROJECTION is measured or acquired

3.18
POINT SOURCE
radioactive source approximating a δ-function in all three dimensions

3.19
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.

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.

3.20
RADIUS OF ROTATION
distance between the SYSTEM AXIS and the collimator front face

4 Test methods

All measurements shall be performed with the analyzer window setting used in clinical practice. Unless otherwise specified, measurements shall be carried out at count rates not exceeding 20 000 counts per second. A complete set of data, as specified in this standard, shall be obtained for each DETECTOR HEAD used, and compared to the corresponding REFERENCE DATA. The outcome of the ROUTINE TEST, as performed according to the following procedures, shall be documented and compared to the REFERENCE DATA. If there are significant deviations, the problem must be fixed either by updating correction factors and correction matrices or by servicing the system, whichever is appropriate.

4.1 Planar imaging

4.1.1 ENERGY WINDOW SETTING

The correct setting of the energy window shall be verified at least once a day for each RADIONUCLIDE used. A source geometry minimizing scatter should be used, i.e. a POINT SOURCE in air.

4.1.2 Background

The determination of the background count rate must be carried out for the most commonly used low energy window. An increased background count rate may be caused by radioactive contamination of the instrument, a radioactive source in the surroundings or by a malfunction of the instrument.

4.1.3 Sensitivity check

The sensitivity is checked by measuring the count rate, using a reference source with photon energy lower than 200 keV in a specified constant geometry.

NOTE If a source with known ACTIVITY is used for qualitative testing of the non-uniformity, this procedure can also be used for the determination of the sensitivity.

4.1.4 Non-uniformity

4.1.4.1 Planar devices

The qualitative check of non-uniformity without collimator (INTRINSIC NON-UNIFORMITY OF RESPONSE) can be carried out by acquisition and processing of the image acquired using a non-collimated POINT SOURCE centered at an appropriate, fixed and reproducible distance. Alternatively, a qualitative non-uniformity check with the collimator ON (SYSTEM NON-UNIFORMITY OF RESPONSE) can be performed with an external uniform flood source. For both cases the count density shall be at least 3 000 counts per cm^2. For SCINTILLATION CAMERAS interfaced to a data processing system a quantitative determination of the integral non-uniformity according to IEC 60789 is appropriate. For this case, the count density should be at least 20 000 counts per cm^2 to obtain statistically reliable results (this corresponds to approximately 10 000 counts per pixel in IEC 60789).

NOTE Care should be taken to assure that the image has the correct size and shape as compared to the reference image.

4.1.4.2 SPECT devices

Rotational SPECT imaging is very sensitive to uniformity errors. Non-uniformity of the DETECTOR HEAD(s) of a SPECT system is always tested with collimators(s) in place (SYSTEM NON-UNIFORMITY OF RESPONSE) and a flood source. The photon flux reaching the front face of the collimator shall be constant within +1 %, measured over areas of about 1 cm^2. The count density shall be at least 20 000 counts per cm^2. The integral and differential non-uniformity must be calculated according to IEC 60789.

NOTE Care should be taken to assure that the image has the correct size and shape as compared to the reference image.

4.1.5 PIXEL SIZE

Two POINT SOURCES should be placed at a maximum distance of 5 cm from the front face of the parallel hole collimator and at a known separation of at least 10 cm, parallel to the X- and Y-axis, respectively, of the DETECTOR HEAD. From a profile across the image of the two POINT SOURCES the distance between the two peak positions shall be determined in pixels. For each axis the ratio of the known distance between the sources expressed in millimetres divided by the number of pixels representing the distance in the image, is the PIXEL SIZE expressed in mm/pixel. The acquisition matrix should be 512×512 or as large as possible up to 512×512. The RADIONUCLIDE used should be ^{99m}Tc or ^{57}Co.

NOTE If software to calculate the PIXEL SIZE is built in, it may be used as instructed.

4.1.6 Resolution/linearity

Using a phantom with a repetitive pattern adapted to simultaneous measurements of resolution and linearity, both parameters can be evaluated over the entire surface of the camera. This test can be performed with a transmission pattern or an active source phantom. The acquisition matrix should be as large as possible. The frequency of this test shall be twice a year.

4.2 Tomographic imaging (SPECT)

4.2.1 DETECTOR HEAD TILT

The correct orientation of the DETECTOR HEAD is essential for the quality of a tomographic image. The axis of the collimator has to be exactly along that direction which is assumed by the reconstruction algorithm.

The proper orientation of the DETECTOR HEAD can be determined with a spirit-level fixed to the DETECTOR HEAD as long as the system is horizontal or as long as the line defined by the spirit level has the same angle to the horizontal as the SYSTEM AXIS. This has to be verified during the ACCEPTANCE TESTS.

If the angle of tilt of the DETECTOR HEAD can be changed by the user, it has to be checked prior to every acquisition.

4.2.2 CENTRE OF ROTATION (COR)

An error-free reconstruction requires the knowledge of the position of the PROJECTION of the COR into the coordinate 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). For multi-head systems, each DETECTOR HEAD shall be characterized by a full data set taken through 360°.

To determine the CENTER 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 should be to about 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 center.

At least 10 000 counts per view shall be acquired. The PIXEL SIZE shall be less than 4 mm. For the calculation of the centroid (center of mass) $X_p(\theta)$ of the source in the X_p direction, 50 mm wide strips in the Y direction centered around 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

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

θ is the angle of PROJECTION, A is the amplitude, φ is the phase shift of the sine function, and X' is the average OFFSET to be reported for the three different axial positions. The accuracy of the OFFSET correction has to be within ±1,5 mm. Correction of the OFFSET will decrease the field of view. Therefore the absolute value of the OFFSET should be small, e.g. less than 10 mm. Otherwise the system should be serviced.

NOTE 1 The preceding procedure is taken from IEC 61675-2.

NOTE 2 If there is 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 DETECTOR HEAD TILT, the centroid is calculated using the 50 mm wide strip. The subscriptt "p" refers to PROJECTION space (see figure 1).

NOTE 3 If a system uses an automatic OFFSET correction which cannot be switched off, then X' shall be zero. In addition, the difference between the sine function fit and the actual data shall be plotted (showing the error) as a function of θ. The maximum difference of each axial position shall be reported. The values are valid only for the collimator used, and shall be stated in millimetres.

NOTE 4 Systematic deviations are indicative of varying OFFSET during rotation of the detector.

4.2.3 Tomographic non-uniformity

The tomographic non-uniformity is checked qualitatively using a cylindrical phantom filled with a homogenous radioactive solution. The reconstructed slices have to be compared visually with the reference images. The acquisition parameters must be the same for both studies (e.g. count density, position of the phantom, RADIUS OF ROTATION, collimator, filter, cutoff frequency, number of PROJECTIONS, attenuation correction) and documented.

4.3 Wholebody imaging

Tests of the spatial resolution and scanning speed constancy are the same as in IEC 61675-3.

4.4 Frequency of ROUTINE TESTS

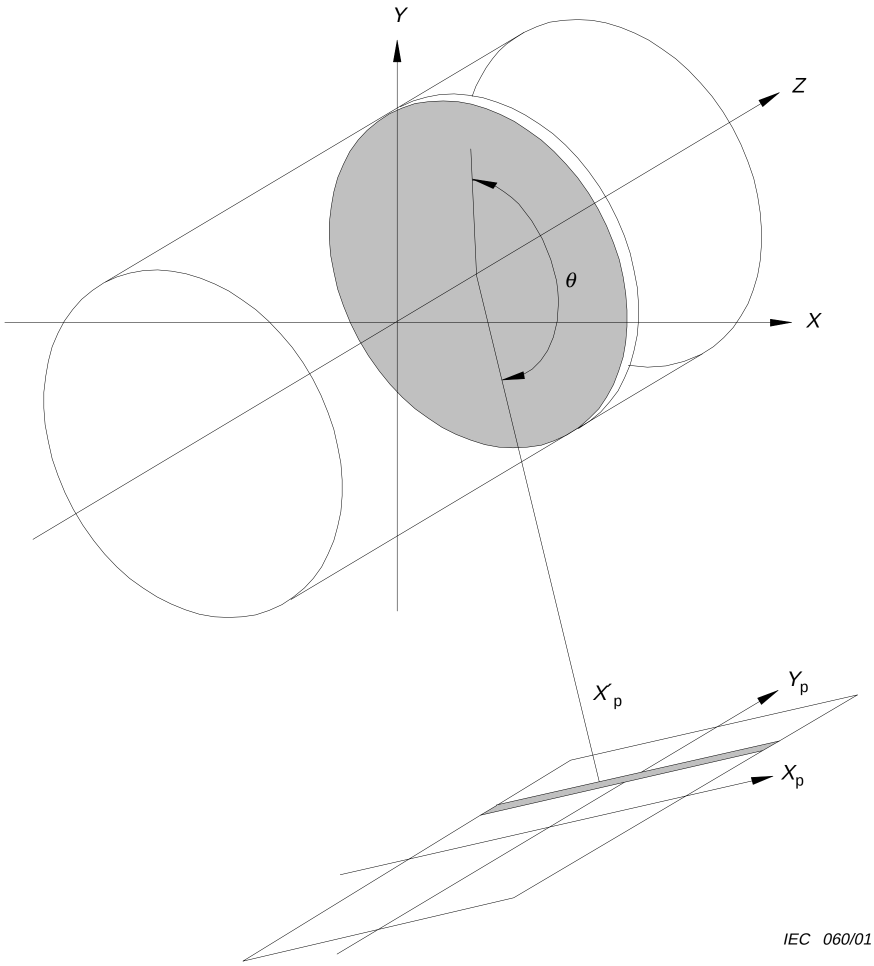
ROUTINE TESTS shall be carried out at the time intervals given in table 1.

Table 1 – Frequency of ROUTINE TESTS

Test	Frequency
Energy spectrum and window setting	Daily
Background	Daily*
Sensitivity**	Weekly
Non-uniformity	Weekly
CENTER OF ROTATION	Monthly
Resolution/linearity	Monthly
PIXEL SIZE	Twice yearly
Tomographic non-uniformity	Twice yearly
Wholebody system	Twice yearly

* Each day the instrument is used.

** If sensitivity changes appreciably, all the tests shall be repeated.



NOTE The fixed coordinate system *X*, *Y*, *Z* has its origin at the center 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 CENTER OF ROTATION is projected onto the address X_p (offset).

Figure 1 – Geometry of PROJECTIONS

Annex A

Index of defined terms

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(2) below average,
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(4) above average,
(5) exceptional,
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