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PET Performance Testing Phantom

1. Product Introduction and Structure

PET Sensitivity Phantom
Length: 70 cm; Wall thickness: 1 mm; Comes standard with 2 line source tubes.
Scatter Fraction Phantom
Length: 70 cm; Diameter: 20 cm; Comes standard with 2 line source tubes.
PET Spatial Resolution Bracket
It can support the sensitivity phantom and capillary tubes for measuring the corresponding PET performance indicators. The coordinates of capillary insertion holes are (0,1 cm), (0,10 cm), (10 cm,0); the coordinates of sensitivity phantom insertion holes are (0,0), (0,10 cm). It features an adjustable horizontal design.
Performance Requirements for Portable Radionuclide Automatic Dispenser

1)Mass < 10 kg;
2)Fully electric control (non-pneumatic);
3)Dispensing realized by peristaltic pump;
4)Three-channel automatic control of radionuclides to be dispensed;
5)Fully automatic control of the dispensing process;
6)The activity meter reading can be displayed in real time in the control software.

Nuclear Medicine Image Quality Control Analysis Software
It analyzes DICOM format images and can calculate the intrinsic spatial uniformity, intrinsic spatial linearity, spatial resolution, system sensitivity, and PET/CT image fusion accuracy.
It can measure the following PET indicators: spatial resolution, sensitivity, scatter fraction, NECR; and provide technical training services for the quality control detection of nuclear medicine equipment. Accuracy: 1; Measurement range: 1-11.

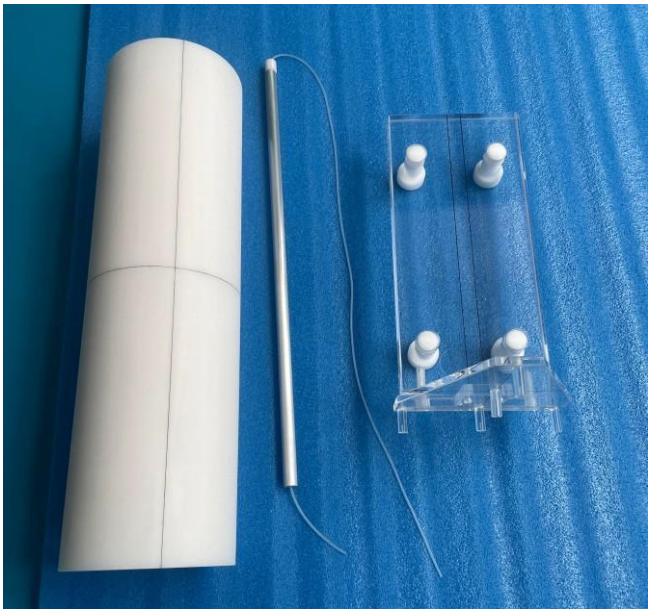


Figure A.1 Schematic Diagram of PET Performance Testing Phantom

A.1. PET Sensitivity Phantom

70 cm in length, 1 mm in wall thickness, and equipped with 2 wire source tubes as standard.

Figure A.2 Schematic diagram of the PET sensitivity phantom

A.2. Scattering Fraction Phantom

Length 70 cm; diameter 20 cm; equipped with 2 wire source tubes as standard.

Figure A.3 Schematic diagram of the scatter fraction phantom

A.3. Point Source Holder for Spatial Resolution Detection

The nuclide used for spatial resolution detection is F-18, and its specific activity is in accordance with the manufacturer's recommendation.

The test source is a high-specific-activity radioactive point source placed in a capillary glass tube, with the linear diameter of the point source in any direction being less than 1 mm. The point sources are arranged at the following 6 positions:

a) Parallel to the long axis of PET, at 1/2 of the axial field of view center, and 1 cm from the cross-sectional center;
b) Parallel to the long axis of PET, at 1/2 of the axial field of view center, and 10 cm from the cross-sectional center;
c) Parallel to the long axis of PET, at 1/2 of the axial field of view center, and 20 cm from the cross-sectional center;
d) Parallel to the long axis of PET, at 3/8 from the axial field of view center, and 1 cm from the cross-sectional center;
e) Parallel to the long axis of PET, at 3/8 from the axial field of view center, and 10 cm from the cross-sectional center;
f) Parallel to the long axis of PET, at 3/8 from the axial field of view center, and 20 cm from the cross-sectional center.

Figure A.4 Schematic diagram of the point source holder for spatial resolution monitoring

2. Detection Performance

PET Phantom Multifunctional Bracket

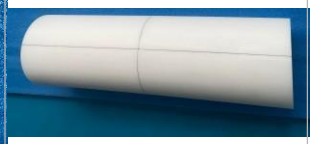
It can support the sensitivity phantom and capillary tubes for measuring the corresponding PET performance indicators; it has an adjustable horizontal design to meet the precise positioning requirements of CT laser lights in X, Y and Z directions.

It meets the quality control requirements of PET standards WS817-2023 and NEMA-2018 for tests at 1 cm, 10 cm and 20 cm off-center.

It complies with the quality control requirements for (1,0), (10,0) and (20,0) specified in PET standards WS817-2023 and NEMA-2012.

It can be horizontally adjusted in forward and reverse directions, suitable for the detection conditions of various models, and ensures that the test phantom is parallel to the PET field of view center.

Table A.1 Phantom Accessory Parameters

NO.	PET Sensitivity Phantom	Scatter Fraction Phantom	Bracket	Bracket
picture				
length (mm)	700	700	455	222
width (mm)	Outer diameter: 20	Diameter: 200	200	222
thickness (mm)	Inner diameter: 18	—	29	10
quantity	1	1	1	1

User Manual for PET Performance Detection Phantom

I. Phantom Composition

The PET performance test phantom includes: spatial resolution bracket and capillary tubes, sensitivity aluminum tubes and line sources, scatter phantom and line sources.

II. Phantom Operation

1. Spatial Resolution

1.1 Bracket Preparation

Place the spatial resolution bracket on the diagnostic bed and adjust it to be horizontal to ensure both horizontal and vertical levels, then fix the bracket on the diagnostic bed. Use laser positioning at the (0,1) position, then move the bed forward to ensure the bracket can move in and out of the CT bore without collision, and move the point source placement position to the 1/2 FOV of PET.

1.2 Point Source Preparation

Prepare a suitable 18F point source in accordance with the manufacturer's NEMA test manual. The point source volume is 1 mm×1 mm×1 mm. For SIEMENS and PHILIPS, the required point source activity is about 100 μCi (the activity of 18F sample solution is more than 60 mCi/ml), with 1 point source required; for GE, the 18F sample solution only needs to have an activity of more than 5 mCi/ml, with 3 point sources required. Insert the point source(s) into the corresponding positions of the bracket.

1.3 Positioning, Data Acquisition and Calculation

The sequence of six point source positions for spatial resolution testing: (X, Y, Z) (Unit: cm)

(0, 1, 1/2FOV)

(0, 1, 3/8FOV)

(0, 10, 1/2FOV)

(0, 10, 3/8FOV)

(0, 20, 1/2FOV)

(0, 20, 3/8FOV)

Open locate and testexec at the same time. Before each test, you must use locate to check the accuracy of the position to ensure that the deviation is within the acceptable range (generally within ±0.5mm). For SIEMENS and PHILIPS, use 1 point source to position and collect at the above six positions in turn, and run the spatial resolution result according to NEMA2018. For GE, place 3 point sources at the 1/2 FOV and 3/8 FOV of the corresponding positions at the same time for positioning and collection, and run the spatial resolution result according to NEMA2018.

2. Sensitivity

2.1 Prepare the sensitivity holder

Fix the test aluminum sleeve at the center of the CT, then move the bed forward to the CFOV of PET.

2.2 Prepare the line source

Dilute 140 μCi of 18F sample solution to 3.3 ml, then use the sensitivity line source tube to absorb the 70 cm-long solution to make a line source, ensuring no air bubbles in the line source (the activity of the line source is about 110 μCi), and insert the line source into the line source hole of the aluminum tube.

2.3 Data Acquisition and Calculation

Position the line source to ensure the deviation is within the acceptable range and acquire data. Then remove one aluminum tube in turn, perform positioning and data acquisition until the last data acquisition is completed, and calculate the result of Sen(0) according to NEMA2018. Move the aluminum tube up or to the side by 10 cm, repeat the operation for Sen(0), and calculate the result of Sen(10) according to NEMA2018. The sensitivity result is equal to 1/2(Sen(0)+ Sen(10)).

3 Scatter Fraction and Noise Equivalent Count Rate

3.1 Prepare the scatter fraction phantom

Assemble the scatter phantom, adjust it so that the center of the scatter phantom is aligned with the CT laser center, with the line source hole directly below the center. Secure the scatter phantom to the diagnostic couch with straps, and move the table so that the center of the scatter phantom is at the PET CFOV.

3.2 Prepare the line source

According to the NEMA test requirements of different manufacturers, prepare for scatter fraction, count loss, and random Prepare a \(^{18} ~F\) line source with the required activity. SIEMENS requires 25-30 mCi; GE requires approximately 24 mCi; PHILIPS requires 13-15 mCi. Configure the \(^{18} ~F\) sample solution according

to the requirements, inject and fill the 70 cm line source without air bubbles, and insert the line source into the line source hole of the scattering phantom.

3.3 Data Acquisition and Calculation

Open the positioning program for positioning to ensure that the line source deviation is within an acceptable range, and start data collection. A total of 45 collections are to be made, with a single collection time of 10 minutes and a 10-minute wait after each collection. The total collection time is 990 minutes. No manual intervention is required during this period; ensure the machine operates normally. After the collection is completed, use the NEMA2018 calculation results, where the scatter fraction is the weighted average of the 45 single scatter fraction results.

4. Accuracy: Count Loss and Randoms Correction

The detection method and data collection are the same as those in Section 7.4. For PET devices with an axial field of view (FOV) less than or equal to 65 cm, all slices are reconstructed. For PET devices with an axial FOV greater than 65 cm, only the slices within the central 65 cm FOV are reconstructed. The data are corrected for attenuation, scatter, random coincidences and dead time.

5. Time-of-Flight Resolution

To evaluate the measurement uncertainty using TOF data, the precise position of the line source needs to be known. For this purpose, the first frame of dynamic acquisition-reconstructed image is the one below the peak of activity RNEC. Reconstruction is performed in the PET coordinate system; all corrections except decay correction are included in the reconstructed image, and the voxel size of the tomogram is no more than 2.5 mm. The line source is localized using the centroid calculation method, covering all imaging slices except those within 10 mm of the axial field-of-view ends. The line is fitted to the centroid position, and the intersection points of this line with the first and last slices of the scanner are defined as P1 and P2.

The unit vector from P1 to P2 is $\vec{v} = \frac{\vec{P_2} - \vec{P_1}}{\left|\vec{P_2} - \vec{P_1}\right|}$