GAMMA CAMERA and DATA PROCESSOR SYSTEM

TENDER QUESTIONNAIRE – PART D Gamma Camera PET

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Contents

The System

Please identify the Gamma Camera PET system make and model to which the following specification applies. Include details of any separate processing workstation and any other options that are required in order to meet the stated performance. If a supplier is able to offer a choice of different detector systems that are all suitable for PET (eg different scintillation crystal material or thickness), then a separate Part D should be completed for each detector option.

Manufacturer	
Gamma camera model	
PET option model or detector option	
Data acquisition system model	
Acquisition software version	
Processing system model	
Processing software version	
Other options required	

PET Acquisition System

For the purpose of this document Positron Emission Tomography (PET) refers only to a modification to a multiple headed gamma camera that enables it to acquire tomographic images of positron emitting radionuclides by detecting two annihilation gamma rays in coincidence. It does not include use of a gamma camera with ultra-high energy collimators to detect a single annihilation photon at a time, or use of dedicated full ring PET scanners.

The questions in this section are additional to those covered in Part B for the standard gamma camera and data acquisition system.

i)	Does the system have an option for PET imaging in coincidence mode? a) Included in the basic system b) As an extra cost option that must be specified at the time of initial purchase c) As an extra cost option that can be purchased at a later date	

2. Detector

i)	What is the material of the scintillation crystal?	
ii)	What is the thickness of the scintillation crystal? (If more than one thickness is available for PET then please complete a separate Part D for each crystal thickness).	
iii)	What detector separation (between crystal faces) can be used in coincidence mode? a) Maximum separation (mm) b) Minimum separation (mm)	
iv)	What additional shielding is provided for the detector, over and above that which is fitted to the standard camera described in Part B?	
v)	Compared with the response given in Part B for the standard detector, describe any changes that are made to the way that signals are processed in order to cope with the high count rates experienced in PET (apart from the addition of a coincidence circuit).	
vi)	For the correction systems described in question 2.2.7 of Part B (ie PM tube gain, energy correction, linearity correction, sensitivity correction etc), are specific sets of correction maps required for PET imaging?	
vii)	How frequently should these PET correction maps be updated?	
viii)	How long does it take to update the PET correction maps?	
ix)	Can the user perform updates to the PET correction maps?	
x)	Would the PET correction maps normally be updated by your service personnel during routine maintenance of the system?	

xi)	Following the use of the system for single photon imaging, specify any recommended time period that should elapse before the system can be used for coincidence imaging (minutes)	
xii)	Following the use of the system for coincidence imaging, specify any recommended time period that should elapse before the system can be used for single photon imaging (minutes)	

3. Low energy performance

This section relates to the performance of the system for low energy (single photon) imaging. The questions are the same as those in section 2.1 of part B and are repeated here because the thicker crystal that is likely to be used for PET may adversely affect the performance for ^{99m}Tc imaging. Please state the performance parameters of the gamma camera as determined according to the methods specified by the National Electrical Manufacturers' Standards Publication NU1-2001.

i)	State the intrinsic spatial resolution of the detector: a) FWHM in CFOV (mm) b) FWHM in UFOV (mm) c) FWTM in CFOV (mm) d) FWTM in UFOV (mm)	
ii)	State the intrinsic flood field uniformity of the detector *before application of sensitivity correction* (ie without scaling counts in inverse proportion to a previously acquired high count flood): a) Integral uniformity in CFOV (%) b) Integral uniformity in UFOV (%) c) Differential uniformity in CFOV (%) d) Differential uniformity in UFOV (%)	

iii)	State the intrinsic flood field uniformity of the detector with all corrections (*including sensitivity correction*) applied: a) Integral uniformity in CFOV (%) b) Integral uniformity in UFOV (%) c) Differential uniformity in CFOV (%) d) Differential uniformity in UFOV (%)	
iv)	State the intrinsic spatial linearity of the detector: a) Absolute linearity in CFOV (mm) b) Absolute linearity in UFOV (mm) c) Differential linearity in CFOV (mm) d) Differential linearity in UFOV (mm)	
v)	State the intrinsic energy resolution of the detector (%)	
vi)	State the system sensitivity for 99mTc using the LEGP collimator (cps/MBq)	
vii)	State the multiple window spatial registration (mm)	
viii)	State the intrinsic count rate performance: a) Maximum observed count rate (kcps) b) Observed count rate at which 20% loss occurs (kcps)	
ix)	If the system is capable of SPET, state the resolution of reconstructed SPET images: a) Tangential resolution (mm) b) Radial resolution (mm) c) Central resolution (mm) d) Which collimator was used for the above measurements?	
x)	State the detector shield leakage: a) Maximum shield leakage at 140 keV (%) b) Maximum shield leakage at 360 keV (%) c) Maximum shield leakage at 511 keV (%)	

xi)	Do the figures stated in **Error! Reference source not found.** to **Error! Reference source not found.** apply to all detectors independently? If not state any differences between detectors.	
xii)	What is the maximum percentage difference between any two detectors in the following parameters: a) Intrinsic resolution (**Error! Reference source not found.**) b) Intrinsic uniformity with sensitivity correction applied (**Error! Reference source not found.**) c) Intrinsic energy resolution (**Error! Reference source not found.**) d) System sensitivity (**Error! Reference source not found.**)	

4. PET Collimators

In this section 'collimator' means any device that may be fixed to the front of the detectors for restricting accepted events during coincidence imaging. This includes both septa, that restrict the axial field of view, as well as filters that reduce low energy events. It does <u>not</u> include ultra high energy collimators that are used for single photon imaging with positron emitting radionuclides.

i)	Please provide a list of all PET collimators available for the system. This may be done by attaching a separate data sheet, provided that all the following parameters are included for each collimator: a) Size of field of view (mm) b) Axial angular acceptance angle (degrees) c) Thickness and material of any filtering d) Any side shielding to reduce out-of-field events e) Weight (kg)	
ii)	Is the method used for changing and storing PET collimators the same as that described in section 2.4 of part B? If 'No' please give details of how it differs.	

iii)	When PET collimators are fixed, is the available range and speed of detector movement the same as that described in section 2.3.1 of Part B? If 'No' describe any limitations of movement or speed.	
iv)	Is it possible to acquire coincidence data with all collimators completely removed?	

5. PET Energy Window(s)

i)	Are all the pulse height analysis features described in section 2.5 of part B also available for coincidence imaging? If 'No' state any limitations.	
ii)	How is the PET photopeak energy window defined? a) Centre and width fixed by the system b) Centre fixed but width adjustable by the user c) Centre and width both user adjustable	
iii)	How is the PET scatter energy window defined? a) No scatter window used b) Centre and width fixed by the system c) Centre fixed but width adjustable by the user d) Centre and width both user adjustable	
iv)	What types of coincidence event can be accepted? a) Coincidence between photopeak windows in two heads b) Coincidence between photopeak window in one head and scatter window in another head c) Coincidence between scatter windows in two heads	

v)	Does the system incorporate a facility to automatically maintain the position of the energy window(s) relative to the spectrum if the spectrum shifts with changing count rate? If 'Yes' give brief details of how this works.	

6. Coincidence Time Window

i)	What is the width of the prompt coincidence time window? a) Recommended value (nS) b) Minimum value (nS) c) Maximum value (nS)	
ii)	Can the width of the prompt coincidence time window be adjusted by the user?	
iii)	Does the system provide a delayed coincidence window for assessment of random coincidences?	
iv)	What is the width of the delayed coincidence time window? a) Recommended value (nS) b) Minimum value (nS) c) Maximum value (nS)	

7. PET Data Format

i)	What data does the acquisition system produce as a result of a coincidence acquisition? a) Raw events in list mode b) 2D Transaxial projections c) Full 3D projections d) Other (specify)	

ii)	If projections are produced on-the-fly during the acquisition, what rebinning method is used? a) Single slice rebinning (SSRB) b) Multi-slice rebinning (MSRB) c) Fourier rebinning (FORE) d) Other (specify)	
iii)	If the system produces list mode data, does the processing system provide facilities for subsequent rebinning of the list mode data into projections using the following methods? a) Single slice rebinning (SSRB) b) Multi-slice rebinning (MSRB) c) Fourier rebinning (FORE) d) Other (specify)	
iv)	During the off-line rebinning of question **Error! Reference source not found.**, can the user specify the following parameters? a) Which energy window combinations to be included (ie only include photopeak events or include scatter in one or both heads) b) Axial angular acceptance range c) Transaxial angular acceptance range	
v)	How much disk space is available on the system for storage of PET studies?	
vi)	How much disc space is used by a typical PET study?	
vii)	What options are available for archiving PET studies	

8. PET Quality Control

i)	What specific protocols are included in the system software for the user to perform routine quality control of coincidence imaging? a) Detector uniformity in singles mode b) Detector uniformity in coincidence mode c) Energy peak position at 511 keV d) Energy resolution at 511 keV e) System sensitivity in coincidence mode	

	f) Spatial resolution in coincidence mode g) Other (specify)	

PET Image Processing

1. Reconstruction

i)	What image reconstruction software is provided? Please indicate whether this software is included as standard (Stnd) or as an extra cost option (ECO). a) Fully 3D reconstruction from list mode data b) Fully 3D reconstruction from 3D projections c) Filtered back projection from 2D transaxial projections d) Iterative reconstruction from 2D transaxial projections e) Other (specify)	

2. Correction Techniques

i)	Is scatter correction implemented within the system software? Please indicate whether scatter correction is included as standard (Stnd) or as an extra cost option (ECO). a) For 3D reconstruction b) For 2D reconstruction	
ii)	Is dead time correction implemented within the system?	
iii)	Is decay correction implemented within the system?	
iv)	Is correction for random coincidences implemented within the system? a) Using a delayed coincidence window b) Using another method (specify)	
v)	Does the system include software to correct coincidence data for uniform attenuation (for example, in brain PET studies).	
vi)	Does the system include software to correct coincidence data for non-uniform attenuation using patient specific attenuation maps created from transmission data?	

3. Transmission Imaging

Note that the questions in this section are very similar to those in section 3.11 of Part B, but they are repeated here because the external source used for PET may be different.

i)	Does the system have an option for transmission imaging that can be used with PET studies? a) Included in the basic system b) As an extra cost option that must be specified at the time of initial purchase c) As an extra cost option that can be purchased at a later date	
ii)	What radiation source does the transmission imaging use? a) External radionuclide source b) X-ray source	
iii)	If a radionuclide source is used, specify the following: a) The radionuclide used b) The number of sources c) The total activity in all sources (MBq) d) The physical form (solid or liquid) e) The shape of the source (eg point or line) f) Whether the source is fixed or scanning g) What shielding is provided around the source	
iv)	If an X-ray source is used, specify the following: a) The range of kVp available b) The range of mAs available c) Electrical power requirements of the source d) X-ray slice thickness e) X-ray detectors used	
v)	Can the transmission scan be acquired: a) Before the emission scan? b) Simultaneously with the emission scan? c) After the emission scan?	

vi)	Does the imaging table have to move between acquisition of the emission and transmission scans?	
vii)	How much extra time does the transmission scan add to the total imaging time of PET study?	
viii)	Describe any calibration or QC procedures that need to be performed for the transmission device	
ix)	How long do these calibration procedures take and how often should they be performed?	
x)	Can the transmission scan be used for a) Non-uniform attenuation of PET studies b) Anatomical localisation by fusion of emission and transmission images for PET studies	
xi)	Is the raw transmission data (rebinned into parallel projections if necessary) available as a separate image file?	
xii)	How is the transmission data corrected for any crosstalk from emission in the patient?	
xii)	Does the system produce attenuation maps based on broad beam or narrow beam attenuation coefficients?	
xiv)	If broad beam attenuation maps are used, how are these generated from the narrow beam data?	
xv)	If narrow beam attenuation maps are used, what alternative means of scatter correction is available?	
xvi)	How are the attenuation maps extrapolated from the energy of the transmission source to the energy required for attenuation correction?	
xvii)	Are attenuation maps available as a separate image file? If 'Yes' specify the units in which they are stored.	
xviii)	This question is not used for PET	
xix)	Is the transmission image acquired using fan-beam or parallel geometry?	
xx)	If transmission data is acquired using fan-beam geometry, does this cause any truncation of the field of view?	

xxi)	Does the transmission image cover the same transaxial field of view as the emission image? If 'No' specify the transaxial field of view of the transmission data	
xxii)	Does the transmission image cover the full axial field of view of the emission image? If 'No' specify the axial field of view of the transmission data	
xxiii)	How frequently would the source detailed in **Error! Reference source not found.** need replacing	
xxiv)	Please provide an estimate of the cost of replacing the source and indicate whether this can be incorporated into annual maintenance costs.	
xxv)	What is the additional effective dose to the patient from use of the transmission source to acquire an attenuation map (mSv)?	
xxvi)	When the transmission source is not in use (source in its shielded position), what is the radiation dose rate due to the source (microSv/hr) a) At the closest point that an operator might stand to the source? b) At a point where an operator might stand at the foot of the patient bed?	
xxvii)	When the transmission source is in use, what is the radiation dose rate due to the source (microSv/hr) a) At the closest point that an operator might stand to the source? b) At a point where an operator might stand at the foot of the patient bed?	
xxviii)	Is a lead-glass screen recommended around the operators' workstation?	
xxix)	Is additional shielding recommended in the walls of the room?	

Whole body PET Imaging

This section refers to a facility for automatically producing coincidence images from an extended length of the patient that covers more of the body than can be imaged in a single rotation of the detectors. The system should perform the necessary movements for the acquisition automatically. Separate acquisitions performed manually at different body positions do not qualify as whole body imaging unless there is a facility for subsequently combining these into one image.

i)	Is it possible to automatically acquire whole body coincidence images? a) Using continuous bed scanning b) Using step and shoot bed movement c) Other (specify)	
ii)	Does the system support whole body coincidence imaging using tomographic and/or non tomographic acquisitions? (Indicate ECO if this is only available as an extra cost option) a) Tomographic mode b) Non-tomographic mode	
iii)	Is whole body acquisition available for all collimators used in coincidence imaging? If 'No' specify any limitations	
iv)	If step and shoot bed movement is used, what overlap between consecutive bed positions is possible?	
v)	Can the user select the amount of overlap between consecutive bed positions?	
vi)	What is the maximum axial length of the patient that can be imaged in whole-body mode?	
vii)	Does the system software support reconstruction of data acquired in whole body coincidence mode into a single whole body tomographic image? (ie all bed positions reconstructed together)	
viii)	Does the system software allow combination of tomographic images reconstructed from several different bed positions into a single whole body tomographic image? (ie each bed position reconstructed separately and then combined)	
ix)	Does the system support display of whole body tomographic images?	

PET System Performance

Suppliers are asked to supply the following performance parameters as measured on a typical system. The procedures for measuring the parameters listed below are described in the BNMS document "Acceptance Tests for Gamma Camera PET systems" by T.D. Fryer and D. Visvikis. These same procedures are outlined in Chapter 6 of IPEM Report 86 [1]. If a different measurement technique has been used for any of the parameters specified below, please describe the alternative method used. Whatever method is used the questions in section **Error! Reference source not found.** should also be completed in order to specify the measurement conditions employed.

In this section '2D mode' refers to acquisitions with a collimator containing axial septa and '3D mode' refers to acquisitions with a collimator containing no septa.

1. Performance Parameters

i)	What is the **spatial resolution** in coincidence mode of a point source placed at a position **on the central axis** of the detector? Give figures for FWHM of a reconstructed tomographic image. a) In the tangential direction (mm) b) In the radial direction (mm) c) In the axial direction (mm)	
ii)	What is the **spatial resolution** in coincidence mode of a point source placed at a position **10cm from the central axis** of the detector? Give figures for FWHM of a reconstructed tomographic image a) In the tangential direction (mm) b) In the radial direction (mm) c) In the axial direction (mm)	
iii)	What is the **energy resolution** of the detector at 511 keV, measured by the FWHM of the photopeak as a percentage of the photopeak energy (%)?	
iv)	What is the **scatter fraction** (SF) as defined in IPEM Report 86 [1]? a) For acquisition in 2D mode (%) b) For acquisition in 3D mode (%)	
v)	What is the **count rate capability in 2D mode** measured using a decaying source method? a) Peak singles count rate (kcps) b) Activity at which peak singles rate occurs (MBq) c) Peak coincidence count rate (kcps) d) Activity at which peak coincidence rate occurs (MBq)	

	e) Activity at which 50% dead time loss in coincidence counts occurs (MBq)	
vi)	What is the **count rate capability in 3D mode** measured using a decaying source method? a) Peak singles count rate (kcps) b) Activity at which peak singles rate occurs (MBq) c) Peak coincidence count rate (kcps) d) Activity at which peak coincidence rate occurs (MBq) e) Activity at which 50% dead time loss in coincidence counts occurs (MBq)	
vii)	What is the **system sensitivity** to true coincidences (T) as defined in IPEM report 86 [1]? a) In 2D mode (cps/Bq/ml) b) In 3D mode (cps/Bq/ml)	

2. Measurement Conditions

This section asks for details of the acquisition and processing parameters used during the measurement of the parameters specified in section **Error! Reference source not found.**

i)	For the spatial resolution measurement of question **Error! Reference source not found.** and **Error! Reference source not found.** state: a) Voxel size of the images in the transaxial direction (mm) b) Voxel size of the images in the axial direction (mm) c) Acquisition method (2D or 3D) d) Any spatial or angular acceptance limits imposed e) Reconstruction method f) Source used	
ii)	For the energy resolution measurement of question **Error! Reference source not found.** state: a) The energy channel width	

	b) The source used	
iii)	For the scatter fraction measurement of question **Error! Reference source not found.** state: a) The phantom used b) Detector separation c) Energy window used d) Any spatial or angular acceptance limits imposed	
iv)	For the count rate measurements of question **Error! Reference source not found.** and **Error! Reference source not found.** state: a) The source geometry used b) The method used to correct the coincidence rate for randoms	
v)	For the sensitivity measurements of question **Error! Reference source not found.** state: a) The phantom used b) Detector separation c) Energy window used d) Any spatial or angular acceptance limits imposed e) The method used to correct the coincidence rate for randoms f) The activity range for each measurement	

References

1. IPEM Report 86. *Quality Control of Gamma Camera Systems*, Ed Alison Bolster, Institute of Physics and Engineering in Medicine, York 2003.