APPENDIX IV

Specific Technical and Performance Information

for *CT Scanner* Bid Submission*

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* Taken from: American Association of Physicists in Medicine. *Specification and acceptance testing of computed tomography scanners. Report of Task Group 2 Diagnostic X-Ray Imaging Committee*. New York: American Institute of Physics; 1993.(AAPM Report 39).

Specific Technical and Performance
Information for *CT Scanner* Bid Submission*

Manufacturer: _____

Model: _____

Address: _____

_____

_____

_____

Phone: (_____) _____

Response prepared by:

Name: _____

Title: _____

Authorized Signature: _____

Date: _____

* Use one set of forms for each model bid.

A. System Environmental Requirements

1. Electrical Power Sources: List voltage, power, and phasing for each; indicate locations on architectural drawing

_____

_____

2. Power Conditioning: Give manufacturer and model numbers of power conditions system provided:

_____

3. Air Conditioning Requirements:

Control Area: _____BTU/hr
Gantry Area: _____BTU/hr
Computer Room: _____BTU/hr
Other _____ : _____BTU/hr

4. Mechanical Requirements:

a. Areas where raised "computer floor" is required:

_____

_____

b. Under-floor cable runways required: (Specify depth, width and locations on architectural drawings)

c. Total weight of equipment: _____ lb. (kg)
Gantry: _____ lb. (kg)
Control Console: _____ lb. (kg)
HV *Generator* & Controller: _____ lb. (kg)
Computer System: _____ lb. (kg)
Other _____ : _____ lb. (kg)

d. Minimum floor space required (entire system): ____ sq.ft.(m^2)

5. Plumbing Requirements:

a. Number of drains required*: _____
b. Number of water inlets required*: _____

* Specify location, flow rate, temperature range, etc., on architectural drawings.

6. Physical modifications: Specify the extent to which facility modifications will be performed by the vendor, with respect to installation of electrical troughs, plumbing, electrical power, air conditioning, etc.

_____

_____

_____

7. **Radiation Protection:** Specify measured maximum ***exposure*** rate 1 meter in any direction from scan isocenter, for widest slice width and highest kVp using a cylindrical tissue equivalent ***phantom*** at least 20 cm in diameter:

Kilovoltage: _____ kVp
Slice width: _____ mm
Phantom diameter: _____ cm
Phantom material: _____
Air ***kerma***: _____ mGy/mAs (mR/mAs)

B. System Characteristics

1. *X-ray Generator*:

a. Voltage waveform: Continuous: _____
Pulsed: _____

b. kVp settings available (List):

_____

c. mA (mAs) stations available (list for each kVp):

settings at ____ kVp _____
settings at ____ kVp _____
settings at ____ kVp _____
settings at ____ kVp _____

d. Available Scan Times:

Time	*Scan Angle*
_____s	_____°
_____s	_____°
_____s	_____°
_____s	_____°
_____s	_____°
_____s	_____°

2. *X-ray* **Tube:**

a. Type: Rotating anode: _____
Stationary anode: _____

b. Focal spot sizes (Nominal):

	Scan Plane Dimension	*Axial Dimension*
Focus #1	_____ mm	_____ mm
Focus #2	_____ mm	_____ mm

c. *X-ray* beam filtrations (operator variable - include both hardening filters and beam flattering or bow tie filters).

Material	*Thickness**	*Intended Use*
_____	_____	_____
_____	_____	_____
_____	_____	_____

* Specify for hardening filters only.

d. Thermal Characteristics:

Housing cooling rate: _____ J/min

Anode cooling rate: _____ J/min

Anode heat storage capacity (cold): _____ J

Housing heat storage capacity: _____ J

Type of thermal overload protection system provided:

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e. Does *x-ray* tube employ a mechanical shutter? _____

3. **Beam Collimation System:**

a. List all available (nominal) slice thicknesses in mm:

---

b. Slice width settings where prepatient collimator is adjustable in axial dimension

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c. Slice width settings where prepatient collimator is fixed in axial dimension

---

d. Slice width settings where postpatient collimator is adjustable in axial dimension

---

e. Slice width settings where postpatient collimator is fixed in axial dimension

---

4. *Gantry*:

a. Type of Scan Motion:

Rotate/translate: _____

Symmetric fan beam, rotating detectors: _____

Asymmetric fan beam, rotating detectors: _____

Fan beam, stationary detector ring: _____

Fan beam, nutating detector ring: _____

Other: _____

b. Variable geometric magnification available? _____

c. Continuous rotation available? _____

d. *Gantry* Aperture:

Maximum *gantry* aperture diameter: _____ cm

Maximum scan (sampled) diameter: _____ cm

e. *Gantry* Tilt (maximum):

Gantry top toward table: _____ °

Gantry top away form table: _____ °

Angulation accuracy: ± _____ °

f. Light-field Localizer:

Type:	Laser:	_____
	Focused Light Beam:	_____
Configuration:	Transaxial:	_____
	Sagittal:	_____
	Coronal:	_____
Position of transaxial localizer:		
	At scan plane:	_____
	External to scan aperture:	_____
Accuracy of transaxial localizer*		± ___ mm

*Coincidence of light and *x-ray* field centers.

5. Patient Scanning Table

a. Maximum motions:

Longitudinal (full out to full in):	_____ cm
Accuracy of table incrementation*:	± _____ mm
Reproducibility*	
* Table loaded with 180 lb (80 kg)	± _____ mm
Minimum table height:	_____ cm
Maximum table height:	_____ cm

b. Location(s) of table position indicators:

Gantry:	_____
Table:	_____
Control console:	_____
Scan image:	_____

c. Table detachable from *gantry*? _____

Specific cost if optional:	$ _____
Cost of extra beds:	$ _____ ea

d. Table tilt (maximum):

Head end up:	_____ °
Head end down:	_____ °
Angulation accuracy:	± _____ °

6. Detectors

a Type:

Scintillator/photodiode:	_____
Scintillator/PM tube:	_____
Type of scintillator:	_____
Pressurized xenon:	_____
Other:	_____

b. Number (exclude reference detectors): _____

c. Efficiency:

Scan Mode	*kVp*	*Geometric (%)*	*Total (%)*
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

d. Data sampling:

Scan Time		*# Projections*	*# Ray Samples**
_____	$	_____	_____
_____	$	_____	_____
_____	$	_____	_____
_____	$	_____	_____
_____	$	_____	_____

* Give all values if independently variable.

e. Recommended calibration frequency:

"Air calibration" scans: _____

"Water calibration" scans: _____

7. Computer System:

a. Image reconstruction time: (measure from scan start to completion of display, i.e., include scan time)*.

Scan Mode	*Reconstruction Matrix*	*Scan Time*	*FOV*	*Reconstruction Time*
Standard Head	_____	_____ s	_____cm	_____ s
Standard Adult Body	_____	_____ s	_____cm	_____ s
Highest Resolution	_____	_____ s	_____cm	_____ s
Fastest Scan	_____	_____ s	_____cm	_____ s

* Indicate when display matrix differs from reconstruction matrix.

b. Faster reconstruction options (Specify)

Option: _____ S _____

Performance (Optional conditions):

Scan Mode	*Reconstruction Time*
Standard Head	_____ s
Standard Adult Body	_____ s
Highest Resolution	_____ s
Fastest Scan	_____ s

c. Simultaneous reconstruction and scanning? _____

d. Data storage and image archiving:

Storage Capacity*

Device	*MBytes Images*	*512^2 Images*	*256^2 Images*	*Raw Data Files*
Magnetic tape	_____	_____	_____	_____
Magnetic tape	_____	_____	_____	_____
Fixed disc drive	_____	_____	_____	_____
Fixed disc drive	_____	_____	_____	_____
Optical disc	_____	_____	_____	_____

* Uncompressed data files

List optional storage devices and additional cost:

_____ $ _____

_____ $ _____

Nondestructive data file compression available? _____

Compression ratio(s): _____

e. Convolution ***kernels*** (reconstruction filter functions):

Name	*Design Purpose*
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

f. Image display system:

Pixels displayed (entire screen): Horizontal _____

Vertical _____

Image screen size (diagonal):

Operator's console: _____ in (cm)

Physician's console: _____ in (cm)

Gray scale bar displayed? _____

Alphanumeric information displayed

(Check where appropriate):

	On Image	*On Separate Data Screen*
Patient's name:	_____	_____
ID number:	_____	_____
Age:	_____	_____
Sex:	_____	_____
Date of exam:	_____	_____
Time of exam:	_____	_____

Slice #	_____	_____
kVp:	_____	_____
mA(s):	_____	_____
Scan time:	_____	_____
Slice width:	_____	_____
Bed position:	_____	_____
Bed increment:	_____	_____
Convolution ***kernel***:	_____	_____
Gantry tilt angle:	_____	_____
Body side (R/L):	_____	_____

g. Diagnostic software features (check if standard, give cost if optional).

Feature	*Standard*	*Cost**
Square region-of-interest (ROI):	_____	$ ____
Rectangular ROI:	_____	$ ____
Circular ROI:	_____	$ ____
Arbitrarily shaped ROI:	_____	$ ____
Average CT number within ROI:	_____	$ ____
Std. deviation of CT number:	_____	$ ____
Histogram of CT numbers within ROI:	_____	$ ____
Distance measuring utility:	_____	$ ____
Accuracy:		± ____ mm
Grid overlay:	_____	$ ____
Profile utility (CT number plot between image points):	_____	$ ____
Highlighting of ***pixels*** within specific CT number range:	_____	$ ____
Multiple image display (e.g., 2 x 2, 3 x 3):	_____	$ ____
Gray scale inversion:	_____	$ ____
Image reversal (left to right):	_____	$ ____
Image inversion (top to bottom):	_____	$ ____
Subtraction of two images:	_____	$ ____
Reconstruction magnification (arbitrary FOV within limits):	_____	$ ____
Non-reconstruction magnification:	_____	$ ____
High density artifact removal:	_____	$ ____
Programmable window settings:	_____	$ ____
Multi-planar reconstruction:	_____	$ ____
Arbitrary angle reconstructions:	_____	$ ____
Dual windowing (simultaneous display of two CT number ranges):	_____	$ ____
Three dimensional image display:	_____	$ ____
Surface rendering:	_____	$ ____
Transparency rendering:	_____	$ ____
Bone mineral density measurement:*	_____	$ ____
Dual energy material decomposition:	_____	$ ____
Xenon (cerebral blood flow) imaging:*	_____	$ ____
Cardiac gating:*	_____	$ ____

Radiation therapy treatment planning:* _____ $ _____
Compiler (Fortran, C, etc.) for research programming: _____ $ _____
ACR/NEMA image transfer interface:* _____ $ _____
Gamma correction to match CRT phosphor to sensitivity curve of film? _____ $ _____
SMPTE pattern for ***QA***: _____ $ _____
Other features* (list):
_____ _____ $ ___
_____ _____ $ ___
_____ _____ $ ___

* Include cost of additional hardware required.

8. Hardware Accessories: (check if standard, give cost if optional).

Feature	*Standard*	*Cost**
Head holder:	_____	$ _____
Infant holder:	_____	$ _____
Flat (radiation therapy simulation) tablet insert:	_____	$ _____
Other: (specify) _____	_____	$ _____
_____	_____	$ _____

9. Radiographic Scan Mode:

a. Projections available: AP: _____
Lateral: _____
Arbitrary angle: _____

b. Maximum scan dimensions (at ***gantry*** axis):
length: ____ mm
width: ____ mm

c. Software for scan localization from radiograph: ____
Localization of slice positions: ____
Accuracy: ____
Localization of ***gantry*** (table) tilt: ____
Accuracy: ____

10. Hard Copy Images:

a. Standard multiformat camera provided: (Manufacturer, model

_____

b. Film sizes and display formats:

Film size(s)	*Display Format*
8" x 10" (20 cm x 25 cm)	1 on 1 _____
	4 on 1 _____
	9 on 1 _____
	other: _____

10" x 12" (25 cm x 30 cm)	1 on 1 _____
	4 on 1 _____
	9 on 1 _____
	other: _____
14" x 17" (35 cm x 43 cm)	4 on 1 _____
	9 on 1 _____
	16 on 1 _____
	other: _____
Other film size: _____	_____
	_____
	_____

c. Optional hard copy imaging devices available:

Device	*Cost*
_____	$ _____
_____	$ _____
_____	$ _____

11. System Performance:

a. Specification of Performance Data:

Spatial Resolution: Measured in cycles/cm at an MTF of 10%.

Image Noise: Measure within an ROI of ≈1 cm^2, centered within a 15-21 cm diameter cylindrical water ***phantom*** for head and pediatric scans, and a 30-32 cm ***phantom*** for adult body scans. Express as a percent of the effective linear attenuation coefficient of water, corrected for the scanner contrast scale.

Radiation Dose: Specify all ***dose*** data in cGy (rads) as either multiple scan average *dose* (MSAD) or computed tomography *dose* index (CTDI), check as appropriate:

CTDI _____
MSAD _____

Dose must be measured at a radial depth of 1 cm in acrylic ***phantoms*** meeting specifications of the U.S. CDRH (FDA). For all 360° scans measure at the 12 o'clock position in the ***phantom***.

Measure at mid scan arc for scans < 360°, and at midpoint of overlap region for scans > 360°.

Performance Conditions:

Scan Mode	*Reconstr. Matrix*	*FOV (cm)*	*Convol. Kernel*	*kVp*	*Scan Time*	*mAs*	*Slice Width*
Std. Head	_____	____	_____	____	_____	_____	_____
Std. Adult Body	_____	____	_____	____	_____	_____	_____
Best Resolution	_____	____	_____	____	_____	_____	_____
Fastest Scan	_____	____	_____	____	_____	_____	_____
Lowest Noise Body	_____	____	_____	____	_____	_____	_____
Lowest Noise Head	_____	____	_____	____	_____	_____	_____
Pediatric Head	_____	____	_____	____	_____	_____	_____

Pediatric Body _____ ____ _____ ____ _____ _____ _____

Performance Specifications:

Scan Mode	*Resolution cycles/cm*	*Noise % SD*	*Dose (cGy)*
Std. Head	_____	_____	_____
Std. Adult Body	_____	_____	_____
Best Resolution	_____	_____	_____
Fastest Scan	_____	_____	_____
Lowest Noise Body	_____	_____	_____
Lowest Noise Head	_____	_____	_____
Pediatric Head	_____	_____	_____
Pediatric Body	_____	_____	_____

b. Collimation performance: Measure sensitivity and radiation profiles in mm at full width half maximum (FWHM) within a radius of 5-15 cm of ***gantry*** axis. Tolerances should reflect manufacturer's range of acceptance error.

Nominal Slice Setting	*Sensitivity Profile*		*Radiation Profile*	
	Width	*Tolerance*	*Width*	*Tolerance*
(min) _____	_____	±_____	_____	±_____
_____	_____	±_____	_____	±_____
_____	_____	±_____	_____	±_____
_____	_____	±_____	_____	±_____
_____	_____	±_____	_____	±_____
_____	_____	±_____	_____	±_____
(max) _____	_____	±_____	_____	±_____

C. ADMINISTRATIVE DETAILS

1. Warranties:

a. Warranty Period (months beyond formal acceptance): _____

Exclusions:

X-ray tubes* _____

Other exclusions (specify):

_____

_____

* If excluded, give additional cost of ***x-ray*** tube warranty during base warranty period: $ _____

b. Normal service hours: _____ AM to _____ PM,

_____ (day) through _____ (day).

2. **Down Time:**
   a. Definition: Down time is defined as time when the scanner is unavailable for patient use due to failure of critical hardware or software component(s). Down time is defined over the base time
   period from _____ AM to _____ PM,
   from _____ (day) through _____ (day).
   Excludes time for required preventive maintenance, component failure directly resulting from inadequate (owner-supplied) preventive maintenance or operation beyond performance specifications.
   b. Guarantee: Down time shall not exceed _____ % of the base time period over any calendar month of the warranty period.
   c. Penalty: The warranty period will be extended by _____ days for every 1% of down time beyond the guaranteed minimum.

3. **Required Preventive Maintenance:**
   _____ hrs per week
   _____ hrs every two weeks
   _____ hrs per month

4. **Service Contracts:** (Use plans B and C as necessary for optional contracts)

Plan A (check all that apply)

All parts excluding *x-ray* tubes:	_____
X-ray tubes:	_____
All labor from 8:00 AM to 5:00 PM Monday through Friday:	_____
Night labor: between _____ PM and _____ AM, Monday through Friday:	_____
Weekend and holiday labor:	_____
Cost: Year 1 after warranty:	$ _____
Maximum annual increase in years 2-5 after acceptance:	_____ %

Plan B (Check all that apply):

All parts excluding *x-ray* tubes:	_____
X-ray tubes:	_____
All labor from 8:00 AM to 5:00 PM Monday through Friday:	_____
Night labor: between _____ PM and _____ AM Monday through Friday:	
Weekend and holiday labor:	_____
Cost: Year 1 after warranty:	$ _____
Maximum annual increase in years 2-5 after acceptance:	_____ %

Plan C (Check all that apply):

All parts excluding *x-ray* tubes: _____
X-ray tubes: _____
All labor from 8:00 AM to 5:00 PM
Monday through Friday: _____
Night labor: between _____ PM and _____ AM,
Monday through Friday: _____
Weekend and holiday labor: _____
Cost: Year 1 after warranty $ _____
Maximum annual increase in years 2-5 after
acceptance: _____ %

5. **Maximum Service Response Time** (normal business hours):
_____ hrs

6. **Other Users:**
If possible, provide list of names, addresses, telephone numbers and a contact person for 3 purchasers of the ***CT scanner*** model bid in this document.

Name: _____
Address: _____
_____
_____
Telephone No.: _____
Contact Person: _____

Name: _____
Address: _____
_____
_____
Telephone No.: _____
Contact Person: _____

Name: _____
Address: _____
_____
_____
Telephone No.: _____
Contact Person: _____

APPENDIX V

Quality Control in Diagnostic Imaging*

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* Taken from: National Council on Radiation Protection and Measurements. *Quality assurance for diagnostic imaging. Recommendations of the National Council on Radiation Protection and Measurements.* Bethesda: NCRP; 1988. (NCRP Report 99).

Note: The following publication is also recommended. Sociedad Española de Protección Radiológica, Sociedad Española de Física Médica. *Protocolo español de control de calidad en radiodiagnóstico. Aspectos técnicos.* Madrid: SEFM-SEPR; 1996.

Table 1
Photographic *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Film and chemical storage	Essential	Visual inspection, thermometer, hygrometer	Fumes? Radiation? 65 ± 5 °F 50% ± 10% Humidity	Monthly
Darkroom conditions	Essential	Visual inspection, thermometer, hygrometer	Clean? 70 ± 5°F 50% ± 10% Humidity	Monthly
Darkroom fog	Essential	Visual inspection, film, cassette, step wedge. Opaque material	<0.05 increase in density in 2 min	Semiannually
Manual processing				
Timer and Thermometer	Essential	Comparison: timer and thermometer	Timer—± 5% Thermometer— ± ½ °F	Monthly
Chemicals	Essential	Sensitometer, Densitometer, Control emulsion	B + F + 0.05 Mid density ± 0.15 Density difference ± 0.15	Daily or before processing any films
Processor sensitometric evaluation	Essential	Sensitometer, Densitometer, Control emulsion	B + F + 0.05 Mid density ± 0.10 Density difference ± 0.10	Daily— before processing any film
Tank level checks clean-up films, clean crossovers	Essential	Visual inspection, Clean-up films	Full tanks, No scratches on films, Clean cross-overs	Daily
Cleaning and preventive maintenance	Essential	As suggested by manufacturer	As indicated by manufacturer	Manufacturer's instructions
Fixer				
Replenishment rate	Essential	Visual inspection	± 5%	Daily
Flow meter accuracy	Essential	Stop watch and graduated cylinder	± 5%	Quarterly
Film washing				
Wash water flow rate	Essential	Visual inspection of water flow meter	± 10%	Daily
Film fixer retention	Essential	Fixer retention test kit	<2 $\mu g/cm^2$ retained thiosulfate	Semiannually

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Processor transport time	Essential	Stop watch	± 3%	Annually
Developer temperature	Essential	Thermometer built into processor	± 0.5 °F	Daily
Wash water temperature	Essential	Thermometer built into processor	± 5.0 °F	Daily
Built-in developer thermometer accuracy	Essential	Calibrated thermometer	± 0.5 °F	Monthly
Developer recirculation filter	Essential	As suggested by manufacturer	As indicated by manufacturer	Manufacturer's instructions
Water filters	Essential	Visual inspection of flow meter	Change when flow rate decreases by more than 10%	Daily
Replenishment rate	Essential	Visual inspection	± 5%	Daily
Flow meter accuracy	Essential	Stop watch and graduated cylinder	± 5%	Quarterly
Daylight systems	Essential	As suggested by manufacturer	As indicated by manufacturer	Manufacturer's instructions
Processor stand-by units (verify function)	Essential	Visual inspection	As indicated by manufacturer	Daily
Automatic chemical mix system	Essential	As suggested by manufacturer	As indicated by manufacturer	Manufacturer's instructions
Silver recovery efficiency	Desirable	Silver test paper, direct reading device, or Hospital laboratory	± 10% of estimated weight	Quarterly

Table 2
Radiographic *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Filtration (HVL)	Essential	Dosimeter, type 1100 aluminum sheets, semi-log paper	See (*40*)	Annually
Light field and *x-ray* field alignment	Essential	Alignment template or nine pennies and tape measure	± 2% of *source*-to-image distance	Semi-annually
Automatic collimation or positive beam limitation and accuracy of x-y scales	Essential	Alignment template or nine pennies and tape measure	± 3% of *source*-to-image distance	Semi-annually
X-ray beam, bucky motion and centering	Essential	Homogeneous *phantom* and lead strips	Lead strips should be centered. Density uniform to ± 0.10 perpendicular to anode-cathode axis	Annually
X-ray beam perpendicularity, and SID indicator accuracy	Essential	Perpendicularity test tool and tape measure	Perpendicularity accuracy provided by tool manufacturer. SID indicator should be within ± 2% of measured value.	Annually
Focal spot size	Essential	Pinhole camera, lead star pattern, or slit	See (*40*)	Acceptance test
Visual checks	Essential	Visual check list	Pass-fail	Annually
Mechanical and electrical safety checks	Essential	See (*40*)	See (*40*)	Annually
Overload protection	Essential	Single *exposure* rating chart	Prevent *exposures* that exceed 80% of tubes's maximum rated load	Annually
kVp	Essential	kVp cassette or direct reading kVp device	± 5%; less over limited range, e.g., ± 2 kVp for 60 to 100 kVp	Annually
timers	Essential	Timing device	Single phase, see (*40*). Three phase, ± 5%	Annually
mR/mAs	Essential	Dosimeter, homogeneous *phantom*	± 10%	Annually

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Linearity	Essential	Dosimeter	± 10% over clinical range	Annually
Exposure reproducibility	Essential	Dosimeter	± 5%	Annually
Phototimers				
Abbreviated tests Sensor panel function	Essential	Lead sheets and dosimeter	± 10% in ***exposure***	Semi-annually
kVp correction circuit		Homogenous ***phantom***	Density of 1.20 ± 0.30	
Proper ***exposure*** at various mA stations		Homogeneous ***phantom*** and dosimeter	± 10% in ***exposure***	
Proper ***exposure*** for various field sizes		Homogeneous ***phantom***	Density of 1.20 ± 0.10	
Phototimer reproducibility		Homogeneous ***phantom*** and dosimeter	± 5% in ***exposure***	
Density control function		Homogeneous ***phantom*** and dosimeter	Steps of 25% in ***exposure***, verify button function, i.e., + gives increase, - gives decrease	
Complete tests All of "abbreviated tests" plus--	Essential			Annually
Sensor panel location		Lead sheets	Pass-fail	
Minimum ***exposure*** time		***Exposure*** timing device	< 10 ms	
Back-up ***exposure*** time		***Exposure*** timing device and lead sheet	< 600 mAs	
Proper ***exposure*** with change in patient size		Homogeneous ***phantom***	Density of 1.20 ± 0.30	
Grid uniformity Bucky grids	Essential	Homogeneous ***phantom***	Uniform films, no grid lines, density of 1.20 ± 0.10 perpendicular to anode-cathode axis	Annually
Grid cassettes and clip-on grids	Essential	Homogeneous ***phantom***	Uniform films, density of 1.20 ± 0.10 perpendicular to anode-cathode axis	Semi-annually
Grid alignment	Essential	Homogeneous ***phantom***	Uniform films, density of 1.0 ± 0.10 perpendicular to anode-cathode axis	Annually

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Screen-film-cassette speed matching	Essential	Standard (comparison) cassette	Densities within ± 0.05 for all cassettes used in one area	Annually
Screen-film contact	Essential	Coarse copper mesh	No significant areas of poor contact	Annually
Exposure per film	Essential	Homogeneous ***phantom*** and dosimeter	Film density of 1.20 ± 0.15 for AP lumbar spine technique and appropriate ***phantom***. ***Exposure*** for AP lumbar spine in 100 to 160 $\mu C\ kg^{-1}$ [a] range or less	Every ***quality control*** check
Matching images and ***exposures***	Essential	Homogeneous ***phantom*** and dosimeter	Film densities within ± 0.15 of average for all rooms. Entrance ***exposures*** within ± 10% for identical rooms	Every ***quality control*** check
X-ray output waveform	Desirable	*X-ray* detector and oscilloscope	Check for spikes, aberrant wave shapes, etc.	Annually

[a] 100 $\mu C\ kg^{-1}$ is equal to 400 mR

Table 3
Fluoroscopic and cine *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
X-ray tubes, collimators, and generators				
All indicated tests	Essential	See (*40*)	See (*40*)	Semi-annually
Maximum fluoroscopic ***exposure*** rates	Essential	Lead sheets and dosimeters	≤1.3 mC kg^{-1a}/min for manual systems; ≤2.6 mC kg^{-1a}/min for automatic ***exposure*** control systems.	Semi-annually
Standard fluoroscopic ***exposure*** rates	Essential	Homogeneous ***phantom*** and dosimeter	0.5 to 0.8 mC kg^{-1a}/min, 6-inch mode, without grid; 0.4 to 0.7 mC kg^{-1a}/min, 9-inch mode, without grid. Automatic ***exposure*** control should set 80 to 90 kVp.	Semi-annually
Spot film and spot film camera ***exposures***	Essential	Homogeneous ***phantom*** and dosimeters	13 to 50 nC kg^{-1a}/image at intensifier; film density of 1.20 ± 0.15. See (*40*)	Semi-annually
Cine film ***exposure***	Essential	Homogeneous ***phantom*** and dosimeter	Approx. 4 nC kg^{-1a}/frame at intensifier for 9-inch mode; approx. 7 nC kg^{-1a}/frame at intensifier for 6-inch mode. See (*40*)	Semi-annually
Automatic brightness, ***exposure***, and gain control systems	Essential	Homogeneous ***phantom*** and dosimeter	ABC-AEC systems should function similar to same installations and other similar systems. AGC should be able to compensate from 3 to 9 inches of acrylic.	Semi-annually
Fluoroscopic, spot film, and cine image size and beam limitation	Essential	Radiographically opaque template, direct ***exposure*** x-ray film	Displayed diameter not less than 1 cm smaller than specified diameter. Error between beam size and image size should be no greater than 3% of SID for all modes and at any tower height.	Semi-annually

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Fluoroscopic, spot film, and cine resolution and distortion	Essential	High and low contrast resolution patterns, homogeneous ***phantom***, distortion grid	See (*40*). Distortion symmetric, same for fluoroscopic, spot film, and cine images	
Radiographic/ Fluoroscopic				Semi-annually
Special procedures labs				Semi-annually
Cardiac catheterization labs				Semi-annually (Each case)
Cine projectors	Essential	SMPTE cine test film	Resolve all resolution elements in image, minimal jitter, clean lenses, prisms, and projection surface, projection bulb clean without metallic deposits	
Image lag	Desirable	Lag shutter, storage oscilloscope and camera	See (*40*)	Semi-annually
Flare	Desirable	Lead disc, video waveform monitor	See (*40*)	Semi-annually
Where low contrast image is important				Quarterly
Relative conversion factor	Desirable	Dosimeter, radiometer	Look for changes over time indicating deterioration of intensifier	Semi-annually

[a] 0.26 mC kg^{-1} = 1 R; 0.26 nC kg^{-1} = 1 μR

Table 4
Mobile radiographic, capacitor discharge, and fluoroscopic systems *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Mobile radiographic				
Batteries (completely discharged, fully charged and serviced)	Essential	As suggested by manufacturer	As indicated by manufacturer	Annually or manufacturer's instructions
All applicable tests	Essential	See (*40*)	See (*40*)	Annually
Capacitor discharge radiographic systems	Essential	See (*40*)	See (*40*) kVp-acceptance test value becomes operating level rather than indicated kVp	Annually
Mobile fluoroscopic systems				
All applicable tests including tests of analog and digital video recording systems	Essential	See (*40*)	See (*40*)	Semi-annually

Table 5
Quality control tests for conventional tomography

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Section level	Essential	Tomographic ***phantom***	± 5 mm	Annually
Level incrementation	Desirable	Tomographic ***phantom***	± 2 mm	Annually
Section thickness	Essential	Tomographic ***phantom***	To be established for the particular unit	Annually
Exposure angle	Desirable	Tomographic ***phantom***	± 5 degrees for wide angle tomography; less for small angle tomography	Annually
Exposure uniformity and pattern	Desirable	Tomographic ***phantom***	Qualitative evaluation	Annually
Spatial resolution	Essential	Tomographic ***phantom***	40 mesh or better	Annually
Patient ***exposure***	Essential	Radiation dosimeter	To be established for the particular unit. See (*40*)	Annually

Table 6
Quality control tests for mammographic equipment

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
kVp accuracy	Essential	Mammographic kVp device	± 2 kVp	Semi-annually
Entrance ***exposure***	Essential	Low-energy ***ionization chamber***	± 10%	Semi-annually
Mammographic low and high contrast resolution	Essential	Resolution ***phantom***	No noticeable deterioration in performance	Semi-annually

Table 7
Dental radiography *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Test film	Essential	Film, CDRH device	± 2 optical density steps	Daily
Test radiograph	Essential	Film	Visual	Daily
Retake log	Essential			Daily
Film processing	Essential	Film, sensitometer, densitometer	< ± 0.1 density	Daily
Operation of darkroom	Essential			Quarterly
Cassette and Screens	Essential	Film, wire mesh	Visual	Annually
Viewboxes	Desirable	Light meter		Annually
X-ray unit leakage radiation	Essential	Survey meter	$<26\ \mu C\ kg^{-1}$*/h at 1 m	Annually
source-end of cone	Essential		>4 in. (<50 kVp) >7 in. (>50 kVp)	Annually
beam alignment and collimators	Essential	Film	$<2^{3}/_{4}$ in. (end of cone)	Annually
filtration (HVL)	Essential	Type 1100 Al filters, *ion chamber*	See (*40*)	Annually
timer	Essential	Spinning top, film		Annually
exposure switch	Essential			Annually
radiation *exposure*	Essential	Calibrated *ion chambers*	Range of acceptable *exposures*	Annually

*26 $\mu C\ kg^{-1}$ = 100 mR.

Table 8
Quality control test for special procedures equipment

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Film changer screen-film contact	Essential	Wire mesh	No significant difference between static and dynamic conditions	Semi-annually
Low and high contrast resolution	Essential	Fluoroscopic resolution test device	No significant difference between static and dynamic conditions	Semi-annually
Optical density of films over duration of filming run	Essential	Fluoroscopic ***phantom***	Optical density difference $< \pm 0.2$	Semi-annually
Cinefluorographic ***exposure*** rates	Essential	Fluoroscopic ***phantom*** and ***ionizing chamber***	Approx. 2.6 to 5 nC/kg^{-1}[a]/frame at intensifier for 23 cm mode; Approx. 5 to 8 nC/kg [a]/frame at intensifier for 15 cm mode. See (*40*)	Semi-annually
Cinefluorographic low and high contrast resolution	Essential	Fluoroscopic resolution test device	No degradation from fluoroscopic measurements	Semi-annually
Ancillary special procedures equipment	Essential	Recommendations of equipment manufacturer	Recommendations of equipment manufacturer	Recommendations of equipment manufacturer

[a] 2.6 nC kg^{-1} = 10 μR.

Table 9
Quality control tests for *CT scanners*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
CT number calibration	Essential	20 cm diameter *phantom*[a]	Air: - 1000 ± 3 CT numbers Water: 0 ± 1.5 CT numbers	Monthly
CT number constancy	Desirable	20 cm diameter *phantom*[a]	Value and std. dev. for water relatively constant	Daily
Hard copy output and visual display	Essential	"Standard" image stored on disk. See (*40*)	Luminance & contrast not significantly different	Daily
Low contrast resolution	Essential	Low contrast *phantom*	0.5 cm holes	Monthly
CT number uniformity	Essential	20 cm diameter *phantom*[a]	Variation ± 5 CT numbers among mean of 100 *pixels*	Monthly
Patient dosimetry	Essential	Dosimetry *phantom*	± 20%	Semi-annually
Table position	Essential	Ruler	± 2 mm	Semi-annually
Table indexing	Essential	Ruler or prepackaged film	± 0.5 mm for each increment	Semi-annually
Table backlash	Essential	Ruler or prepackaged film	± 1 mm	Semi-annually
CT number dependence on slice thickness	Essential	20 cm diameter *phantom*[a]	Mean ± 3 CT numbers ave. over 100 *pixels*	Semi-annually
Dependence of CT number on *phantom* size	Desirable	5 cm to 30 cm diameter *phantom*[a]	± 20 CT numbers	Semi-annually
Accuracy of scout localization view	Essential	Small object in *phantom*	± 1 mm	Annually
Accuracy of distance measurements	Essential	1 cm spaced holes	± 1 mm	Annually
High contrast resolution	Desirable	High contrast *phantom*	0.1 cm holes	Monthly
Distortion of video monitor	Desirable	1 cm spaced holes	± 1 mm anywhere on image projection to life size	Monthly
Sensitivity profile	Desirable	45° wire in *phantom*	FWHM within 1 mm of nominal (5-15 mm) and within 0.5 mm (< 5 mm)	Monthly

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Noise characteristics	Desirable	20 cm diameter *phantom*[a]	Std deviation of CT numbers (mAs)$^{-1/2}$	Semi-annually
Dependence of CT number on *phantom* position	Desirable	20 cm diameter *phantom*[a]	± 5 CT numbers	Annually
Dependence of CT number on algorithm	Desirable	20 cm diameter *phantom*[a]	± 3 CT numbers	Annually

[a] Water filled or water equivalent solid material.

Table 10
Digital imaging systems *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Digital subtraction angiographic imaging systems				
Fluoroscopic and conventional film imaging portions of system	Essential	See (*40*)	See (*40*)	Semi-annually
Digital imaging portion of system	Essential	Patient equivalent *phantom* with removable simulated iodine-filled vessels, step wedge, low contrast resolution pattern, mesh pattern, dosimeters	Low contrast resolution 1.6 c/mm for 6-inch and 1.2 c/mm for 9-inch intensifier; Other tests—similar results to acceptance tests and similar pieces of equipment	Quarterly
Visual (video) display and hard copy camera	Essential	SMPTE test pattern	See (*40*)	Daily

Table 11
Nuclear medicine *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Radiation Calibrator				
Zero setting	Essential			Daily
Background setting	Essential			Daily
Test setting	Essential			Daily
Precision	Essential	^{137}Cs ***source***	± 5%	Daily
Relative response to reference	Essential	^{57}Co, ^{137}Cs and ^{133}Ba ***sources***	± 2-5%	Quarterly
Linearity response	Essential	^{99m}Tc eluant, lead filters	± 5%	Quarterly
Accuracy	Essential	^{57}Co, ^{137}Cs and ^{133}Ba standards	± 5%	Annually
Geometry	Desirable	^{99m}Tc liquid	± 2%	Bi-annually
Scintillation Spectrometer				
Pulse height analyzer	Essential	^{137}Cs ***source***	Voltage or gain adjust	Daily
Background	Essential		$< \pm 3\sigma$	Daily
Precision	Essential	^{137}Cs ***source***	$< \pm 3\sigma$	Daily
60-cycle	Essential	60 cycle pulse signal	3600 ± 1 or 2 counts	Weekly
Chi-square test	Essential	^{137}Cs ***source***	$0.1 < p < 0.9$	Quarterly
Energy calibration	Essential	^{137}Cs ***source***	Voltage or gain adjust	Quarterly
Energy resolution	Essential	^{137}Cs ***source***	8-9% solid crystal 10-12% well crystal	Annually
Linearity	Essential	^{99m}Tc, ^{131}I, ^{137}Cs ***sources***	± 2 keV	Annually
Zero offset	Essential	^{99m}Tc, ^{131}I, ^{137}Cs ***sources***	± 2 keV	Annually
Count rate effects	Essential	^{99m}Tc liquid (high ***activity***), paired ***sources***	correction	Annually
Nonimaging Scintillation Systems				
Precision	Essential	^{137}Cs ***source***	$< \pm 3\sigma$	Daily

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Geometry	Essential	liquid *source*	correction factor	Bi-annually
Rectilinear Scanners				
Precision	Essential	^{137}Cs flood *source*	$< \pm 3\sigma$	Daily
Density calibration	Essential	Point *source*, pulse generator	Within ± 0.2 density	Weekly
Contrast enhancement	Essential	Step wedge	Compare with baseline O.D. vs count density	Quarterly
Collimator spatial resolution	Desirable	Point *source*	Compare 50% response	Annually
Collimator depth of focus	Desirable	Point *source*	Compare 50% response	Annually
Scintillation Cameras				
Uniformity	Essential	^{99m}Tc or ^{57}Co Flood or point *source*	± 6-7% or computer corrected	Daily
Linearity	Essential	Flood or point *source*; bar or hole *phantom*	Visual	Weekly
Resolving power	Essential	Same as above	Visual	Weekly
Relative sensitivity	Essential	Flood or point *source*	± 10%	Weekly
Count rate characteristics	Essential	Different *source activities*	Input count rate for 20% loss	Semi-annually
Energy resolution	Essential	^{99m}Tc or ^{57}Co point *source*	Minimum of 50 channels per FWHM	Annually
System spatial resolution	Desirable	^{99m}Tc line source, scatter material	Comparison with acceptance value	Annually
Imaging Accessories				
Multiformat camera	Essential	Bar or hole *phantom*	See (*40*)	
Video tape systems	Essential		See (*40*)	
Single Photon Emission Computed Tomography				
Uniformity	Essential	Flood *source*	$< \pm 1\%$ corrected	Daily
Center of rotation	Essential	Point *source*	$< \pm 0.5$ *pixels* (< ± 2 mm)	Weekly
Pixel sizing	Essential			Weekly

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Table-camera	Essential		Within ± 2 mm	Weekly
Spatial resolution	Desirable	Line *sources*, scattering medium, high or medium sensitivity collimator		Annually
Phantoms	Desirable			
Camera-computer interface	Desirable	Point *source*		Annually

Table 12
Ultrasound *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Depth calibration accuracy	Essential	***Phantom*** or test object	± 1%	Monthly
Digital caliper accuracy	Essential	***Phantom*** or test object	± 1% vertical ± 3% horizontal	Monthly
Compound scan misregistration	Essential	***Phantom*** or test object	5 mm maximum separation	Quarterly
Externally referenced measurement accuracy	Essential	***Phantom*** or test object	Tolerance varies with the clinical need	Annually
System sensitivity	Essential	Tissue-mimicking ***phantom***	Max. visualization depth within ± 1 cm	Monthly
Gray scale display and photography	Essential	Tissue ***phantom***/patient image	Same gray bars visualized; All parenchymal scatterers detected	Daily
M-mode depth calibration and Time markers	Essential	***Phantom*** or test object	± 1% depth calibration; time markers ± 10%	Quarterly
Spatial resolution	Desirable	***Phantom***		Annually
Gray scale dynamic range	Desirable	Gray scale ***phantom***; Electronic burst ***generator***	Within ± 5 dB	Annually
Air filters	Essential	Examination	Clean	Monthly
Cables	Essential	Examination	Intact	Monthly

Table 13
Video imaging systems *quality control*

Test	Essential or desirable	Test device	Suggested performance criteria	Minimum frequency
Video signal levels and line terminations	Essential	Video waveform monitor or oscilloscope	75 —ohm termination at *end* of video cable; video signal— ± 5% of peak-to-peak voltage.	Semi-annually
Television monitors	Essential	Video signal generator	All 10% steps visible, minimal distortion, resolution as specified by manufacturer	Semi-annually
Hard copy cameras and visual displays	Essential	SMPTE test pattern	Mid-density ± 0.15, film and visual display should give similar appearing images, 5% and 95% patches should be visible on film and visual display. Resolution should be consistent.	Daily
Video tape, disc, and digital recorders	Essential	Video signal generator, SMPTE video test tapes, video waveform monitor, high & low contrast *x-ray* resolution patterns	All 10% steps visible, minimal distortion, resolution as specified by manufacturer, drop-outs and jitter minimal, some increase in noise will be apparent in gray scale, some (minimal) loss in contrast between *x-ray* (fluoroscopic) and recorded image should be anticipated	Semi-annually