ATOMIC ENERGY COUNCIL

ATOMIC ENERGY COUNCIL CRITERIA FOR ACCEPTABILITY OF MEDICAL RADIOLOGICAL EQUIPMENT

Authorization

Under section 74 of the Atomic Energy Act N0.24 of 2008, issues guidelines for improving radiation safety at facilities using radiation generators.

Users of radiation generators are responsible for ensuring that the radiological equipment is working properly to avoid unjustified doses to the exposed person.

Approval

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1.0 INTRODUCTION

Regulations 49 (3) (a)-(c) of the Atomic Energy Regulations requires authorized persons to ensure that quality control tests are performed on their equipment. The results of these tests should be maintained and availed to AEC on request. This guide provides a compilation of criteria which radiological equipment in normal use should be able to pass. In order to ensure radiation protection and safety of the patients, workers and the members of the public, suspension levels have been set for each performance parameter of the equipment.

At suspension level, the equipment is temporarily suspended from use or taken out of service. The operator is advised to rectify the error in the equipment. Beyond suspension levels, it is expected that the user of the equipment must repair the equipment to correct for the deficiencies. Failure to do so will automatically lead to the equipment made inoperable by Council upon discovery till a commitment is made to repair it. Therefore, all users of the radiation equipment must

- Perform initial acceptance testing of new equipment,
- Identify criteria of acceptability for equipment safety and performance throughout its life, and
- Establish and implement quality assurance programmes.

1.1 Purpose

The purpose of this document is to provide criteria for acceptability for different performance parameters on the different equipment in medical exposure.

1.2. End-users of this document

The primary audience to which this report is addressed is the holders and end-users of the equipment specifically health care agencies and professionals, including hospitals, other institutions, medical physicists, practitioners, radiographers, clinical technologists and other staff/agents including health service management professionals, all of whom have a role in the deployment of equipment for use with patients.

In addition, it is of value to Atomic Energy Council Inspectors in assessing if holders of radiological installations meet their obligations with respect to equipment performance standards.

1.3 How to use the document

Facilities should carry out the different quality control tests on the equipment and the results should conform to those stated in the different tables in the subsequent sections. However, facility owners are encouraged to set their own action levels in line with the manufactures recommendations. Therefore, after machine repairs, the machines must be recalibrated to ensure that the performance parameters do not exceed the action levels as well as suspension levels.

2.0 X-Ray Generators and Equipment for General Radiography

The following X-ray generators and equipment shall be deemed unacceptable

i. Equipment without the ability to collimate the beam,
ii. Systems intended to include paediatric use, without the option to remove the grid,

iii. Equipment without a device (where practicable) to show the quantity of radiation,
iv. Equipment without AEC devices (where practicable)

The suspension levels for X-Ray generators and general radiography systems are as shown in Table 1

Table 1: Suspension Levels for General Radiography System

#	Physical parameter	Suspension level
X-ray tube and generator		
1.	Tube voltage accuracy	Deviation from set voltage > 10 % or 10 kVp whichever is the greater
X-ray tube output		
2.	Magnitude of output at 1m	Output outside range of 25 to 80 µGy/mAs at 80 kV and total filtration of 2.5 mm Al
3.	Repeatability of output for a Fixed setting	COV > 20 %
4.	Consistency of output in µGy/mAs for a range of mA and mAs values	COV > 20 %
Exposure time		
5.	Accuracy of exposure time	Deviation from set time > 20 % (for times ≥ 100 ms). Deviation from set time > 30 % (for times < 100 ms)
Alignment		
6.	X-ray/light beam alignment	Misalignment in any direction > 3 % of focus-image receptor distance
7.	Light beam/bucky centering	Alignment of crosswire with center of Bucky > 1% of focus-image receptor distance
Collimation		
8.	Automatic collimation	X-ray beam outside the active area of the image receptor > 2% of the focus-image receptor distance
Grid		
9.	Grid artefacts	If significant grid artefacts are visible
10.	Moving grid	If lamellae visible on image
Focal Spot (FS) and Resolution		
11.	Spatial resolution (as indicator of focal spot integrity)	< 1.6 lp/mm
Leakage radiation		
12.	Leakage radiation	KA(1 m) > 1 mGy in one hour at maximum rating specified by the manufacturer
Dosimetry		
13.	Integrated "dose indicator" calibration (DAP/KAP meter accuracy)	Overall uncertainty > ± 25 %
14.	HVL (refer to tables below)	

Table 2: Suspension levels for minimum first HVL

Parameter	Suspension level
X-ray Tube Voltage kV	Minimum permissible first HVL mm Al
50	1.8
60	2.2
70	2.5
80	2.9
90	3.2
100	3.6
110	3.9
120	4.3
130	4.7
140	5.0
150	5.4

Table 3: Automatic exposure Control Suspension Levels for Film/ Screen systems

#	Physical Parameter	Suspension Level
1.	Limitation of overexposure	Focal spot charge > 600 mAs
2.	Verification of AEC optical density (OD) under reference conditions	OD outside of range 0.9 - 1.4
3.	Repeatability of OD	Film density > ±0.3 OD from mean value
4.	Verification of sensors of AEC	Film density for each sensor > ±0.5 OD from mean value
5.	Verification of AEC	Film density for a phantom thickness > ±0.3 OD from mean value for all thicknesses

Table 4: Automatic Exposure Control Suspension Levels for Computed Radiography (CR) and Direct Digital Radiography (DDR)

#	Physical Parameter	Suspension Level
1.	Limitation of overexposure	Maximal focal spot charge > 600 mAs
2.	Verification of receptor air-kerma for CR and DDR Systems under AEC	≥ 10 µGy
3.	AEC device repeatability	DDI or measured kerma differs by > 40 % from mean value
4.	Verification of AEC at various phantom thicknesses	DDI or measured kerma for a given phantom thickness differs by > 40 % from mean value for all thicknesses

3.0 Suspension Levels for Image Receptors

The Suspension Levels for screens, cassettes, CR and DDR are presented in Tables 17-20 below excluding mammography or dental radiography. Installation and calibration of a CR system is extremely important. It is also essential to note that the X-ray systems needs to be properly set up for use with CR/DDR systems. Likewise, with DDR systems, the tube, generator, workstation and/or laser printer must be known to be working properly.

Table 5: Suspension Levels for screens (mammography and dental excluded)

#	Physical Parameter	Suspension Level
1.	Screens and Cassettes	Significant visible artefacts present.
2.	Relative Speed of batch of Intensifying Screens	Deviations from mean relative speed > 20%
3.	Film Screen Contact	Non-uniform density or loss of sharpness.

Table 6: Suspension Levels for cassettes and Computed Radiography Plates

#	Physical Parameter	Suspension Level
1.	Condition of cassettes and image plates	Damage to plate
2.	Visual check of uniformity	Artefacts likely to affect clinical image quality

Table 7: Suspension Levels for Computed Radiography readers

#	Physical Parameter	Suspension Level
1.	Dark Noise	Agfa SAL>100 Fuji pixel value > 284 Kodak EIGP > 80 Kodak EIHR > 380 Konica pixel value < 3975
2.	Signal Transfer Properties (STP)	If relationship unknown or complex
3.	Measured uniformity	Deviation from mean value of STP corrected ROI values > 20 %
4.	Erasure cycle efficiency	> 1 %
5.	Detector Dose Indicator (DDI) repeatability	Deviation from mean value of DDI > 20 %
6.	Scaling errors: (distance measurement)	Errors > 4%
7.	Blurring	Clinically significant visible blurring present
8.	Image quality: High Contrast Limiting Spatial Resolution	Spatial resolution < 2.8 lp/mm for dose ≤ 10 μGy Spatial resolution < 2.4 lp/mm for dose ≤ 5 μGy.
9.	Image Quality: Low Contrast Resolution	< 7 steps are visible
10.	Laser beam function	Occasional jitter
11.	Moiré Patterns (wavelike, cloudy or frosted appearance of textile fabrics or metallic surfaces	Moiré Patterns visible

Table 8: Suspension Levels for Direct Digital Radiography system

#	Physical Parameter	Suspension Levels
1.	Dark Noise	Excessive noise in the system
2.	Signal transfer properties (STP)	Relationship unknown or complex
3.	Image retention	> 1 %
4.	Detector Dose Indicator (DDI) repeatability	Deviation from mean value of DDI > 20 %
5.	Measured and visual uniformity	Deviation from mean value of STP corrected ROI values > 20 %
6.	Scaling errors	Errors > 4%
7.	Blurring / line defects / stitching artefacts	Clinically significant visible blurring present or defective lines
8.	Image quality: High contrast Limiting Spatial Resolution	Spatial resolution < 2.8 lp/mm for dose ≤ 10 µGy. Spatial resolution < 2.4 lp/mm for dose ≤ 5 µGy
9.	Image Quality Low Contrast Resolution	< 7 steps are visible

4.0 Dual Energy X-ray Absorptiometry

Dual-energy X-ray absorptiometry (DXA) is a widely used method for quantifying Bone Mineral Density (BMD) and body mass composition assessment.

Table 9: Suspension Levels for DXA Equipment

#	Physical Parameter	Suspension Level
1.	Entrance surface air-kerma (incl. backscatter	> 500 µGy, (spine examination) or outside manufacturer's specification by > 35 %
2.	BMD precision of an individual machine	Deviation of measured BMD > 3 % from manufacturer's specification
3.	Other features of x- ray generator	Use Table 1-5 as appropriate

5.0 DENTAL RADIOGRAPHY.

The following Intra-oral Dental Equipment shall be deemed unacceptable

i. Film class lower than E for which special justification has not been made
ii. Non rectangular collimators on intraoral equipment, for which special justification has not been made
iii. Rectangular collimation on intra oral equipment, resulting in a field size greater than 40 x 50 mm

Suspension levels for various types of dental equipment are provided for in Table 1

Table 1: Suspension Levels for Dental X-ray Tubes and Generators (excluding Cone Beam Computed Tomography CBCT)

#	Physical parameter/test	Suspension level
1.	Tube voltage range, Intra Oral	Outside the range 60 to 90 kVp
2.	Tube voltage range, Cephalometric and all others except CBCT	Outside the range 60 to 125 kVp
3.	Tube voltage accuracy	Deviation from set kVp > 10 %
4.	Exposure time accuracy	Deviation from set exposure time > 20%
5.	Exposure time precision	Deviation from measured value of time > 10 %
6.	Repeatability of radiation output	Deviation from mean measured output >20 %
7.	Focus Skin Distance for Intra Oral Equipment	< 20 cm
8.	HVL	Operating voltage <70 kVp, HVL < 1.5 mm Al, refer to Table 2 & 3 for more
9.	Leakage radiation at Im from focus	>0.25 mGy/h –Standard I/O units >1.0 mGy/h - Ceph & OPG units

Table 2: HVL- Minimum Values

kVp	HVL (mm Al)	
	intraoral	Ceph/OPG
60	1.5	1.8
70	1.5	2.1
80	2.3	2.3
90	2.5	2.5

Table 3: Suspension Levels for Dental Cone Beam Computed Tomography Equipment

#	Physical parameter	Suspension level
1.	**X-ray tube and generator**	
	Tube voltage accuracy	Deviation from set voltage > 10 % or 10 kVp whichever is the greater
	Magnitude of output (Y) at 1m	Y outside range of 25 to 80 µGy/mAs at 80 kV and total filtration of 2.5 mm Al
	Repeatability of output for a Fixed setting	Deviation from mean value of measurements > 20 %
	Consistency of output in µGy/mAs for a range of mA and mAs values	Deviation from mean value of measurements > 20 %
2.	**Dosimetry**	
	Integrated "dose indicator" calibration (DAP/KAP meter accuracy)	Deviation of the measured and indicated values > 35 %
	DAP/KAP	Deviation > 2 x achievable dose
	CTDI – free in air	Does not meet manufacturer's specification or deviation from baseline > 40 %
3.	**Field of View and alignment**	
	Field of View	Field > size of the solid detector
4.	**Image quality**	
	Image noise	Deviation from baseline > 25 %
	Spatial resolution	< 1 lp/mm (in high resolution mode)
	Image density values	Deviation from manufacturer's specification > 25 %
	Artefacts	Any artefacts likely to impact on clinical diagnosis

Table 4: Suspension Levels for Dosimetry for dental systems excluding Cone Beam Computed Tomography

#	Physical Parameter	Suspension Level
1.	**Intra-Oral**	
	Incident air kerma for mandibular lower molar tooth	> 4 mGy
2.	**Panoramic Systems**	
	Kerma area product of a typical clinical exposure or calculated kerma area product from dose width product or equivalent	> 100 mGycm2 or current national reference dose
3.	**Cephalometry Systems**	
	Incident air kerma for skull AP/PA	> 3 mGy
	Incident air kerma for skull lateral	> 1.5 mGy

6.0 FLUOROSCOPY

The following Fluoroscopy Equipment shall be deemed Unacceptable

i. Equipment without a device (where practicable) to show the quantity of radiation, Equipment using direct fluoroscopy.
ii. Equipment without a functioning audible 5 minute timer.
iii. Equipment without devices to control the dose rate in the absence of special justification.
iv. Systems intended to include paediatric use, without the option to remove the grid.
v. Equipment without beam collimation facilities

Table 1: Suspension levels for fluoroscopy equipment

#	**Physical parameter**	**Suspension level**
1.	Collimation Limits	Deviation > 3 % of SID in either lateral or longitudinal directions or > 4 % for the sum of the two directions
2.	Radiation/Image field size	Radiation area > 1.25* image area
3.	Patient Entrance Dose Rates (Fluoroscopy/normal mode)	> 100 mGy/min at appropriate position
4.	Patient Entrance Dose per frame (Normal digital fluorographic acquisition mode)	> 2 mGy/frame For cardiac mode: > 0.2 mGy/frame
5.	Image receptor Air Kerma Rate (Fluoroscopy normal mode)	> 1 µGy/second
6.	Image receptor Air Kerma per frame. (Normal digital fluorographic acquisition mode)	> 5 µGy/frame For cardiac mode: > 0.5 µGy/frame.
7.	Integrated "dose indicator" calibration (DAP/KAP meter accuracy)	Deviation of the measured and indicated values >35 %
8.	Limiting spatial	Fluoroscopy: 36-40 cm: <= 0.7 Lp/mm 30-35 cm: <= 0.8 Lp/mm 25-29 cm: <= 0.9 Lp/mm 20-24 cm: <= 1.0 Lp/mm 15-18 cm: <= 1.25 Lp/mm Fluorography: Base line reduced by 2 groups
9.	High contrast resolution	Spatial Resolution: < 0.8 lp/mm for field sizes > 25 cm < 1 lp/mm for field sizes ≤ 25
10.	Low contrast sensitivity (Fluoroscopy mode)	Threshold Contrast: >4 %
11.	Radiation output using manual settings	Output outside range of 25 to 80 µGy/mAs at 80 kV and total filtration of 2.5 mm Al

7.0 COMPUTED TOMOGRAPHY

The following CT equipment shall be deemed Unacceptable

i. Lack of paediatric protocols in scanners used with children
ii. Single slice CT scanners that have not been subject to a formal risk assessment in respect of the procedures for which they are being used
iii. Scanners with artefacts likely to impact on clinical diagnosis
iv. Absence of indication of CTDIw or CTDIvol in new equipment
v. Absence of a Digital Imaging Communication in Medicine (DICOM) structured dose report in new equipment.

Table 1: Suspension Levels for CT Scanners

#	Physical parameter	Suspension level
1.	Accuracy of indicated dose parameters (CTDIvol)	Deviation of measured dose from indicated dose> 20 %
2.	Patient protocol doses (CTDIvol)	Adult routine Head (acute stroke) >80 mGy Adult Abdomen >30 mGy Paediatric Abdomen (5 year old) > 25 mGy
3.	CTDI free-in-air	Deviation of CTDI free-in-air from manufacturer's specifications > 20 %
4.	Image noise	Deviation of CT number accuracy >10 HU for water up to 30cm diameter
5.	CT number uniformity	Deviation of CT number from specified value> 10 HU for water up to 20cm diameter Deviation of CT number from specified value > 20 HU for water above 20cm diameter
6.	Image slice width	Deviation of image slice width from nominal value >0.5 mm for < 1 mm ; > 50 % for slices of 1 to 2 mm; > 1 mm for slices above 2 mm
7.	Irradiated beam width	Deviates from manufacturers' specifications
8.	CT alignment lights	> ± 5 mm
9.	Scan Projection Radiography (SPR) accuracy	> ± 2 mm
10.	Spatial resolution	Deviation ≥ 10% from manufacturer's specification or 0.5 lp/mm whichever is greater
11.	Couch top alignment and index accuracy	Deviation > 2 mm from specified distance

8.0 MAMMOGRAPHY

The following Mammography Equipment shall be deemed Unacceptable

i. Equipment without AEC.
ii. Non digital equipment without a grid.
iii. Equipment with the focus-to- image receptor distance less than 60 cm
iv. Equipment with a field of view less than 18 x 24 cm^2 (excluding stereotactic devices).
v. Equipment without a foot pedal operated motorized compression plate and readout of compression thickness and force.

Table 1: Acceptance Criteria for Mammography

UNIT ASSEMBLY	Physical parameter /TEST	Acceptance criteria
Radiological Equipment	1. Radiation leakage	<1 mGy/h at 1 m
	2. kV Accuracy of the tube	within +-5%, suspension >10%
	3. kV repeatability (reproducibility) of the tube	COV ≤2%, suspension >2%
	4. Half value layer	Not less than 0.28 mm Al @ 28 kVp for Mo, Mo
	5. Output repeatability (reproducibility)	COV 5%
	6. Output linearity	within ±10%
	7. Normalized output value	Greater than 30 µGy/mAs at 1 m, 28 kV, Mo/Mo
Compression	8. Compression force (Power and manual)	Power Comp: 150 N<200 N; Manual Comp: <300 N i.e No breast compression device shall be able to apply a force exceeding 300 N; For power-driven compression, the breast compression device shall be able to apply a force of at least 150 N, and it shall be unable to apply a force exceeding 200 N;
	9. Compression force: Accuracy	±20 N
	10. Compression thickness accuracy	5mm
Automatic Exposure Control	11. Repeatability of the automatic exposure control	mAs: COV 5%
	12. Compensation for different kV and thicknesses (and target/filter combination):	Acceptable: Maximum deviation from OD target 0.2
	13. Density control setting	Difference per step %mAs: 12%–15%, change: ΔOD : 0.1–0.2
	14. Exposure time 45 mm thick PMMA test	Contact mammography: Acceptable: t < 2s Magnification mammography: Acceptable: t <3 s
Collimation System	15. Light field/radiation field coincidence: 1% of FFD on any side	within 1% of FFD on any side
	16. Radiation field/image receptor coincidence	Acceptable: Chest side 0 to 5 mm; ≤2% of FFD for other three sides

	17. Compression paddle/breast support alignment	+1% of FFD
Image Quality	18. High contrast resolution	>10 lpmm (group 19)
	19. Threshold contrast resolution	➢ 1.4% for 5-6 mm details (group 6) ➢ 8% for 0.5 mm detail (group 6) ➢ 11% for 0.25 mm detail (group 5)
Dosimetry	20. Mean glandular dose	Acceptable: MGD 2.5 mGy

Table 2: Suspension Levels for Mammography

#	Physical Parameter	Suspension Level
1.	AEC short term Repeatability	Deviation from mean value of mAs > 15%
2.	X-ray/Image receptor Alignment	X-ray field extending beyond the image receptor > 5 mm on any side. Chest wall side: distance between image receptor and edge > 5 mm
3.	Compression	No breast compression device shall be able to apply a force exceeding 300 N; For power-driven compression, the breast compression device shall be able to apply a force of at least 150 N, and it shall be unable to apply a force exceeding 200 N;
4.	Compression Force Consistency	Change in force > 20 N
5.	Tube voltage	Deviation of tube voltage > 2 kVp from set value
6.	Exposure Time	> 2 s for standard breast 4.5 cm PMMA
7.	Specific radiation output	≤ 120 µGy/mAs @ 50cm for 28 kVp, Mo, Mo
8.	Dosimetry (Average Glandular Dose, AGD)	2 cm > 1 mGy 3 cm > 1.5 mGy 4 cm > 2 mGy 4.5 cm > 2.5 mGy 5 cm > 3 mGy 6 cm > 4.5 mGy 7 cm > 6.5 mGy
9.	HVL	< 0.28 mm Al @ 28 kVp for Mo, Mo

Table 3: Suspension Levels for Film/Screen Mammography Systems

#	Physical Parameter	Suspension Level
1.	Standard Film Density	OD < 1.3 or > 2.1
2.	AEC Thickness Compensation	Deviation from mean value of OD > ±0.15 from standard breast (4.5 cm PMMA) for 2 cm to 7 cm of tissue-equivalent material.
3.	Film/Screen Contact	>1 cm^2 of poor contact
4.	High Contrast Resolution	< 12 lp/mm
5.	Threshold Contrast	> 1.5% for 5-6 mm detail

Table 4: Suspension levels for Digital Mammography Systems

#	Physical Parameter	Suspension Level
1.	AEC Thickness Compensation	With Contract to Noise Ratio calculated from 5 cm of PMMA and 0.2 mm Al and X-ray exposure to just pass the contrast/detail criteria set as a reference, CNR at other thicknesses of PMMA acquired under clinical conditions should not be 2.0 cm < 115 % 3.0 cm < 110 % 4.0 cm < 105 % 4.5 cm < 103 % 5.0 cm < 100 % 6.0 cm< 95 % 7.0 cm< 90 %
2.	Threshold Contrast	With clinical exposure using an equivalent of 5cm PMMA > 0.85 % 5-6 mm > 2.35 % 0.5 mm > 5.45 % 0.25 mm > 23.0 % 0.10 mm

Table 5: Suspension Levels for stereotactic biopsy tables

#	Physical Parameter	Suspension Level
1.	Threshold contrast	With clinical exposure using an equivalent of 5cm PMMA, contrast threshold value > 1.25 % for 5-6 mm details > 5 % for 0.5 mm details > 8 % for 0.25 mm details
2.	Accuracy of localization	Deviation in alignment > 1 mm in X and Y or > 3 mm in Z

9.0 NUCLEAR MEDICINE

The safe, efficient and efficacious practice of nuclear medicine involves the integration of a number of processes. The quality of each process will have an impact on the overall quality of the clinical procedure and ultimately on the benefit to the patient. This section gives tables for Activity meters, well counters and probes, gamma camera systems, positron emission tomography and combined modality systems.

Table 1: Suspension Levels for Activity Meters

#	Physical Parameter	Suspension Level
1.	Accuracy	> 5 %
2.	Linearity	> 5 %
3.	System reproducibility	> 1 %

Table 2: Suspension Levels for Well Type Gamma Counters and Probes

#	Physical Parameter	Suspension Level
1.	Count rate performance	> 5 %
2.	Energy resolution	> 10 %
3.	Counting precision	Within the 95 % confidence limits of a chi square test

Table 3: Suspension Levels for Gamma Camera Systems

#	Physical Parameter	Suspension Level
1.	Intrinsic Spatial Resolution	> 6 mm
2.	Intrinsic energy resolution	> 15 %
3.	Multiple window spatial registration (for systems used for dual isotope studies)	> 1 pixel
4.	Differential and Integral System/Intrinsic Non-uniformity	> 7 %
5.	Detector to detector sensitivity variation (systems with opposing detectors)	Variation > 10 %
6.	System alignment (systems with opposing detectors)	Misalignment > 1 pixel

Table 4: Additional Suspension Level for Whole Body Imaging Systems

#	Physical Parameter	Suspension Level
1.	Whole Body Spatial Resolution Without Scatter	> 10 mm at 10 cm

Table 5: Additional Suspension Levels for Single Photon Emission Computed Tomography (SPECT) Systems

#	Physical Parameter	Suspension Level
1.	Centre of Rotation (CoR) and Detector Head Tilt	Offset > 1 pixel
2.	SPECT System Spatial Resolution	FWHM > 15 mm

Table 6: Suspension Levels for Positron Emission Tomography (PET) Systems

#	Physical Parameter	Suspension Level
1.	Spatial Resolution	> 7 mm
2.	Sensitivity	< 1 cps/kBq for 2D imaging and < 4 cps/kBq for 3D imaging

Table 7: Suspension Level for the Image Registration of Combined Modality System

#	Physical Parameter	Suspension Level
1.	Image registration	> 1 SPECT or PET pixel size

10.0 RADIOTHERAPY

This section includes linear accelerators, simulators, CT simulators, Cobalt-60 units, kilovoltage units, brachytherapy, treatment planning systems and dosimetry equipment.

10.1 Linear Accelerators

Essentially for the safe operation of the equipment, the suspension levels for linear accelerators are as shown in Table 1 below.

Table 1: Suspension Levels for Linear Accelerators

#	Physical Parameter	Suspension Level
1.	**Uniformity of radiation fields**	
	X-radiation	
	Flatness of square X-ray fields (max/min ratio)	> 1.06
	Symmetry of square X-ray fields (max/min ratio)	> 1.03
	Maximum deviation of wedge factor with all angular positions of the gantry and beam limiting system	2 %
	Maximum deviation of wedge angle	2°
	Maximum deviation of dose distribution of electron fields with angular position	3 %
	Symmetry of electron fields (max/min ratio)	>1.05
	Maximum ratio of absorbed dose (max/min ratio)	1.09
2.	**Dose monitoring system**	
	Weekly calibration check	>2 %
	Reproducibility	>0.5 %
	Proportionality	>2 %
	Dependence on angular position of gantry and beam limiting device	>3 %
	Dependence on gantry rotation	>2 % - electron radiation >3 % - X-radiation
	Stability throughout the day	>2 %
3.	**Depth dose characteristics**	
	X-radiation	
	Penetrative quality	>3 % or 3 mm
	Depth dose and profiles	>2 %
	Electron radiation	
	Minimum depth of dose maximum	>1 mm
	Ratio of practical range at 80% absorbed dose.	>1.6
	Deviation of actual value of penetrative quality	>3 % or 2 mm
	Maximum relative surface dose	100 %
	Stability of penetrative quality	>1 % or 2 mm
	Indication of radiation fields	
	X-radiation	
	Numerical field indication	>3 mm or 1.5 %
	For MLCs	>3 mm or 1.5 %

	Light field indication	>2 mm or 1 %
	Maximum distance between the centres of radiation and light fields	2 mm
	Maximum distance between the centres of radiation and light fields for MLCs	2 mm
	Maximum distance between the centres of radiation and light fields for SRS/SRT	0.5 mm
	Reproducibility	>2 mm
	Alignment of an SRS stereotactic frame	>0.5 mm
	Electron radiation	
	Light field indication	>2 mm
	Geometry of adjustable BLDs	
	Maximum angular deviation from parallelity of opposing edges	0.5°
	Maximum angular deviation from orthogonality of adjacent edges	0.5°
	Maximum displacement of the radiation field from symmetry when rotating the beam limiting system	2 mm
	Illuminance and penumbra of the light field	
	Illuminance (minimum)	25 lux
	Edge contrast ratio (minimum)	4.0
4.	**Indication of the radiation beam axis**	
	On entry	
	X-rays	>2 mm
	Electrons	>4 mm
	SRS	>0.5 mm
	On exit	
	X-rays	>3 mm
	SRS	>0.5 mm
5.	**Isocentre**	
	Maximum displacement of radiation beam axis from isocentre	2 mm
	Mechanical isocentre	>1 mm
	Indication of the isocentre	>2 mm
	Indication of the isocentre for SRS	>0.5 mm
6.	**Indication of distance along the radiation beam axis**	
	Maximum difference for isocentric equipment	2 mm
	Maximum difference for non-isocentric equipment	5 mm
7.	**Zero position of rotational scales**	
	Gantry rotation	>0.5°
	Roll and pitch of radiation head	>0.1°
	Rotation of beam limiting system	>0.5°
	Isocentric rotation of the patient support	>.5°
	Table top rotation, pitch and roll	>0.5°
	Accuracy of rotation scales	>0.5°
8.	**Congruence of opposed radiation fields**	> mm
9.	**Movements of patient support**	

	Vertical movements	>2 mm
	Longitudinal and lateral movements	>2 mm
	Isocentric rotation axis	>2 mm
	Parallelism of rotational axes	>0.5°
	Longitudinal rigidity	>5 mm
	Lateral rigidity	>0.5° and 5 mm
10.	**Electronic imaging devices**	
	Minimum detector frame time	0.5 s
	Corresponding maximum frame rate	2 / s
	Minimum signal-to-noise ratio	50
	Maximum imager lag	
	Second to first frame	5 %
	Or fifth to first frame	0.3 %
	Minimum spatial resolution	0.6 lp/mm

10.2 Radiotherapy Simulators

Table 2: Suspension Levels for Radiotherapy Simulators

#	Physical Parameter	Suspension Level
1.	**Indication of radiation fields**	
	Numerical field indication	>2 mm or 1.0 %
	Numerical field indication for MLCs	>2 mm or 1.0 %
	Light field indication	>1 mm or 0.5 %
	Maximum distance between the centres of radiation and light field	>1 mm or 0.5 %
	Maximum distance between the centres of radiation and light field for MLCs	>1 mm or 0.5 %
	Reproducibility	>1 mm
	Delineator geometry	
	Angular deviation from parallelity of opposing edges	>0.5°
	Angular deviation from orthogonality of adjacent edges	>0.5°
	Displacement of the radiation field from symmetry when rotating the beam limiting system	>2 mm
	Light field	
	Field size (10x10 cm^2)	>1 mm
	Minimum illuminance	50 lux
	Minimum edge contrast ratio	4.0
2.	**Indication of the radiation beam axis**	
	On entry	>1 mm
	On exit	>2 mm
3.	**Isocentre**	
	Displacement of radiation beam axis from isocentre	>1 mm
	Mechanical isocentre	>1 mm
	Indication of the isocentre	>1 mm

4.	**Indication of distance along the radiation beam axis**	
	From isocentre	>1 mm
	From radiation source	>2 mm
	Image receptor to isocentre	>2 mm
5.	**Zero position of rotational scales**	
	Gantry rotation	>0.5°
	Roll and pitch of radiation head	>0.1°
	Rotation of delineator	>0.5°
	Isocentric rotation of the patient support	>0.5°
	Table top rotation, pitch and roll	>0.5°
	Accuracy of rotation scales	>0.5°
6.	**Congruence of opposed radiation fields**	>1 mm
7.	**Movements of patient support**	
	Vertical movements	>2 mm
	Longitudinal and lateral movements	>2 mm
	Isocentric rotation axis	>1 mm
	Parallelism of rotational axes	>0.5°
	Longitudinal rigidity	>5 mm
	Lateral rigidity	>0.5° and 5 mm
8.	**Electronic imaging devices**	
	Minimum detector frame time	0.5 s
	Corresponding maximum frame rate	2 / s
	Minimum signal-to-noise ratio	50
	Maximum imager lag	
	Second to first frame	5 %
	Or fifth to first frame	0.3 %
	Minimum spatial resolution	0.6 lp/mm
9.	**Radiographic QC**	
	Alignment of broad and fine foci images	>0.5 mm
10.	**Alignment of Shadow Trays**	>1 mm

10.3 CT Simulators

CT simulators usually comprise a wide bore CT scanner, together with an external patient positioning and marking mechanism using projected laser lines to indicate the treatment isocentre. This is often termed "virtual simulation".

Table 3: Suspension Levels for CT Simulators

#	Physical Parameter	Suspension Level
1.	**Alignment of CT Gantry Lasers**	
	With centre of the imaging plane	> 2 mm
	Parallel & orthogonal over length of laser projection	> 2 mm
2.	**Alignment of Wall Lasers**	
	Distance to scan plane	> 2 mm
	With imaging plane over length of laser projection	>2 mm
3.	**Alignment of Ceiling Laser**	
	Orthogonal with imaging plane	> 2 mm
4.	**Orientation of Scanner Table Top**	
	Orthogonal to imaging plane	> 2 mm
5.	**Scales and Movements**	
	Readout of longitudinal position of table top	> 1 mm
	Table top indexing under scanner control	> 2 mm
	Gantry tilt	> 1º from vertical
6.	**Scan Position**	
	Scan position from pilot images	> 1 mm
7.	**Image Quality**	
	Left & right registration	None
	Image scaling	>2 mm
	CT number/electron density verification	> 20 HU (all materials)

10.4 Cobalt-60 units

Table 4: Suspension Levels for Cobalt-60 Units

#	Physical Parameter	Suspension Level
1.	**Uniformity of radiation fields**	
	Flatness of square fields (max/min ratio)	>1.06
	Symmetry of square fields (max/min ratio)	>1.04
	Wedge fields	
	Maximum deviation of wedge factor with gantry angle	2 %
	Maximum deviation of wedge angle with all angular positions of the gantry and beam limiting system	2º
	Source position (when applicable)	>3 mm
2.	**Controlling Timer and Output Checks**	
	Timer check on dual timer difference	>1 s

	Weekly calibration check	>2 %
	Reproducibility	>0.5 %
	Proportionality	>2 %
	Dependence on gantry rotation	>1 %
	Timer linearity	>1 %
	Stability of timer	> 0.01 min
	Output vs field size	>2 %
	Shutter correction	>2 %
3.	**Depth dose characteristics**	
	Penetrative quality	>1 %
	Depth dose and profile	>2 %
4.	**Indication of radiation fields**	
	Numerical field indication	>3 mm or 1.5 %
	Light field indication	>2 mm or 1 %
	Maximum distance between the centers of radiation and light field	>2 mm or 1 %
	Reproducibility	>2 mm
	Collimator geometry	
	Angular deviation from parallelity of opposing edges	>0.5°
	Angular deviation from orthogonality of adjacent edges	>0.5°
	Displacement of the radiation field from symmetry when rotating the beam limiting system	>2 mm
	Light field	
	Field size (10x10 cm^2)	>2 mm
	Minimum illuminance	25 lux
	Minimum edge contrast ratio	4.0
5.	**Indication of the radiation beam axis**	
	On entry	>2 mm
	On exit	>3 mm
6.	**Isocentre**	
	Displacement of radiation beam axis from isocentre	>2 mm
	Mechanical isocentre	>2 mm
	Indication of the isocentre	>2 mm
7.	**Indication of distance along the radiation beam axis**	
	Maximum difference for isocentric equipment	2 mm
	Maximum difference for non-isocentric equipment	5 mm
8.	**Zero position of rotational scales**	
	Gantry rotation	>0.5°
	Roll and pitch of radiation head	>0.1°
	Rotation of beam limiting system	>0.5°
	Isocentric rotation of the patient support	>0.5°
	Table top rotation, pitch and roll	>0.5°
	Accuracy of rotation scales	>1°
9.	**Congruence of opposed radiation fields**	>2 mm

10.	**Movements of patient support**	
	Vertical movements	>2 mm
	Longitudinal and lateral movements	>2 mm
	Isocentric rotation axis	<1 mm
	Parallelism of rotational axes	>0.5°
	Longitudinal rigidity	>5 mm
	Lateral rigidity	>0.5° and 5 mm

10.5 Kilovoltage units

Table 5: Suspension Levels for Kilovoltage Units

#	Physical Parameter	Suspension Level
1.	Output calibration	>3 %
2.	Monitor chamber linearity (if present)	>2 %
3.	Timer end error	>0.01 min
4.	Timer accuracy	>2 %
5.	Coincidence of light and X-ray beams	>5 mm
6.	Field Uniformity	>5 %
7.	HVL constancy	>10 %
8.	Measurement of HVL	>10 %
9.	Applicator output factors	>3 %

10.6 Brachytherapy

Table 6: Suspension Levels for Brachytherapy Equipment

#	Physical Parameter	Suspension Level
1.	**Source calibration**	
	Single source when only one source is used(e.g. HDR)	>3 %
	Individual source in a batch Mean of batch (e.g. LDR or permanent implant)	>5 % >3 %
	Linear source uniformity of wire sources	>5 %
2.	**Source position**	>2 mm
3.	**Applicator length**	>1 mm
4.	**Controlling timer**	>1 %
5.	**Transit dose reproducibility**	>1 %

10.7 Treatment Planning Systems

Table 7: Suspension Levels for External Beam Radiotherapy Treatment Planning Systems for Photons

#	Physical Parameter	Suspension Level
1.	**Output factors at the reference point**	>2 %
2.	**Homogeneous, simple geometry**	
	Central Axis data of square and rectangular fields	>2 %

	Off-axis data	>3 %
3.	**Complex geometry**	
	Wedged fields, inhomogeneities, irregular fields, asymmetric collimator setting; Central and off-axis data	>3 %
4.	**Outside beam edges**	
	In simple geometry	>3 %
	In complex geometry	>4 %
5.	**Radiological field width 50% - 50% distance**	>2 mm
6.	**Beam fringe / penumbra (50% - 90%) distance**	>2 mm

10.8 Dosimetry equipment

Table 8: Suspension Levels for Dosimetry Equipment

#	Physical Parameter	Suspension Level
1.	**Ionization Chambers**	
	Leakage current	>0.1 %
	Linearity	>0.5 %
	Radionuclide stability check	> 1 %
	Calibration against secondary standard	>1 %
2.	**Beam Data Acquisition Systems**	
	Positional accuracy	>1 mm
	Linearity	>0.5 %
	Ion recombination losses	>0.5 %
	Leakage current	>0.1 %
	Effect of RF fields	>0.1 %
	Stability of compensated signal	>0.2 %
	Standard percentage depth dose plot	>0.5 %
	Constancy of standard percentage depth dose plot	>0.5 %
	Standard profile plot: flatness	>3 %
	Standard profile plot: field size	>2 mm
3.	**Accessories**	
	Thermometer Calibration	>0.5 °C
	Barometer calibration	>1 mbar
	Linear rule calibration	>0.3 %