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RPA-AUT/RQ-01/RT/14

RADIATION PROTECTION AUTHORITY OF ZIMBABWE

RADIATION PROTECTION ACT (CHAPTER 15:15)

REQUIREMENTS FOR RADIOTHERAPY FACILITIES

a) Administrative Requirements

i. Completion and submission of the attached Authorization Application Form. The Form and the Guide for filling the Form could also be downloaded from the RPAZ website at www.rpaz.co.zw.
ii. Payment of applicable authorization fees in accordance with SI 134 0f 2012
iii. Type of licence application
iv. Purpose of application
v. Appointment of the legal person

b) Personnel/Training

Category	Staffing
Radiation oncologist-in-chief	One per programme
Staff radiation oncologist	One additional for each 200–250 patients treated annually. No more than 25–30 patients under treatment by a single physician at any one time. Higher numbers of predominantly palliative patients can be managed.
Radiation physicist	One per centre for up to 400 patients annually. Additional in ratio of 1 per 400 patients treated annually.
Treatment planning staff: Dosimetrist or physics assistant	One per 300 patients treated annually.
RTT-MR (Mould Room)	One per 600 patients treated annually
Radiation therapy Technologist (RTT): Supervisor RTT	One per centre Two per megavoltage unit up to 25 patients treated daily;
RTT-Sim (Simulator)	. Two for every 500 patients simulated annually
RTT-Br (Brachytherapy)	As needed
Nurse	One per centre for up to 300 patients treated annually and

	an additional one per 300 patients treated annually.
Social worker	As needed to provide service
Physiotherapist	As needed to provide service
Dietician	As needed to provide service
Maintenance engineer or electronics technician	One per two megavoltage units or one megavoltage unit and a simulator if equipment serviced'in-house'

Physicians

Physicians practising radiation therapy must first be qualified as medical practitioners with a postgraduate training in radiation oncology. Radiation oncologists have knowledge, involving special expertise in the therapeutic applications of ionizing radiation, about the causes, prevention and treatment of cancer and other diseases. They must have an understanding of the biology of cancer and of the biological aspects of the interaction of radiation with tissues as well as of the fundamentals of the physical aspects of radiotherapy.

Radiotherapy medical physicists

The responsibilities of radiotherapy medical physicists cover five major areas:
(1) Dosimetry;
(2) Radiation safety ;(Roles of the Radiation Safety Officer as promulgated by the Radiation Protection Act Chapter 15:15 of 2004)
(3) Treatment planning;
(4) Quality control;
(5) Equipment selection.

Medical physicists practising in radiotherapy (or radiation oncology) must be qualified as physicists with academic studies in medical physics (typically at postgraduate level) and clinical training in radiotherapy physics. Medical physicists specialized in radiotherapy physics are referred to as clinically qualified radiotherapy physicists. A clinically qualified radiotherapy physicist should have at least:

a) A university degree in physics, engineering or an equivalent physical science.
b) At least one year of academic postgraduate studies leading to a master's degree in medical physics (or an equivalent). This requires studies in several areas of medicine (e.g., radiodiagnostics, nuclear medicine and radiotherapy).
c) The equivalent of at least two years of full-time comprehensive clinical in service training in radiotherapy physics undertaken in a hospital. This radiotherapy physics residence training will be under the supervision of an experienced or senior radiotherapy physicist. In addition:

i. In the case that the academic studies include a considerable clinical training component, this should be taken into account in the fulfilment of the time requirement.
ii. This training should preferably be approved and certified by a suitable professional body such as the Health Professions Authority of Zimbabwe.

NB: The holder of a university degree in medical physics without the required hospital training cannot be considered to be clinically qualified.

Radiation therapy technologists/therapists/ radiation therapists/ radiotherapists

These personnel are responsible for the following:
(a) Operating teletherapy machines: linacs, Co-60 units, and superficial and orthovoltage X ray units;

(b) Operating simulator and other imaging devices for therapy purposes: CT scanners and simulators (RTT-Sims);
(c) Providing mould room services: production of immobilization masks, lead blocks, etc. (RTT-MRs);
(d) Under the supervision of medical physicists, they may also calculate the monitor units for treatment, and operate HDR brachytherapy machines (RTT-Brs) or treatment planning units (RTT-TPSs).
RTTs must have a minimum of a diploma in Therapy Radiography from a reputable institution and relevant clinical experience.

Radiation oncology nurses, social workers and dieticians

Appropriate training in nursing equivalent to a State Registered Nurse, together with specialist training in oncology, is required. A social worker trained in oncology is required to help the patient and their family with arrangements regarding transport, employment, care of children, etc. This staff member should be well informed about radiation procedures, in order to allay initial fears and clarify misconceptions arising from communications from technical and medical staff.
The role of this staff member in ensuring patient compliance with what are repetitive and unfamiliar procedures is pivotal to achieving a cure. Where necessary, a dietician trained in radiation oncology may assist patients with their nutritional needs during treatment. Radiation oncology nurses may be able to perform some of the duties of the social worker and dietician.

Maintenance personnel

Electronics technicians with the minimum of a National Diploma in either Electronics or Instrumentation together with Medical Physicists must be trained at least to carry out first line maintenance of the equipment. Second line maintenance is usually contracted to the manufacturer.

c) Facility and Equipment design

Activities in radiotherapy include imaging (simulators and/or CT Scanners), immobilization (mould room facilities) and treatment planning. Spaces common to all activities include office space for physicians and physicists, laboratories, a darkroom, a registration area and a filing room. A physics laboratory with cabinet space to store phantoms, ionization chambers, electrometers, cables and film should be available. If thermoluminescent dosimetry (TLD) and film dosimetry are available, an area should be designed for these activities. The darkroom should be located conveniently near the simulator, external beam therapy and brachytherapy activity rooms. An area should be designated for clerical staff to make bookings and register new patients, sign in patients under treatment and retrieve files for follow-up patients. A file storage area should be provided sufficient for long term storage of documentation. It is preferable to provide air conditioning for the entire facility; however, as a minimum, air conditioning should be provided for the treatment rooms, planning room and the treatment control areas where computers are located.

Facilities for radiation therapy fall into three groups:
(1) External beam radiotherapy;
(2) Low dose rate brachytherapy (including pulsed dose rate (PDR));
(3) High dose rate brachytherapy
External Beam Therapy

An external beam facility requires examination rooms, a simulator room, a treatment planning room, a mould room, a treatment room (bunker) and waiting areas. The simulator room, treatment planning room and treatment room should be designed in consultation with the manufacturer of the equipment. The requirements for power, air conditioning, monitoring ports and emergency system must be considered. The facility must be isolated from other parts of the hospital to minimize radiation safety concerns, preferably on the ground floor or basement to provide good structural support for the equipment and omit shielding of the floor where necessary.

- **Examination rooms**

The examination rooms should be in close proximity to the treatment room. The examination rooms should include standard and gynaecological examination tables, a head and neck examination chair, appropriate examination instruments and medical supplies.

- **Simulator room**

The shielding of the simulator room shall be designed according to the recommendations of US National Council on Radiation Protection and Measurements (NCRP) Report No. 151 [6], paying due regard to the requirements of the BSS [1]. The room should be large enough to accommodate the simulator, allowing the full range of motion of the treatment table. A means for securely mounting the patient positioning lasers to the wall at points appropriate for projection of lines through the isocentre should be included in the plans. A means for dimming the room lights should be considered in the design of the room. Adequate space should be planned for cabinetry to store treatment devices and daily used quality assurance equipment. If the immobilization devices are to be fabricated in the simulator room, cabinet space to store supplies for their fabrication will be required. A sink should then be provided in this room. A viewing window should be provided for the control room. Light boxes in the control room and simulator room are useful.

- **Treatment planning room**

The treatment planning room should be located in close proximity to the simulator room, although the two areas do not have to be adjacent. The room should be large enough to house the treatment planning computer with its video monitor, a printer and plotter, a digitizer tablet and other required computer equipment. Space will also be required for supplies of paper and pens or ink for the printer and plotter. An area designed to accommodate an L shaped arrangement of the digitizer tablet and video monitor is more desirable than a linear arrangement with the two devices side by side. Space for light boxes and a high intensity light for viewing CT scans and plane X ray films must be provided. In larger centres, more than one computer video terminal will be required.

- **Mould room**

Space should be planned for a mould room to fabricate custom designed blocks and compensators. Space for tools, a block cutter and counter-top workspace for pouring and mounting the blocks is required. Storage space for supplies of styrofoam, trays and shielding material for custom blocking is necessary. Adequate ventilation should be provided if shielding materials are melted in this area. If immobilization devices are fabricated in the mould room, space for a patient couch will be required. A sink with a refuse trap is required, as plaster of Paris is frequently utilized.

- **Treatment room**

The treatment room shielding should be designed in accordance with the recommendations of NCRP Report No. 151 [6], paying due regard to the requirements of the BSS [1]. The room should be large enough to accommodate the treatment machine, allowing the full range of motion of the treatment table. If total body irradiation (TBI) is planned, a larger treatment room is required. A sign should be posted at the entrance warning of the radiation hazard, in accordance with statutory instrument 62 of 2011. For a 60Co unit, an area radiation monitor safe against a power failure should be visible on entering the room. A means for dimming the room lights should be considered in the design of the room. Adequate space should be planned for cabinetry to store treatment devices, immobilization devices, blocks and daily used quality assurance equipment. A means for secure mounting of patient positioning lasers to the wall at points appropriate for projection of lines through the isocentre should be included in the plans. A maze entrance leading into the room must be designed to provide shielding. Space for a console immediately outside the treatment area overlooking the treatment room door shall be planned. This

console area should be large enough to accommodate not only the control console for the unit but also a workspace for the treatment technologist, in addition to space for an intercom and closed circuit television system. The console area should also accommodate any computer equipment associated with the treatment machine. The layout of the treatment room is illustrated in the figure below:

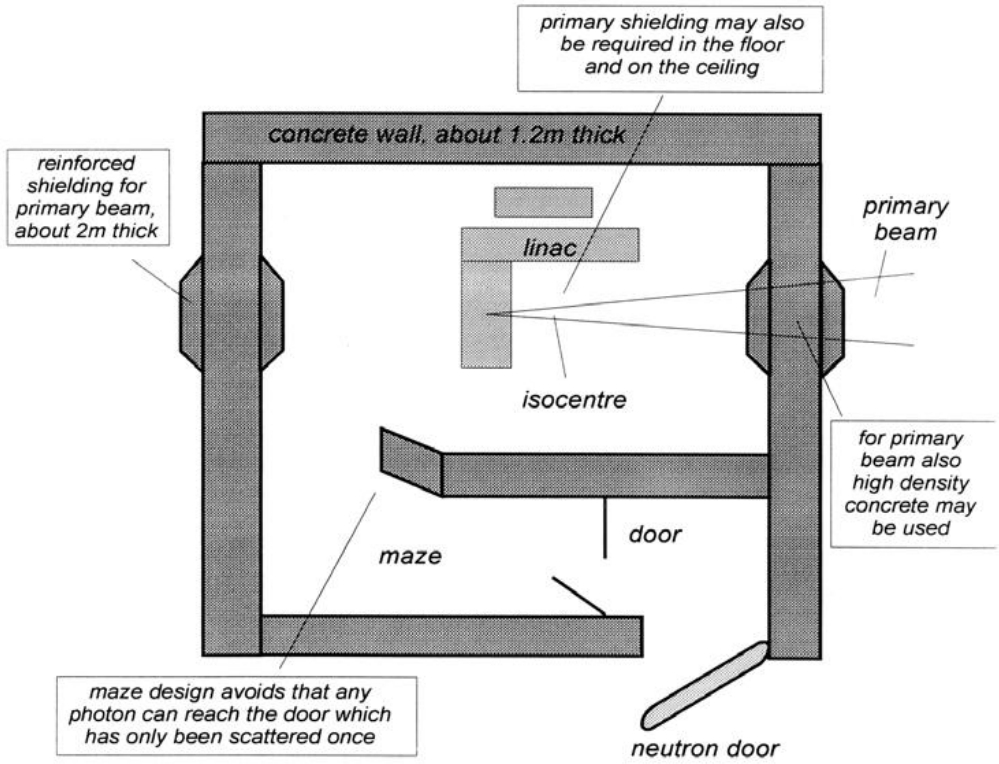

Fig 1: Layout of an External beam therapy facility

Waiting areas

Separate waiting areas for patients attending clinics and those awaiting treatment should be designed. The clinic waiting area should have space for approximately eight patients for each physician. The treatment waiting area should be adjacent to the treatment room, with space for seating of about twelve people for each machine. There should also be an area provided for patients on stretchers, which should be adjacent to the treatment area, but they should preferably be separated from ambulatory patients. The area should be large enough to accommodate three stretchers. Patients will usually have to remove some of their clothes for treatment. The provision of appropriate changing facilities close to the entrance of the treatment room, and shielded from the view of other patients and visitors, can avoid patients having to undress in the treatment room. This will reduce the time needed for treatment of each patient.

Low Dose Rate Brachytherapy

Low dose rate brachytherapy requires a source storage and preparation room, operating room, treatment planning room and patient room. Facility design should incorporate features to avoid transport in elevators of patients containing radioactive sources. Sterilization facilities for applicators will also be required. The sterilization process should be appropriate to prevent damage of the applicators.

Source storage and preparation room

This room should be designed in accordance with the recommendations of NCRP Report No. 151 [6], paying attention to the requirements of the BSS [1] and be provided with a locked door to control access to the radioactive material. A sign should be posted on the door warning of the radiation hazard, in

accordance with statutory instrument 62 of 2011. It should contain shielded storage for all sources and have facilities for receiving, preparing, calibrating and returning sources. An area radiation monitor should be visible on entering the room and while preparing the sources. Space for a workbench should be provided. A cabinet for the necessary instruments, equipment, treatment aid and the required documents should also be available. Space for source transportation trolleys should be provided. It may also be necessary to provide storage to allow decay of sources to safe levels.

Operating theatre

If anaesthesia is required for placement of applicators or catheters to contain the radiation sources, an operating room facility and recovery area are required. An X-ray unit, preferably with fluoroscopic capabilities, is desirable in the operating room because it enables the position of the applicator or catheters to be checked, and if necessary repositioned, before the patient leaves the operating suite. In addition, localization X rays (orthogonal or stereo-shifted X rays) required for dose calculation purposes can be taken with this unit. If no X ray unit is in the operating room, these functions must be available elsewhere.

Treatment planning room

Treatment planning for LDR brachytherapy is usually performed on a general TPS for teletherapy and brachytherapy using brachytherapy planning software.

Patient rooms

Each LDR brachytherapy patient must be housed in a separate room. The rooms should be shielded according to the recommendations given in NCRP Report No. 151 [6], paying due attention to the requirements of the BSS [1]. A sign should be posted on the door warning of the radiation hazard in accordance with the requirements of SI-62 of 2011. A list with the maximum duration of daily visits by members of the general public should be posted on the door. If several rooms are required, they should be adjacent to each other. The patient should be attended by nurses with special training in the care of radiation therapy patients. A toilet for each room has added patient convenience but increases the risk of losing sources. A bell connected to the nurses' station is essential as gynaecological patients need to use bedpans and may not use even common toilets. Storage for a bedside shield and emergency source container should also be provided.

Additional requirements for LDR remote afterloading

Additional requirements for remote afterloading include:
(a) Additional floor space and required utilities (dedicated compressed air and power sources);
(b) A door interlock or other suitable means to prevent unauthorized access to the patient rooms;
(c) An area radiation monitor that is safe against a power failure in the patient rooms.

High Dose Rate Brachytherapy

An HDR brachytherapy facility requires:
(a) An operating theatre;
(b) A radiographic imaging system;
(c) A treatment room;
(d) A treatment planning area.

NB: Treatment planning for HDR is a separate system from that used for external beam therapy and must be housed in a convenient place for usage of the HDR machine.

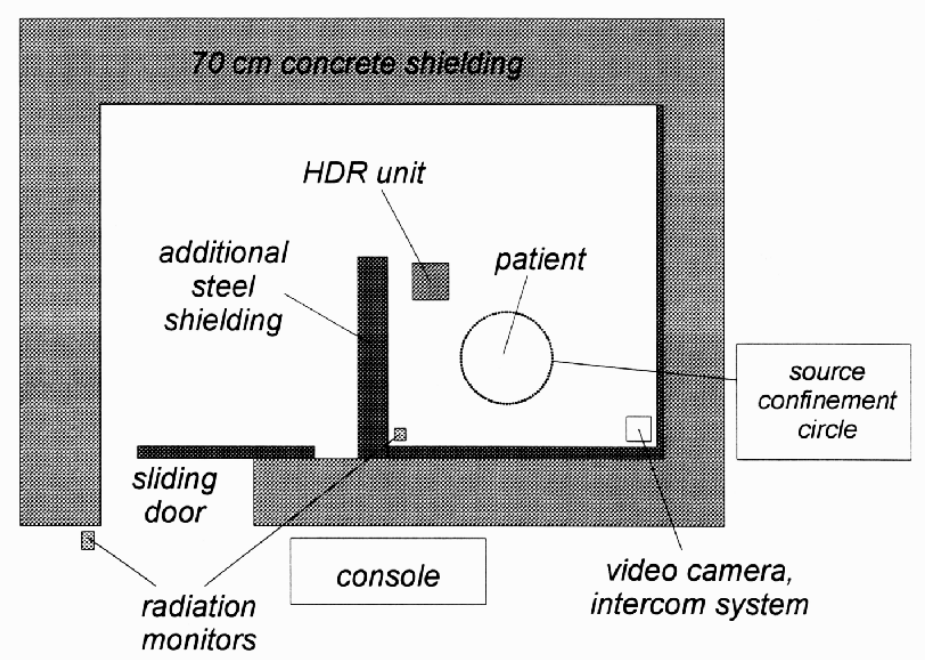

Fig 2: Layout of an HDR brachytherapy facility

Equipment Specifications

The equipment needed to perform external beam radiation therapy falls into five main categories:
(1) Imaging;
(2) Treatment planning;
(3) Treatment delivery;
(4) Quality assurance;
(5) Radiation safety.

- Imaging

  Imaging systems should include:
  (a) An image intensifier with a diameter of ≥ 23 cm;
  (b) Lateral and longitudinal movements of the image intensifier;
  (c) A maximum vertical source to input screen distance of ≥ 175 cm;
  (d) A 35 cm × 43 cm cassette film holder, including four cassettes;
  (e) A TV circuit and monitor TV.
- Treatment Planning

  Gantries
  The gantry should have the following characteristics:
  (a) Motorization of gantry with isocentric design;
  (b) A gantry rotation of 0–360°;
  (c) An X ray focus to isocentre distance of 80–120 cm (depending on the local equipment);
  (d) An isocentre height above floor level ≤ 130 cm;
  (e) An isocentre maximum sphere diameter of 3.0 mm (2.0 mm preferred);
  (f) Control of parameters inside the treatment room.

  X ray housings and collimators
  The X ray housing and collimator should meet the following requirements:
  (a) The X ray tube and housing should be with a rotating anode, even in fluoroscopy. There should be two foci.

(b) The X ray beam should be collimated by a motorized diaphragm with both local and remote control.
NB: If a department is equipped with Multileaf Collimators (MLCs) on its accelerators, it is important that the simulator should be equipped to plan for these devices. Some method of displaying the intended leaf positions superimposed on the radiographic image should be provided.
(c) The field should be defined by wires, independent of the X-ray beam diaphragm, motorized and with both local and remote control.
(d) The projection of the wires should be ≤ 2.5 mm at the isocentre.
(e) The collimator rotation limits should be ±100° (manual and/or motorized rotation).
(f) The optical distance indication range — source–axis distance (SAD) should be SAD ± 20 cm.
(g) The maximum field size at the isocentre should be ≥ 30 cm × 30 cm at 100 cm from the focus (40 cm × 40 cm preferred).
(h) The minimum field size at the isocentre should be ≤ 5 cm × 5 cm (3 cm × 3 cm preferred).
(i) An asymmetric setting of the jaw positions is desirable.
(j) The light/radiation field congruence should be ≤ 2 mm.
(k) There should be a transparent shadow tray.

Couch tables
Couch tables should meet the following requirements:
(a) X ray transparency of the table top;
(b) Isocentric rotation limits of ±90°;
(c) A patient lateral motion range of ±20 cm;
(d) Motorized vertical movement, with a minimum height of ≤ 80 cm and not less than 40 cm below the isocentre, and up to at least 3 cm above the isocentre;
(e) A longitudinal range of ≥ 70 cm;
(f) Sag of table top of ≤ 5 mm with a patient of 80 kg.

Remote control consoles
Movement and light controls should be provided together with the appropriate X ray control switches: gantry, collimator, image intensifier and couch.

X ray generators
X ray generators should include:
(a) Fluoro/radiography;
(b) A 30 kW high frequency generator; otherwise ≥ 50 kW;

NB: The shadow tray should duplicate the geometry of the treatment machine and be able to bear the weight of the lead blocks used for shielding during treatment without distorting the isocentric stability.

(c) Radiography: 125 kVp and 300 mAs. Fluoroscopy: up to 15 mA.

Computerized treatment planning systems

HARDWARE
The personal computer (PC) should be equipped with:
(a) Screen coordinated positioning (joystick, mouse and a light pen);
(b) A colour display monitor for high resolution presentation of graphics
(matrix ≥ 256 × 256) and multipresentation (text and images).
The data input/output (I/O) devices require:
(a) A digitizer for image size 40 cm × 50 cm or greater;
(b) A resolution better than 0.5 mm;
(c) A printer.

A plotter should:
(a) Be of DIN A3 format or have continuous paper 40 cm wide;
(b) Be at least four colour;
(c) Have a resolution better than 0.5 mm;
(d) Have reproducibility better than 0.5 mm.

SOFTWARE
If absolute dose calculations (time) are performed, the system shall provide a detailed list of all corrections (wedges, tray, decay, etc.) and physical constants (gamma factors, half-life, etc.). The minimum requirements are:
(a) For external therapy:
(i) 2.5-D7 calculations for ^{60}Co beams;
(ii) Fixed source–skin distance (SSD) and isocentric calculations;
(iii) Calculation with at least six simultaneous external beams;
(iv) Irregular field calculations;
(v) Corrections for obliquity and distance;
(vi) Correction for tissue inhomogeneity;
(vii) Wedge calculation;
(viii) Ability to modify contours to accommodate boluses.
(b) For brachytherapy:
(i) Source position reconstruction from X ray film;
(ii) Cs-137, ^{192}Ir and ^{125}I sources;
(iii) Correction for source filtration;
(iv) Support for the most common gynaecological applicators
(Henschke, Fletcher–Suit, Manchester and Delouche, depending on equipment available in the hospital);
(v) Calculation for point and line sources, as well as combinations of these;
(vi) Source rotation display.
(c) For data input:
(i) Manually acquired patient contours;
(ii) User radiation beam data (possibility for extracting data tables and plotting distributions);
(iii) Source position and anatomical landmarks for brachytherapy.
(d) For data output:
(i) Real size plots.

- Linear accelerators and 3-D planning need:

(a) Computer tomography image input (e.g. via DICOM3);
(b) Three dimensional dose calculations and display algorithms (or at least 2.5-D) for high energy photon and electron beams;
(c) Combination of photon and electron beams;
(d) Combinations of external beams and brachytherapy;
(e) Arc therapy treatment planning;
(f) Output for customized blocks;
(g) Output plots at varying scales;
(h) Selection of bolus density;
(i) Support for dynamic and automatic wedges (depending on the linacs in use);
(j) Support for MLC planning (if available in the hospital).

- **Specifications for orthovoltage units**

Support systems

The ceiling or floor mounted support system for the X ray tube assembly should permit movement in all three orthogonal planes, together with rotation about two orthogonal horizontal axes. If the movements are motorized, provision shall be made for a motion inactuator.

Couch tables

There should be a wheeled patient support table (preferably with height adjustment), and the table surface should be non-absorbent.

Control consoles

The control console should include:
(a) A dual timer and a timer/ionization chamber or dual ionization chamber dose control system;
(b) Selectable kilovoltage settings interlocked to filter interlocks on the treatment head.

X ray generators

The X ray generator system should include:
(a) A three phase X ray generator with a voltage regulator;
(b) A generator to operate at a range of kilovoltages up to about 300 kV.

- **Specifications for ^{60}Co teletherapy units and their radiation sources**

Gantries and treatment heads

Gantries and treatment heads should have the following characteristics:
(a) A gantry motorized with isocentric design;
(b) A gantry rotation of 0–360°;
(c) A source isocentre distance SAD ≥ 80 cm;
(d) An isocentre height above floor level ≤ 130 cm;
(e) An isocentre clearance (with devices inserted) ≥ 15 cm;
(f) An isocentre maximum sphere ≤ 3.0 mm diameter;
(g) Hand-held control of parameters inside the treatment room;
(h) Collimator:
(i) Collimator jaw indication, either mechanical or electrical;
(ii) Collimator rotation at least ±100°, with manual and/or motorized rotation;
(i) An optical distance indication range — SAD ± 20 cm, with mechanical backup;
(j) Secondary collimators (trimmers) to reduce penumbra;
(k) A transparent shadow tray for secondary collimation (blocks) to support blocks up to 20 kg. To allow treatment at any angle with blocks, it shall be possible to fix the blocking tray to the collimator without the use of hand tools. A standard set of blocks shall be supplied. It shall be possible to use blocks and wedges simultaneously. The block tray should be interlocked to the console.

Radiation field

The radiation field should have the following characteristics:

(a) Maximum field size at isocentre ≥ 30 cm × 30 cm (50% isodose level)
(Section V.7.4);
(b) Minimum field size at isocentre ≤ 5 cm × 5 cm (50% isodose level);
(c) Symmetry better than ±3%;
(d) Uniformity of ±3% over 80% of the field;
(e) Light/radiation field congruence ≤ 2 mm;
(f) Source diameter ≤ 2.5 cm;
(g) Achievable penumbra ≤ 1 cm, either with trimmers or blocks;
(h) Output ≥ 1.5 Gy/min at isocentre (at a depth of *d*max) for a 10 cm × 10 cm field during the acceptance test;

(i) Four wedge angles (15, 30, 45 and 60°) available for 15 cm in the wedged direction and 18 cm in the perpendicular direction. Insertion of wedges must not restrict the use of secondary collimation. The maximum field size covered by the wedge should be specified on the wedge. Wedges shall be fixed for collimator and gantry rotation. It shall be possible to use blocks and wedges simultaneously. Interlocks must be provided so that the operator has to positively select the correct wedge.

Couch tables
Couch tables should have the following characteristics:
(a) The table top should have a transparent window exceeding the maximum field size.
(b) The limits of the angle of rotation of the top should be ±180°.
(c) The isocentric rotation limits should be ±90°.
(d) The range of patient lateral motion should be ±20 cm (necessary for treatment of lateral fields without moving the patient, irrespective of the couch, from the initial position). This shall be achieved either by moving the table top laterally or by a combination of isocentric and column rotation.
(e) Vertical movement should be motorized, with a minimum height ≤80 cm; not less than 40cm below the isocentre and at least up to 3 cm above the isocentre.
(f) The longitudinal range should be ≥ 70 cm.
(g) The sag of the table top should be ≤ 5 mm with a patient of 80 kg weight.

Control console
The control console should have a general on/off key.

Options and accessories include:
(a) A counterweight (or beamstopper – only if the room design is inadequate);
(b) Independent head rotation on arm (range: ±90°) (Section V.7.5);
(c) A couch table with centred spine section;
(d) An area monitor with an acoustic/optical signal of radiation;
(e) Three lasers for patient centring (two cross and one sagittal);
(f) A 35 cm × 43 cm cassette holder for portal films, including four cassettes;
(g) A closed circuit TV8 or window;
(h) Immobilization devices for arms, legs and head;
(i) A backpointer;
(j) Intercommunication with the patient (two stations).

- **Specifications for Linear Accelerators**

Gantries and treatment heads
The gantry and treatment head should have the following characteristics:
(a) A gantry motorized with isocentric design;
(b) A gantry rotation of ±190º;
(c) A source–isocentre distance (SAD) of 100 cm;
(d) An isocentre height above floor level of ≤ 135 cm;
(e) Isocentre clearance (with devices inserted) ≥ 30 cm;
(f) Isocentre maximum sphere ≤ 2.0 mm in diameter;
(g) Hand-held control of parameters inside the treatment room;
(h) A collimator with:
(i) Collimator jaw indication either mechanical or electrical with mechanical backup;
(ii) Collimator rotation at least ±100° with motorized rotation;
(i) Optical distance indication range: SAD ± 20 cm, with mechanical backup;
(j) A transparent shadow tray for secondary collimation (blocks) to support blocks up to 20kg. To allow treatment at any angle with blocks, it shall be possible to fix the blocking tray to the collimator without use of hand tools. A standard set of blocks shall be supplied. It shall be possible to use blocks and wedges simultaneously.

Photon radiation field

The photon radiation field should have the following characteristics:
(a) The single photon energy should be equivalent to 6 MV
(b) The maximum field size at the isocentre should be ≥ 40 cm × 40 cm (50% isodose level).
(c) The minimum field size at the isocentre should be ≤ 4 cm × 4 cm (50% isodose level) (3cm × 3 cm is preferred).
(d) Symmetry should be to better than ±3%.
(e) The uniformity should be to ±3% over 80% of the field.
(f) The light/radiation field congruence should be ≤ 2 mm.
(g) A penumbra ≤ 8 mm should be achievable.
(h) The output should be variable from 0.5 Gy/min to more than 3 Gy/min at the isocentre (at a depth of *d*max) for a 10 cm × 10 cm field.
(i) Nominal wedge angles of 15, 30, 45 and 60° must be available. An extended set of wedge angles (achievable as a single beam) would be preferred. The wedged field size should be at least 20 cm (w) × 30 cm.(Coverage of the full field size in the unwedged direction is preferred.) Insertion of wedges must not restrict the use of secondary collimation.
The maximum field size covered by the wedge must be interlocked to the machine. Wedges shall be fixed for rotation of collimator and gantry. It shall be possible to use blocks and wedges simultaneously. Ideally, wedges should be selectable from outside the treatment room either using a motorized wedge or a 'dynamic wedge' created by jaw movements.

Dose monitoring

The dose monitoring equipment should include the following:
(a) A dual ionization chamber system with independently monitored high voltage supply;
(b) Interlocks to detect dose rate differences between the two channels;
(c) A high dose rate interlock to prevent an excess dose rate;
(d) An independent backup timer.

Couch tables

For the couch table:
(a) The table top should have a transparent window up to the maximum field size.
(b) The angular rotation limits of the table top should be ±180º.
(c) The isocentric rotation limits should be ±90º.
(d) The lateral motion range of the patient should be ±20 cm (necessary for treatment of lateral fields without moving the patient, from initial positioning with respect to the couch). This shall be achieved either by moving the table top laterally or by a combination of isocentric and column rotations.
(e) Vertical movement should be motorized, with a minimum height of ≤ 80 cm but not less than 40 cm below the isocentre, and at least up to 3 cm above the isocentre.
(f) The longitudinal range should be ≥ 70 cm.
(g) Table top sag should be ≤ 5 mm with a patient of 80 kg (≤ 3 mm is preferred).

Control consoles

Control consoles should have a general on/off key.

Options and accessories should include:
(a) A counterweight or a beamstopper;
(b) A couch table with a centred spine section;
(c) An acoustic or optical signal for the radiation dose rate;
(d) Three lasers for patient centering;
(e) A 35 cm × 43 cm cassette holder for portal films, including four cassettes;
(f) A closed circuit TV;
(g) Immobilization devices for arms, legs and head;
(h) A backpointer — preferably optical;
(i) An intercommunication device with the patient (two stations);
(j) Connectivity to a Record and Verify (R&V) system;

(k) The accelerator should have protection to avoid collisions with the patient where this could be hazardous to the patient, and collisions with other parts of the accelerator where this could lead to damage or interruption of dynamic treatments.

Specification of Equipment For Remote LDR And HDR Afterloading Brachytherapy

- Equipment for Low Dose Rate Afterloading Brachytherapy

- Ir-192 source loading and cutting devices
- Source storage and transport containers (for remote LDR this should be part of the equipment) within the department
- Source handling instruments and accessories (in source preparation room and patient loading room)
- An area radiation monitor in treatment room with a light signal outside the entrance door, safe against power failure
- A portable radiation monitor
- Highly recommended: an area radiation monitor with an audio signal at the entrance to the treatment room.
- An emergency container and emergency source handling instruments in the treatment room.
- Radioactive waste storage.
- Equipment for source/applicator localization and identification (e.g. X ray equipment)
- Dummy sources for applicator localization in patients
- A patient couch adapted for LDR brachytherapy applications: gynaecological, head and neck, bronchial (leg rests, film cassette holders, anaesthesia requirements, etc.)
- A device for fixation of a connector between the transportation applicator tubes to the patient.(Remote LDR only)
- A set of applicators for intracavitary (e.g. Henschke, Fletcher–Suit, Manchester or Delouche type) and interstitial treatments.
- A radiation protection barrier for source loading in patients and for patient care.(Manual LDR only)
- Portable radiation protection barriers in the case of insufficient protection in patient ward walls and doors.

- The following features are required:

(a) A source positioning reproducibility to ±1 mm;
(b) Automatic source retraction in the case of a power failure;
(c) An intermediate source storage container;
(d) A minimum of three source channels for intracavitary and endoluminal treatments (but four source channels are highly desirable);
(e) A remote nurse alarm station.

Minimum Equipment Requirements for HDR Brachytherapy

a) An area radiation monitor in the treatment room, connected to the door interlock with an audio signal safe against power failure and independent of treatment equipment;
(b) A portable radiation monitor instrument at the entrance of the treatment room;
(c) Highly recommended: an area radiation monitor with an audio signal at the entrance to the treatment room;
(d) Emergency container and emergency source handling devices at the entrance of the treatment room door
(e) Equipment for applicator localization and identification (e.g. an X-ray unit);
(f) Dummy sources for applicator localization;

(g) A treatment couch adapted for HDR brachytherapy: gynaecological and bronchial equipment (leg rests
film cassette holders, anaesthesia requirements, etc.);
(h) A set of applicators for intracavitary (e.g. Henschke, Fletcher–Suit, Manchester or Delouche type) and endoluminal treatments;
(i) film cassette holders, anaesthesia requirements, etc.);
(ii) A device for applicator fixation to the treatment couch.

Minimum Equipment for Quality Assurance programmes in Brachytherapy

- A well type ionization chamber or an isotope calibrator with source holding inserts, calibrated at a standards laboratory for the clinical sources available
- If Cs-137 sources are not available, a long lived reference source for checking the stability of the well chamber
- A facility to verify source homogeneity and source position (requires access to film development)
- A barometer (minimum scale: 1 mbar or 0.5 mmHg), preferably of aneroid type or digital, calibrated or compared at a standards laboratory (if not available in external radiotherapy)
- Calipers and a metal ruler

Quality Control Programmes

(1) External beam treatments

Quality Control of Orthovoltage Units

Frequency	Procedure	Tolerance
Daily	Output constancy	±5%
	Interlocks and warnings	Functional
	Mechanical fixtures	Functional
	Filter interlock	Functional
Monthly	Output measurement	±3%
	Timer end error	±0.01 min
	Timer accuracy	±2% or ±0.02
	Backup timer	Functional
	Timer response to power failure	Functional
	Filter interlocks	Functional
	Mechanical fixtures	Functional
	Monitor chamber linearity	±2%
	Coincidence of light beam and X ray beam	
	HVL constancy	±5 mm
		±5%
Annually	Field uniformity	±5%
	Half-value layer	±10%
	Applicator factors	±3%

Quality Control of ^{60}co Units

Frequency	Procedure	Tolerance
Daily	*Safety* Door interlock Radiation room monitor Audiovisual monitor *Mechanical* Localizing lasers Optical distance indicator (ODI)	 Functional Functional Functional 2 mm 2 mm
Weekly	*Check of source positioning*	3 mm
Monthly	*Dosimetry* Output constancy *Mechanical checks* Coincidence of light and radiation fields Field size indicator (collimator setting) Gantry and collimator angle indicator Cross-hair centring Latching of wedges and trays *Safety interlocks* Emergency off switches Wedge interlocks	 2% 3 mm 2 mm 1° 2 mm Functional Functional Functional
Annually	*Dosimetry* Output constancy traceable to SSDL Field size dependence of output constancy Central axis dosimetry parameter constancy (PDD/TAR)c Transmission factor constancy for all standard accessories Wedge transmission factor constancy Timer linearity and error Output constancy versus gantry angle Beam uniformity versus gantry angle Off-axis point measurements with and without wedges *Safety interlocks* Follow test procedures of manufacturer	 2% 2% 2% 2% 2% 1% 2% 3% 3% Functional
	Mechanical checks Collimator rotation isocentre Gantry rotation isocentre Couch rotation isocentre	 2 mm diameter 3 mm diameter 2 mm diameter

	Coincidence of collimator, gantry and couch axes with isocentre Coincidence of radiation and mechanical isocentres Table top sag with 80 kg mass evenly distributed Vertical travel of table Field intensity of light	2 mm diameter 2 mm diameter 5 mm 2 mm Functional

The tolerances listed should be interpreted to mean that if a parameter either exceeds the tabulated value (e.g., the measured isocentre under gantry rotation exceeds 2 mm diameter) or the change in the parameter exceeds the nominal value (e.g., the output changes by more than 2%), then an action is required. The distinction is emphasized by the use of the term 'constancy' for the latter case. Moreover, for constancy, per cent values are plus/minus the deviation of the parameter with respect to its nominal value; distances are referenced to the isocentre or nominal SSD.

Quality Control of Linear Accelerators without Electron Beams

Frequency	Procedure	Tolerance
Daily	*Dosimetry* Output constancy *Safety* Door interlock Audiovisual monitor *Mechanical* Localizing lasers ODI	 3% Functional Functional 2 mm 2 mm
Monthly	*Dosimetry* Output constancy with field instrument, with appropriate corrections Backup monitor constancy Central axis dosimetry parameter constancy (e.g. PDD and TAR) Beam flatness constancy Beam symmetry *Mechanical checks* Coincidence of light and radiation fields Field size indicator (collimator setting) Field light intensity Jaw symmetry Gantry and collimator angle indicator Cross-hair centring Wedge position *Tray position* Treatment couch position indicators Latching of wedges and blocking tray *Safety interlocks* Emergency off switches Wedge interlocks	 2% 2% 2% 3% 3% 2 mm or 1% on a side 2 mm Functional 2 mm 1º 2 mm diameter 2 mm or 2% change in transmission factor 2 mm 2 mm/1º Functional Functional

		Functional
Annually	*Dosimetry* Output calibration traceable to SSDL Field size dependence of output constancy Transmission factor constancy for all standard accessories Off-axis factor constancy Wedge transmission factor constancy (including depth and field size dependence) Monitor chamber linearity Output constancy versus gantry angle Beam uniformity constancy versus gantry angle Arc mode Off-axis point measurements with and without wedges *Safety interlocks* Follow test procedures of manufacturer *Mechanical checks* Collimator rotation isocentre Gantry rotation isocentre Couch rotation isocentre Coincidence of collimator, gantry and couch axes with isocentre Coincidence of radiation and mechanical isocentres Table top sag with 80 kg mass evenly distributed Vertical travel of table	 2% 2% 2% 2% 2% 1% 2% 2% As specified 3% Functional 2 mm diameter 2 mm diameter 2 mm diameter 2 mm diameter 2 mm diameter 2 mm 2 mm

TthThe The tolerances listed should be interpreted to mean that if a parameter either exceeds the tabulated value (e.g., the measured isocentre under gantry rotation exceeds 2 mm diameter) or the change in the parameter exceeds the nominal value (e.g., the output changes by more than 2%), then an action is required. The distinction is emphasized by the use of the term 'constancy' for the latter case. Moreover, for constancy, per cent values are plus/minus the deviation of the parameter with respect to its nominal value; distances are referenced to the isocentre or nominal SSD.

Quality Control of Linear Accelerator Electron Beams

Frequency	Procedure	Tolerance
Daily	*Dosimetry* Output constancy with constancy meter	 ±3%
Monthly	*Dosimetry* Output constancy with field instrument, with appropriate corrections Central axis dosimetry parameter constancy (PDD)	 2%

	Beam flatness constancy Beam symmetry *Mechanical checks* Applicator position *Safety interlocks* Electron cone interlocks	2 mm at therapeutic depth 3% 3% 2 mm
Annually	Field u Half-value layer Applicator factors	±5% ±10% ±3%

These tests are those that are additional to those given in the previous table, for accelerators equipped with an electron beam. All these procedures should be carried out during commissioning. Appropriate tests should be performed following any repair of the teletherapy unit.
The tolerances listed should be interpreted to mean that if a parameter either exceeds the tabulated value (e.g., the measured isocentre under gantry rotation exceeds 2 mm diameter) or the change in the parameter exceeds the nominal value (e.g., the output changes by more than 2%), then an action is required. The distinction is emphasized by the use of the term 'constancy' for the latter case. Moreover, for constancy, per cent values are plus/minus the deviation of the parameter with respect to its nominal value; distances are referenced to the isocentre or nominal SSD.

Quality Control of Simulators

Frequency	Procedure	Tolerance
Daily	Localizing lasers ODI	2 mm 2 mm
Monthly	Field size indicator Gantry/collimator angle indicators Cross-hair centring Focal spot-axis indicator Fluoroscopic image quality Emergency/collision avoidance Coincidence of light and radiation fields Film processor sensitometry	2 mm 1° 2 mm 2 mm Baseline Functional 2 mm or 1% Baseline
Annually	*Mechanical checks* Collimator rotation isocentre Gantry rotation isocentre Couch rotation isocentre Coincidence of collimator, gantry, couch axes and isocentre Table top sag with 80 kg mass evenly distributed Vertical travel of couch *Radiographic checks* Exposure rate Table top exposure with fluoroscopy kVp and mAs calibration High and low contrast resolutions	2 mm diameter 3 mm diameter 2 mm diameter 2 mm diameter 5 mm 2 mm Baseline Baseline Baseline Baseline

- The tolerances mean that the parameter exceeds the tabulated value (e.g., the measured isocentre under gantry rotation exceeds 2 mm diameter).

Quality Control for Treatment Planning Systems and Treatment Time Calculations

Frequency	Procedure	Tolerance
Commissioning and following software updates	Understand algorithm Single field or source isodose distributions Treatment time calculations including inhomogeneity corrections where appropriate *Test cases* I/O system	Functional 2%[a] or 2 mm[b] 2% or 5% if including inhomogeneities 2% or 2 mm 1 mm
Daily	I/O devices	1 mm
Monthly	Check sum Subset of reference quality assurance test set (when check sums not available) I/O system	No change 2% or 2 mm[c] 1 mm
Annually	Treatment time calculations Reference quality assurance test set I/O system	2% 2% or 2 mm[d] 1 mm

[a] Per cent differences between calculations of the computer TPS and measurements (or independent calculations).
[b] In the region of high dose gradients, the distance between isodose lines is more appropriate than the percentage difference. In addition, less accuracy may be obtained near the end of single sources.
[c] These limits refer to a comparison of dose calculations at commissioning with the same calculations subsequently.
[d] These limits refer to a comparison of calculations with measurements in a water tank.

2) Quality Control of Remote Afterloading Brachytherapy Units

Frequency	Test	Tolerance
Each treatment day	Room safety door interlocks, lights and alarms Console functions, switches, batteries and printer Visual inspection of source guides Verify accuracy of ribbon preparation	 Functional Functional Free of kinks and firmly attached Autoradiograph
Weekly	Accuracy of source and dummy loading (dummies used for spacing and/or simulation/verification) Source positioning	 1 mm 1 mm
At each source change or quarterly	Calibration[a] Timer function Check accuracy of source guides and connectors Mechanical integrity of applicators (by X ray if appropriate)	3% 1% 1 mm Functional

Annually	Dose calculation algorithm (at least one standard source configuration for each isotope) Simulate emergency conditions Verify source inventory	3%, 1 mm

NB: When changing a source, calibrate both the new and the old sources to establish and document the reproducibility of the calibration method.

Quality Control Tests for Brachytherapy Sources

Type of Source	Test	Frequency	Tolerance
Long half-life: description	Physical/chemical form Source encapsulation Radionuclide distribution and source uniformity Location of radionuclide in encapsulation	I I I I	D D D D
Long half-life: calibration	Mean of batch Deviation from mean Verification of calibration	I I E	3% 5%, D [a]
Short half-life: description	Physical/chemical form Source encapsulation	I I	D D
	Mean of batch Deviation from mean[b] Radionuclide distribution and source uniformity	E E	3% 5% V[c]

Key:
I, initial purchase; D, documented; E, at every use. [a] Visual check of source colour code or measurement in a calibrator. [b] For short half-life sources, this may not always be practical. [c] V, visual check, autoradiograph or ionometric check.

Quality Control Tests for Brachytherapy Applicators

Type of applicator	Test	Frequency	Tolerance
Intracavitary	Source location Coincidence of dummy and active sources Location of shields	I, yearly I[a] I[b]	D 1mm D
Interstitial	Coincidence of dummy and active sources	I,E	1mm

Key:
I, initial use or following malfunction and repairs; D, documented and correction applied or noted in report of measurement, when appropriate; E, as a minimum, a visual inspection to verify that the dummy sources fairly represent the active source distribution [a] To reduce exposure of personnel, the dummy source location may be checked instead of the active source if it is established that the dummy and active source locations are coincident [b] The location of shields should be verified by radiograph before first use. Before every use, the applicator may be shaken to listen for loose parts.

Quality Control Tests for Brachytherapy Source Calibrators

Instrument type	Test	Frequency	Tolerance
Well type ionization chamber	Standards laboratory calibration	I, S[a]	D
	Precision	I	2%
	Linearity	I, every two years	1%
		I	
	Collection efficiency	I	1%
	Geometrical/length dependence	I	D
	Energy dependence	I	D
	Source wall dependence	I	D
	Venting	E	D
	Redundancy check	E	2%
	Leakage		D
In-air calibration chamber and external source holder	SSDL calibration	I, S[a]	D
	Accuracy of source chamber distance	Annually, S	1%, D
	Redundancy	E	D

Key:
I, initial use or following malfunction and repairs a*; S, isotope/source specification;*
D, documented and correction applied or noted in report of measurement,when appropriate; E, at each use (measurement sequence) or ongoing evaluation.

(3) Measurement equipment;

Basic Equipment recommended for Dosimetry in External Radiation Therapy

	Type of Installation		
Basic Equipment	Co-60	Linac, photons only	Linac with electrons
An ionization chamber of Farmer type, of 0.6 cm^3 volume approximately, with plastic walls (robust), a Co-60 buildup cap, a 10 m long cable and a 10 m long extension cable with connectors calibrated at a standards laboratory.	×	×	×
An ionization chamber of Farmer type, of 0.6cm^3 volume approximately, with graphite walls, a Co-60 buildup cap and a 10 m long cable, calibrated at a standards laboratory in terms of absorbed dose to water.	×	×	×
A cylindrical ionization chamber, of 0.1–0.3 cm^3 volume approximately, with a 10 m long cable (maximum electrode diameter: 1 mm)	×	×	×
A radioactive source for checking the stability of the cylindrical ionization chamber	×	×	×

A plane-parallel ionization chamber for electrons (minimum width of guard ring: 4mm).			×
An electrometer compatible with the chambers above and calibrated or compared at a standards laboratory	×	×	×
An additional electrometer with varying voltage bias (V1/V2 ratio equal to or greater than 3), and the possibility to reverse the polarity		×	×
A water phantom for calibration and checks, of volume 20 ×20 × 10 cm^3 approximately, with PMMA walls, including a holder for ionization chambers	×	×	
A water phantom for calibration, of 30 × 40 × 40 cm^3 volume approximately, with PMMA walls, including a holder for ion chambers with manual steps or an automatic system to vary the position of the chamber	×	×	
A plastic slab phantom for verification of field size and coincidence of radiation and light field. Used also for output verification, with holes for the chambers, and preferably TLD	×	×	×
A barometer (minimum scale 1 mbar or hPa, or 0.5 mmHg),preferably of aneroid type or digital, calibrated or compared at a standards laboratory	×	×	×
A thermometer (minimum scale: 0.25°C), calibrated or compared at a standards laboratory	×	×	×
A densitometer to measure the optical density (OD) of X ray films, with an automatic reader and coordinate system. An OD calibration film strip for checking of the instrument OD scale. Requires having access to film development	×	×	×
A radiation field analyser to measure isodose distributions, of 50 × 50 × 40 cm^3 volume approximately, with a water tank, a phantom trolley with vertical movement and a water pump		×	×

All chamber models and electrometers must be included in IAEA dosimetry publications [1

Additional equipment includes but is not limited to:

1) A TLD system (both relative dosimetry and in vivo)
2) An array of diodes or ion chambers for daily quality assurance checks
3) A precision water level
4) Calipers and a metal ruler
5) A multimeter (volt, ohm)

Additional Equipment for Low Energy X Ray Dosimetry

Equipment	50 kV or less	50-100kV
Grenz ray chamber	×	
Ionization chamber		×
Plastic phantom		×

Quality Control of Measurement Equipment

Instrument type	Test	Frequency	Tolerance[a]
Local standard[b]	SSDL calibration Linearity Venting Extra-cameral signal (stem effect)	2a[c] 2a[c] 2a[c]	D 0.5% D

	Leakage Redundancy check[d] Recombination Collecting potential	I E E I E	0.5% 0.1% 2% D D
Field instruments	Local standard comparison Linearity Venting Extra-cameral signal Leakage Recombination Collecting potential	2a 2a 2a 2a E I E	1% D D D 0.1% D D
Local Output check	standard comparison	M	1%
Ion chamber	Linearity	1a	D
Film	Extra-cameral signal Dose response Densitometer linearity Processor uniformity/reproducbility Calibration	I B 1a E E	1% D D D D
TLD	Linearity	I	D
Accessories	Thermometer calibration Barometer calibration Linear rule calibration	I 3 months I	0.1°C 1 mmHg 0.3

Key:
I, initial use for each mode used or following malfunction and repairs; E, each use (measurement sequence) or ongoing evaluation; B, each batch or box at the appropriate energy (the position of the dosimeter element should also be considered); D, documented and correction applied or noted in report of measurement; M, monthly; a, annually; 2a, once every two years
[a] *Per cent values are plus/minus the deviation of the parameter with respect to the nominal value, and distances are referred to the isocentre or nominal SSD.*
[c] *Without a redundancy programme, this may be inadequate.*