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**CODE OF PRACTICE
FOR THE APPLICATION OF QUALITY CONTROL
ON A
MEDICAL LINEAR ELECTRON ACCELERATOR**

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1. INTRODUCTION

Successful radiotherapy is based inter alia on the application of the correct absorbed dose to the target volume in the patient. This means that accurate planning of the course of radiation should be followed by accurate and reproducible application on the radiation. The teletherapy unit (cobalt unit or linear accelerator) should therefore comply with certain specifications and requirements and the user should ensure by establishing quality control program that these specifications are maintained.

The specifications with which a high energy teletherapy unit should comply are laid down by the International Electrotechnics Commission (IEC). The manufacturers of these equipment use the specifications of the IEC as a guide when designing and manufacturing teletherapy units.

Before a teletherapy unit is taken into clinical use in a radiotherapy department the user should check that the unit comply with the IEC and the relevant national specifications. This task is performed by the medical physicist in co-operation with the supplier and is known as ACCEPTANCE. Acceptance is followed by CALIBRATION when the medical physicist measured the radiation properties (percentage depth doses, isodose curves, etc) required for planning and treatment of patients. On completion of acceptance and calibration of the unit an application for LICENSING of the unit may be put to the Department of National Health and Population Development. Finally a QUALITY CONTROL PROGRAM should be introduced for the clinical application of the unit. This program describes routine tests that check the constancy of the mechanical, optical radiation and safety characteristics of the treatment unit.

The requirements to be complied with during quality control are based on the results obtained during acceptance. Therefore it is essential to put the results of the acceptance tests on record to be used as a reference values in the quality control program.

The frequency of the various tests in the quality control program is determined by the specific properties to be tested. Characteristics that may vary at random and in an instant should be checked daily. Characteristics that may vary slowly or for which a change is highly improbable may be checked less frequently. Recording of the results of quality control tests is necessary to observe any slow change in a specific characteristic of the unit.

Whenever reparations requiring replacement of parts and adjustments are done, or when a modification is done, a test program should be drawn up to determine new values of the characteristics concerned. These new values of characteristics should comply with the specifications laid down and will be used as guide in the quality control program.

In sections 2, 3 4 and 5 of this document a description for the various characteristics of a medical linear accelerator to be tested during acceptance is given. These characteristics are discussed under the following headings:

1. Mechanical and optical characteristics (section 2)
2. Beam characteristics (section 3)
3. Dosimetry (section 4)
4. General safety and radiation safety (section 5)

Example procedures of tests will be discussed for certain characteristics. The sources of literature that are used will be given.

In these instances where limiting values for specific characteristics are given in literature, these values will be given for the characteristics concerned. In the publications of the IEC it is required that the supplier should supply the limiting values for the equipment to the user. This approach of the IEC is followed for many of the characteristics discussed in this document.

This document is concluded with a recommended quality control program (section 6) which may be followed during the life of the linear accelerator. The frequency of testing the various characteristics is given with reference to the previous section in which the characteristic is discussed.

2. MECHANICAL AND OPTICAL CHARACTERISTICS

2.1. STABILITY OF THE ISOCENTRE

2.1.1. POSITION OF THE ISOCENTRE

PROCEDURE¹ Attach the mechanical front pointer to the radiation head. With the gantry at 0° position a sheet of graph paper horizontally and approximately on the isocentre as indicated by the tip of the mechanical pointer. Rotate the collimator through 360° and note the locus of the tip to verify that the collimator rotate around an axis through the isocentre. (fig. 1)

Position a pen with its tip approximately at the isocentre. Rotate the gantry through 360° and note the maximum distance between the tip of the front pointer and the fixed pen.

When light beam (LASER-beams) from units on the walls and the ceiling are used, it should be checked that these beams intersect in the isocentre.

LIMITS¹ Locus of the tip of the mechanical front pointer with collimator rotation; < 2mm.
Distance between the end points of the mechanical front pointer and fixed pen should not exceed 2mm during a gantry rotation through 360°.

2.1.2. ALIGNMENT OF RADIATION HEAD AND CROSS WIRES

PROCEDURE¹ With the gantry on 0° position a sheet of graph paper horizontally through the isocentre. Rotate the collimator through 360° and record the locus of the cross wires in the optical beam of the radiation head.

LIMITS¹ Locus on isocentric plane < 2mm circle diameter
Locus on floor level < 4mm circle diameter

2.1.3. ACCURACY OF THE OPTICAL DISTANCE INDICATOR

PROCEDURE¹ With the gantry on 0° and a sheet of graph paper horizontally through the isocentre, check that the point of intersection of the cross wires corresponds with the 100cm mark on the scale. By raising and lowering the paper check that the scale is correctly indicating distances of 85cm and 135cm.

LIMITS^{1,3} Deviation at 100cm: ±1mm
85cm: ±3mm
135cm: ±3mm

2.1.4. ALIGNMENT OF THE TREATMENT COUCH

PROCEDURE¹ Position the gantry on 0°, the collimator on 0° and the treatment couch with its surface corresponding to the isocentre. Attach a sheet of graph paper to the couch top and mark the position of the cross wires. Rotate the couch on its isocentre axis through the maximum permissible angle (eg. 270°) and record the position of the cross wires at suitable intervals (eg. 30°). Note the maximum diameter of the circle enclosing the remarked points.

Record the position of the cross-wired on the paper with the couch top at the isocentre. Fully lower the treatment couch and record the position of the cross wires.

LIMITS¹ Circle diameter: <2mm
Distance between the two marks: ≤ 2mm

2.2. ALIGNMENT OF THE RADIATION BEAM

Checking the alignment of the radiation beam requires film exposures as indicated in table 1. Use slow films, e.g. KODAK X OMAT V in its envelope.

Put the gantry on 0° and use the numerical field size indicators on the accelerator to set the field size. Position the film perpendicular to the beam at a distance of 1m from the x-ray target. Use 50mm tissue equivalent phantom material below the film and sufficient build-up material for the specific x-ray quality. The edges of the light field and the cross wires should be clearly

marked on the envelope using lead markers. The orientation of each film with respect to the accelerator should be marked.

TABLE 1 Exposures required for alignment of the radiation beams

Film#	Gantry Angle	Collimator Angle	Field size cm x cm	Source to film distance (m)	Radiation type	Nominal energy (MV)
1	0°	90°	3x3	1	x-ray	Every
2		0°	10x10	1	x-ray	available
3		180°	10x10	1	x-ray	Energy
4		90°	15x15	1	x-ray	
5		90°	30x35	1	x-ray	

2.2.1. CORRESPONDENCE OF THE SET FIELD SIZE AND THE X-RAY FIELD SIZE

PROCEDURE¹ Use an optical densitometer and measure the distance between the 50% density points along both main axes on the film images.

LIMIT 1 The difference between the measured field size on the film and the numerical read out on the accelerator should not exceed 2mm for fields up to and including 20 x 20 cm² and 1% for field above 20 x 20 cm².

2.2.2. CORRESPONDENCE OF THE X-RAY FIELD SIZE AND OPTICAL FIELD SIZE

PROCEDURE¹ Determine for the film exposure in table 1 the difference between the x-ray field size and the optical field size as marked on the film prior to exposure.

LIMIT¹ Difference: < 2mm for fields up to and including 20x20 cm²
< ± 1% for field above 20 x 20 cm²

2.2.3. CORRESPONDENCE OF THE X-RAY FIELD SIZE AND OPTICAL FIELD SIZE

PROCEDURE¹ Use the film exposures in table 1 and measure the displacement between the corresponding edges of the x-ray field, defined by the 50% optical density lines on the film and on the light field.

LIMIT¹ Displacement: < 2mm for fields up to 20x20 cm²
< ± 1% for fields above 20x20cm²

2.2.4. CORRESPONDENCE OF THE CENTRE POINT OF THE X-RAY FIELD AND THE ISOCENTRE

PROCEDURE¹ Use the films, no. 2 and no. 3, (table 1) and measure the difference between the centre point of the x-ray field, defined by means of the 50% optical density lines, and the isocentre indicated by the cross wires in the light field.

LIMIT¹ Difference: < 2mm

2.2.5. GEOMETRY OF THE X-RAY BEAM

PROCEDURE³ Use the films, no. 2, 3 and 4, (table 1) and check whether opposing edges of the x-ray field are parallel and whether the angles between neighbouring edges form rectangles.

LIMIT³ Deviation from parallel lines: 0,5°
Rectangles: 90° ± 0,5°

3. BEAM CHARACTERISTICS

3.1. PHOTONS

3.1.1. BEAM QUALITY (ENERGY)

The quality of the photon beam is described by the “nominal accelerating potential” of the linear accelerator. According to the TG 21 protocol of the AAPM⁶ the nominal accelerating potential is a function of the ratio of two ionisation measurements done on specific depths in a phantom in the beam.

3.1.2. FIELD UNIFORMITY

PROCEDURE¹ Put the gantry on 0° (or 90°), and the beam size on 10x10 cm². Use a water phantom with external dimensions of 30 cm x 30 cm (or alternatively a polystyrene or perspex phantom). Using a suitable detector measure the ionisation for a selected number of monitor units (e.g. 100 MU) or depths of 10 cm and 20 cm in the water with the detector on a fixed distance of 1m from the source of radiation. Calculate the ratio of the ionisation readings on 20cm and 10cm, J₂₀/J₁₀. The normal accelerating potential may be calculated using the data in the TG21 protocol.

LIMIT¹ The experimentally determined nominal accelerating potential should correspond within ±2% to the quality given by the supplier.

3.1.2.1. Flatness³

Flatness is expressed by the ratio of the maximum relative intensity to the minimum relative intensity. The area for which the beam should be flat is defined by straight lines joining points on the major axes and diagonal axes of square beam: as specified in table 2³ and illustrated in fig. 2.

TABLE 2 DESCRIPTION OF THE FLATTENED AREA OF THE BEAM

Field size, F (cm)	Dimensions defining the flattened area	
	D_m	d_d
$5 \leq F \leq 10$	1,0 cm	2,0 cm
$10 \leq D \leq 30$	0,1 F	0,2 F
$30 < F$	3 cm	6,0 cm

- PROCEDURE
1. Use (i) a water filled phantom at least 30cm deep and which extends at least 5cm outside the radiation beam on the surface, and (ii) a suitable dosimetry system which allows scanning of a detector on the major axes and the diagonal axes. The major and diagonal axes for each field are scanned at a depth of 10cm in the water on a plane containing the isocentre. Thus the water surface is 10 cm from the isocentre in the direction towards the source of radiation.

Profiles are measured for each of the sets of parameters given in table 3.

TABLE 3 Parameters of the required beam profiles

Angular Position of Gantry Collimator		Radiation field (cm x cm)	Absorbed Dose Rate	Type of Radiation	Nominal Energy
0° (or 90°)	0°	5 x 5	Selected value	x-radiation	Each of the available energies
		10 x 10			
		30 x 30			
		Maximum			

2. Verify the constancy of the beam flatness with rotation of the gantry. Attach a suitable dosimetry system to the radiation head with the detector at a depth of 10 cm in a tissue equivalent solid phantom (e.g. A block of polystyrene). The phantom therefore rotates with the gantry around the horizontal isocentric axis. Repeat the profile measurements for the 30 x 30 cm²-beam at gantry angles of 90°, 180° and 270°.

LIMIT^{1,3}

1. From 5 x 5cm² to 30 x 30 cm²: $I_{max}/I_{min} \leq 1,06$

Above 30 x 30 cm²: $I_{\text{max}}/I_{\text{min}} \leq 3\%$

2. Variation of the beam profiles as a function of the gantry angle: $\leq 3\%$

3.1.2.2. Symmetry of the beam

The symmetry of the beam is defined as the maximum value of the ratio (I_H/I_L) of the higher to the lower relative intensity as any two positions symmetrically placed relative to the central beam axis and within the flattened area.

PROCEDURE Use the profiles measured in 3.1.2.1 above and determine the maximum of the above-mentioned ratio.

LIMIT¹ Symmetry: $(I_H/I_L)_{\text{max}} \leq 1,03$.

COMMENT Routine weekly tests of the flatness and symmetry of the beam may be done using a more convenient (or simpler) dosimetry system, e.g. an air scanner.

3.1.3. PENUMBRA

The penumbra of the beam is defined as the distance between the 20% and 80% relative intensity values on the beam edge with the 100% - value on the central axis^{1,3}.

PROCEDURE Use the film nos. 1, 3, 4 and 5 in 2.2 above. Determine the distance between the 20% and 80% optical density value along each of the main axes.

LIMIT¹ Penumbra: $< 8\text{mm}$

3.2. ELECTRONS

3.2.1. ENERGY

- PROCEDURE** 1. Measure the central axis depth ionisation curves for each available nominal beam energy in a water phantom with the gantry on 0°. Use a field size of 20x20 cm² or the maximum available field size. The phantom should comply with the requirements in 3.1.2 above.

Determine the depth at which the relative ionisation decreases to 50% of the 100% value on each curve. The mean energy of the electron beam at the phantom surface is given by⁵

$$\bar{E}_0 = 2,33R_{50}$$

2. Determine the relative ionisation I_x at the depth of the practical range R_p plus 10 cm. This value I_x gives an indication of the x-ray contamination in the beam.

LIMIT	Difference between E_0 and the set nominal energy: $\leq \pm 3\%$ X-ray contamination I_x : $< 5\%$ up to 15 MeV $< 7\%$ 15-20 MeV
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3.2.2. UNIFORMITY

3.2.2.1. Flatness

PROCEDURE^{1,3} Use a suitable water phantom and a dosimetry system which allows scanning of electron beams. Measure beam profiles along the main axes and the two diagonals on the depth of maximum relative ionisation in water (or at a depth half the depth of the 80% depth dose). Do the measurements for each electron energy at a gantry angle 0° and the water surface at the normal treatment distance.

Do the measurements for each of the data sets in table 4.

TABLE 4 Parameters of electron beam profiles

Angular position of		Field size (cm ²)	Absorbed Dose Rate	Radiation type	Nominal Energy
Gantry	Collimator				
0°	0°	10 x 10	Arbitrarily	Electrons	Each of the available energies
		20 x 20	Chosen		

LIMIT²: The maximum distance between 90% relative ionisation (intensity) and the edge of the geometrical beam (50%) relative ionisation should not exceed the following limits:
10mm – along main axes
20mm – along diagonals

Within the flat area the ratio of any intensity to the intensity on the central axis should not exceed 1,03.

3.2.2.2. Symmetry

Symmetry is expressed in terms of the ratio I_H/I_L , of the relative ionisation values at any two points symmetrically placed around the central axis. These two points should lie within an area 1cm within the 90% relative ionisation contour at the standard measurement depth.

Use the profiles measured in 3.2.2.1 above.

LIMIT⁴: Ratio $\leq 1,05$.

4. DOSIMETRY

4.1. MEASUREMENT OF ABSORBED DOSE

The absorbed dose for a standard field size (10 x 10 cm²) applied to a suitable tissue equivalent phantom on the central axis of the beam should be measured for each type of radiation (photons and electrons) and each beam quality or energy. These measurements should be done with a suitable ionisation chamber calibrated by the CSIR at the beam qualities concerned or with any other suitably calibrated detector. The procedures, formulas and correction factors described in the TG21-protocol of the AAPM⁶ should be used in the determination of the absorbed dose.

4.2. THE MONITOR SYSTEM

The absorbed dose given to the patient is controlled by the MONITOR SYSTEM and the reliability of the monitor system should be thoroughly investigated.

4.2.1. REPRODUCIBILITY OF THE MONITOR SYSTEM

The reproducibility is defined as the maximum coefficient of variation of the ratio R, of the set number of monitor units to the measured absorbed dose for the x-ray and electron beams.

The reproducibility should be supplied by the supplier and confirmed by the user during acceptance.

Measurements are done at a gantry angle of 0°, collimator angle of 0°, field size 10 x 10cm² for the x-ray and electron beam: at the maximum and minimum absorbed dose rate. The reproducibility is calculated from 10 sequential measurements for each set of parameters.

4.2.2. PROPORTIONALITY

The relationship between the registered values of the monitor units U and the absorbed dose D should be linear;

$$D = SU$$

Where S is the constant of proportionality.

The supplier should supply the maximum deviation of the measured absorbed dose from the product SU. This maximum deviation should be given as a percentage for each beam energy and should be valid over the range of absorbed doses and absorbed dose rates to be used.

The proportionality may be determined by measuring the absorbed dose for each of a series of 5 settings of the beam monitor. The settings should be selected at approximately equal intervals over the range to be used. The test is done for X-ray energy and one electron energy at a gantry angle of 0° , collimator on 0° and a field size of $10 \times 10 \text{ cm}^2$. For each set of measurements the constant S and the maximum deviation are determined.

4.2.3. DEPENDENCE ON THE POSITION OF THE TELETHERAPY UNIT

Determine the ratio R from measurements of the absorbed dose at each of the gantry angles 0° , 90° , 180° and 270° as well as at each of the collimator angles 0° , 45° , 90° , 180° and 270° . The ratio R is defined in section 4.2.1 above. Use a field size of $10 \times 10 \text{ cm}^2$ for both the x-ray and electron beams and do the test in each case at the minimum and maximum nominal energy.

LIMIT: The measured ratios should correspond within 2% with the mean ratio for the rotation concerned.

4.2.4. DEPENDENCE ON THE GANTRY ANGLE DURING ROTATION THERAPY

In the instance of moving beam therapy (rotation therapy) the supplier should supply the maximum difference between the average value of the ratio R during gantry rotation through different sectors and the average value of R determined in section 4.2.3.

This maximum difference should be checked by determining the ratios R from 5 measurements for each set of measuring conditions. Measurements are done for rotation through sectors of 45° for both clockwise and anti clockwise rotation. Use $10 \times 10 \text{ cm}^2$, one absorbed dose rate and one nominal energy for the electrons as well as the x-rays.

LIMIT: Maximum difference $< 3\%$

4.2.5. DEPENDENCE ON THE FORM OF THE RADIATION FIELD

The supplier should supply the maximum difference in the value of R between two positions of the radiation field with the respective sides perpendicular to one another.

This maximum difference should be checked by determining the ratio R from 5 measurements for each set of measuring conditions. Use a gantry angle of 0° , collimator angle 0° , field size of $20 \times 5 \text{ cm}^2$, one absorbed dose rate and one nominal energy for the electrons as well as the x-rays. Determine the maximum difference between the measured R for the $20 \times 5 \text{ cm}^2$ field and the measured R for the $5 \times 20 \text{ cm}^2$ field, i.e. with the X and Y dimensions exchanged.

LIMIT¹: Maximum difference $\leq 1\%$

4.2.6. STABILITY OF THE CALIBRATION OF THE MONITOR SYSTEM

The stability of the calibration of the monitor system should be checked with respect to the following aspects. The supplier should supply the necessary data to be verified by the user.

4.2.6.1. Stability after a high absorbed dose (~100 Gy) has been given.

4.2.6.2. Stability through the day.

4.2.6.3. Stability through the week.

5. RADIATION SAFETY²

5.1. PROTECTION OF THE PATIENT AGAINST APPLICATION OF AN INCORRECT ABSORBED DOSE

5.1.1 Two separate monitor systems should be active to control termination of the applied absorbed dose. One of these systems should be connected to a battery to facilitate display of the monitor units given in case of a power failure.

5.1.2 A Timer (integrating) with a display on the console should be supplied. The timer will act as a back up for the above-mentioned monitors and will terminate the irradiation after a set period.

5.1.3 A Monitor system monitoring the absorbed dose rate at a fixed point in the beam should be supplied. This system will terminate the irradiation should the absorbed dose rate exceed a value twice the specified maximum dose rate.

5.1.4 In the case of equipment producing x-radiation and electrons, irradiation will not be possible before selection of the type of radiation (X-radiation or electrons) on the console and switching by the unit. The selected radiation type should be indicated on the console before and during irradiation. The necessary interlocks should be available to ensure that this requirement is satisfied.

5.1.5 In equipment producing radiation beams with various nominal energies, irradiation will not be possible until a specific nominal energy is selected on the console and the necessary switching is performed by the unit. The nominal energy of the beam produced would be displayed on the console before and during irradiation. The necessary interlocks satisfying this requirement should be available.

5.1.6 In equipment capable of both fixed beam and moving beam radiotherapy, irradiation shall not be possible until a selection of STATIONARY BEAM THERAPY or MOVING BEAM THERAPY has been made at the control panel and switching has been completed by the equipment. The necessary

interlocks shall prevent irradiation if these requirements are not satisfied. The irradiation mode should be displayed on the control panel before and during irradiation.

- 5.1.7 In equipment using wedge fitters irradiation shall not be possible until the specified wedge fitter has been selected on the control panel. The necessary interlocks shall control selection of the correct wedge fitter. The wedge fitter selected will also be displayed on the console.
- 5.1.8 It shall only be possible to start irradiation for a treatment from the console.
- 5.1.9 Irradiation as well as any movement of the equipment may be interrupted at any stage from the console. Following all interruption it shall be possible to re-start irradiation only from the console but without reselecting the operating parameters.
- 5.1.10 Termination of irradiation at any time from the console or certain points in the treatment room shall be possible. The unit shall automatically terminate irradiation should any one of the selected operating conditions change.
- 5.1.11 In the case of an unplanned termination of irradiation the cause of the termination should be displayed.
- 5.1.12 It should be possible to test the correct functioning of the interlocks of the unit.

5.2. PROTECTION OF THE PATIENT AGAINST CONTAMINATION COMPONENTS IN THE USEFUL BEAM²

5.2.1. X-RAY CONTAMINATION DURING ELECTRON IRRADIATION

The absorbed dose on the central axis at a depth of 100 mm past the practical range (in water) should not exceed 5% of the maximum absorbed dose for energies to 15 MeV and 7% for energies from 15 to 20 MeV.

5.2.2. ABSORBED DOSE ON THE SURFACE DURING X-RAY IRRADIATION

The absorbed dose on the surface on the central axis of the largest field size available should not exceed 60% of the maximum absorbed dose at 5 MV, 50% at 15 MV and 40% at 35 MV.

- 5.2.3 The supplier should indicate the maximum absorbed dose as a percentage of the total absorbed dose at the normal treatment distance produced by neutron contamination.

5.3. PROTECTION OF THE PATIENT AGAINST RADIATION OUTSIDE THE USEFUL BEAM²

5.3.1. LEAKAGE RADIATION THROUGH THE COLLIMATOR

5.3.1.1. X-Radiation

The collimator should attenuate the radiation to such an extent that the absorbed dose in the area shielded by the collimator does not exceed 2% of the absorbed dose on the central axis as measured at equal distance from the radiation source.

5.3.1.2. Electron Beams

The absorbed dose in a plane perpendicular to the central axis at the normal treatment distance should not exceed the following limits:

- 1) An average of 2% of the absorbed dose on the central axis at the normal treatment distance. This limit applies in the area between a line 4 cm outside the 50% isodose contour and the outer edge of the maximum available geometrical field size.
- 2) A maximum of 10% of the absorbed dose on the central axis at the normal treatment distance. This limit applies between a line 2cm outside the 50% isodose contour and the outer edge of the maximum available field size.

5.3.1.3. Large Beams

The following limits apply to equipment in which the geometrical field size exceeds 500 cm² at the normal treatment distance.

For square fields of any size the product of the mean absorbed dose due to leakage radiation through the collimator and the area shielded by the collimator should not exceed one tenth of the product of the maximum absorbed dose on the central axis and the area of the useful beam for a field size of 10cm x 10cm. All values of the absorbed dose and area refer to the normal treatment distance.

5.3.2. LEAKAGE RADIATION OUTSIDE THE MAXIMUM USEFUL BEAM

The equipment shall contain a shield attenuating the radiation to such an extent that the following requirements are satisfied:

In a plane circular surface with a radius of 2m and with its centre on and perpendicular to the central axis of the beam at the normal treatment distance and lying outside the maximum useful beam, the absorbed dose due to leakage radiation (excluding neutron radiation) should not exceed a maximum of 0,2% and an average of 0,1% of the absorbed dose measured at the intersection of the central axis and the plane. These values refer to measurements that have been averaged over 100 cm².

The absorbed dose due to leakage (excluding neutron radiation) at 1 m from the path of the electrons between the electron gun and the target (or electron

window) should not exceed 0,5% of the maximum absorbed dose on the central axis at the normal treatment distance. The area described excludes the area in the previous paragraph.

5.3.3. *NEUTRON LEAKAGE OUTSIDE THE MAXIMUM USEFUL BEAM*

The absorbed dose due to neutrons outside the maximum useful beam, measured on the plane defined in 5.3.2 above should not exceed a maximum of 0,05% and an average of 0,02% of the absorbed dose in the useful beam as measured at the intersection of the central axis and the plane. The specified values refer to measurements that have been averaged over 200cm².

The supplier should indicate any areas and any conditions for which the level of 0,025 is exceeded.

Except in the area defined above, the absorbed neutron dose measured at a distance of 1 m from the path of the electrons between the electron gun and the target or the electron window should not exceed 0,05% of the maximum absorbed dose of the central axis at the normal treatment distance.

- 5.3.4 An interlock shall terminate the irradiation automatically if the leakage radiation levels in the plane defined in 5.3.2 and 5.3: above exceed values 5 times higher than the specified values; due to an error condition in which the electron beam hits the target or the electron window incorrectly.

5.4. RADIATION SAFETY FOR PERSONS OTHER THAN PATIENTS

5.4.1. *OPERATING STATES*

It shall be possible to lock the accelerator into the STAND BY STATE. When the interlock is removed, the accelerator is in the PREPARATORY STATE.

The preparatory state shall be indicated at the console. A special circuit shall be provided to allow external interlocks to be connected (for example for room doors). There shall be an indication at the console that this special circuit open or closed. The special circuit together with the interlocks described in sections 5.1 to 5.3 shall constitute a system of interlocks. Irradiation shall not be possible unless the system of interlocks is satisfied and all selection procedures have been completed. When these conditions are satisfied, the equipment is in the ready state.

The ready state shall be indicated at the console and if necessary at other locations. Access to the interlock system shall be provided so that it is possible to interlock the equipment from other locations against progress to the ready state, for the protection of persons in the controlled areas.

5.4.2. DISPLAY OF IRRADIATION

There shall be a display at the console when irradiation is occurring with the possibility of display at other locations.

5.4.3. EMISSION OF RADIATION IN STAND-BY AND PREPARATORY STATES

In the stand-by and preparatory states the absorbed dose rates shall not exceed during a period greater than 10 s immediately following termination of irradiation a value of:

- 0,2 mGy⁻¹ at any readily accessible place 5 cm from the surface of the equipment
- 0,02 mGyh⁻¹ at 1 m from the surface.

These dose rates may arise from, for example, radioactivity originally present or induced in the equipment, or from field emission.

6. QUALITY CONTROL PROGRAM

6.1. WEEKLY TESTS

Characteristics of the linear accelerator which may change suddenly and without giving an external indication, should be checked weekly (or more frequently if there is a possibility of accelerator instability). These checks include:

- 6.1.1 Measuring the absorbed dose for the standard field size on the specified depth in water (section 4.1).
- 6.1.2 Checking the uniformity of the photon and electron beams (section 3.1.2).
- 6.1.3 Comparing the optical distance indicator against the mechanical front pointer (a fixed distance indicator sections 2.1.3 and 2.1.1).
- 6.1.4 Checking the alignment of the radiation head and the cross wires. (section 2.1.2).
- 6.1.5 Checking the alignment of the optical (LASER)-beams (section 2.1.1).
- 6.1.6 Checking the alignment of the radiation beam (section 2.2).
- 6.1.7 Checking the correct functioning of all the safety systems e.g. collision mechanisms, interlocks, warning lights, secondary monitors, timers, etc. (sections 5.1, 5.4.1 and 5.4.2).

6.2. MONTHLY TESTS

A monthly test shall be done on those characteristics that are likely to change a small amount. These include:

- 6.2.1 Visual inspection of mechanical parts including the collimator system.
- 6.2.1 Checking the alignment of the treatment couch (section 2.1.4).
- 6.2.1 Checking the quality (energy) of the photon and electron beams (section 3.1.1 and 3.2.1).
- 6.2.1 Checking the penumbra of the photon beams (section 3.1.3).

6.3. INITIAL AND YEARLY TESTS

The complete set of tests described in sections 2 to 5 above should be conducted at acceptance of the unit by the user and annually thereafter.

After replacement of parts (e.g. the magnetron), major repairs or any modifications approved by the manufacturer, the characteristics concerned should be tested and new reference values should be determined.

7. REFERENCES

1. Philips Medical Systems, "Customer Acceptance Test Schedule: SL 75-20 Medical Linear Accelerator:", Publication 4513370 116712 (M.E.L. England).
2. International Electrotechnical Commission, "Safety of Medical Electrical Equipment. Part 2: Particular requirements for medical electron accelerators in the range 1 MeV to 50 MeV. Section One: General, Section Two: Radiation Safety for Equipment". IEC Standard, Publication 601-2-1, First Edition (Geneve, Switzerland 1981).
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4. Philips Medical Systems. Publication 4513370 02015. SL25 Linear Accelerator "Customer Acceptance Test Schedule" (M.E.L. England).
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7. National Council on Radiation Protection and Measurements, Report No. 69, "Dosimetry of X-ray and gamma-ray beams for radiation therapy in the energy range 10 keV to 50 MeV". (NCRP, Washington, D.C., 1981).
8. American Association of Physicists in Medicine, Symposium Proceedings No. 3, "Proceedings of a symposium on quality assurance of radiotherapy equipment". (AIP, New York, NY, 1983).