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Quality Control of Medical Electron Accelerators

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1 Introduction

The aim of the recommendations described in this document is to provide medical physicists working in radiation therapy departments with guidelines on which to base Quality Assurance programmes for medical electron accelerators as required by the Radiological Protection Act [1], the Radiological Protection Ordinance [1] and the "Beschleunigerverordnung, BeV" [2]. These recommendations replace in part (medical electron accelerators only) the Recommendations No 1 1982 and Revision 1992 of the Swiss Society of Radiobiology and Medical Physics (SSRMP) [3].

For the preparation of the present recommendations, it was decided to rely as much as possible on published national and international guidelines, with particular reference to those listed in chapter 10 [3-13]. The structure of this document is intended to be as general as possible, in order that the recommended procedures may be easily adapted to the different structures of Swiss radiation therapy departments. At the same time, the document aims to introduce a reasonable level of uniformity for quality assurance methods throughout Switzerland.

This document addresses mechanical, dosimetric and safety tests on linear accelerators (photons and electrons). Determination of absolute dosimetry under reference conditions is not within the scope of this document. For the dosimetry of high energy photon and electron beams the user should refer to Recommendations No. 8, 2000 [14] and No.10, 2002 [15] of the SSRMP.

It should be noted that the tests described in this document are considered insufficient for the following situations:

- acceptance and commissioning of new equipment,
- acceptance following major corrective interventions, or after major upgrades,
- acquisition of data directly used for treatment planning.

It should be noted that whenever possible standard set-up conditions are proposed and suggestions are made about equipment to be used. These should, however, be considered as recommendations and not as mandatory requirements. It is recommended that specific procedures are written for any tests used which differ substantially from that indicated in the present document.

It should also be noted that it may be unrealistic to carry out some of the tests described in this document in certain centres, either because major investments (human or technical resources) are required, or because the item being tested is not available, or not in clinical use. It remains the responsibility of a qualified medical physicist to apply these recommendations in a suitable manner.

It is also recommended that the magnitude of any deviations from the reference value is recorded for each test, rather than simply using a tick to confirm that the test has been carried out and the results lie within the allowed tolerances limits. This enables trends to be seen, which may allow action to be taken before the tolerances are exceeded.

A certain degree of overlap between some of the described tests is unavoidable. It is the responsibility of a qualified medical physicist to combine the tests such that all aims are covered. For example, if the congruence of light and radiation field is checked for different field sizes and gantry angles, it is not necessary to check radiation- and mechanical-isocentre with respect to gantry rotation. Only one of the two isocentre-checks needs to be carried out at different gantry angles. Similarly, if radiation- and mechanical-isocentre is tested with respect to gantry rotation, the congruence of light and radiation field does not need to be checked at different gantry angles.

Some of the checks could be delegated to other co-workers (technicians, radiographers or other suitably trained employees). The limits of such delegation are left to the responsibility of the medical physicists. The quality assurance programme itself, nevertheless, remains the responsibility of the medical physicist only.

It is a legal requirement that all tests executed are documented with written protocols containing enough information to demonstrate the performance status of the equipment. These protocols should

be undersigned by the local responsible medical physicist, which guarantees for their conformity to the present recommendations.

Finally, the execution of the checks described in this document require the appropriate allocation of time and of human resources, which directly affects the daily workload of the treatment machines. This cannot be used as an argument to reduce or limit the control programme. The quality assurance procedures should be considered as an integral part of the machine workload and the required time should be allocated within the normal working hours. The work of medical physicists, or delegated co-workers, during evenings or weekends should be considered only in exceptional cases, or for urgent interventions.

Test frequencies are expressed as annually (a), monthly (m), weekly (w), or daily (d). Definitions of relevant symbols used in the text are reported at the end of the document.

2 Mechanical checks

2.1 Check of optical SSD indicators

Aim:

To check the SSD-light-indicator versus the mechanical distance indicator.

How to perform the test:

Compare the SSD-light-indicator with the mechanical distance indicator, (e.g. front pointer fixed to the gantry).

Suggested set-up conditions:

The test should be performed at three positions: at the reference SSD and also at both smaller and larger distances.

Frequency and tolerance:

w 2 mm

2.2 Collimator, gantry and treatment table rotation scales

Aim:

To check the correspondence between the readings at the treatment control panel or the display monitor, the mechanical scale readings and the absolute position.

How to perform the test:

Collimator rotation: Rotate the gantry to approx. 90° or 270°. Align the light field edges at 0° collimator angle with appropriate horizontal or vertical marks (e.g. set up with the help of a spirit level for absolute measurements) on the treatment room wall. Note the collimator reading at the treatment control panel or the display monitor and the reading on the mechanical scale on the treatment head. Repeat the above at 90° collimator angle.

Gantry rotation: Rotate gantry to 0°, 90°, 180° and 270° according to the mechanical scale. Note readings from the treatment control panel or the display monitor and compare to the mechanical readings. A spirit level should be used to check the 0° gantry position for the absolute measurement.

Table rotation: Rotate the table to, for example, 0°, 90°, and 270° about the isocentre and compare the reading at the control panel or the display monitor to the mechanical reading on the table (if available).

Frequency and tolerance:

| | agreement between the readings | absolute measurement |
|---------------------|-----------------------------------|----------------------|
| Collimator rotation | m 1° | m 1° |
| Gantry rotation | m 1° | m 1° |
| Table rotation | m 1° | - |

2.3 Treatment table movement scales

Aim:

To check the accuracy and linearity of the treatment table latitudinal, longitudinal and vertical motion scales.

How to perform the test:

The table height should be adjusted so that the top of the table intersects the isocentre and this table height should read zero. The table should be set to the zero position in the latitudinal and longitudinal directions. It is then moved a defined distance in each of the orthogonal directions and the

displacement of the table should be measured with a ruler and checked against the table latitudinal, longitudinal and vertical readouts.

Frequency and tolerance:

m 2 mm

2.4 Treatment table top deflection under load

Aim:

To check the reading of the treatment table height under load, in order to assess the sagging of the table top with time.

How to perform the test:

The same as 2.3, but loading the table top with an average expected load, with the weight spread symmetrically either side of the isocentre. A repeat check of the table height reading at the isocentre should be made after approximately 20 minutes of the table top under load.

Frequency and tolerance:

a 2 mm

2.5 Light and radiation field coincidence

Aim:

To test the congruence of the radiation and light field at various gantry angles.

How to perform the test:

A film is placed perpendicular to the beam central axis at the isocentre. The edges of the light field and the crosshair are marked before the film is exposed. The difference between the edges of the light and radiation fields can be checked on this film, for example using a densitometer to establish the radiation field edge. The size of the radiation field is compared to the light field size and the radiation field centre is compared to the crosshair position.

This test is normally performed at a gantry angle of 0° , but possible movement of the light source as the gantry is rotated could be detected if the congruence of the radiation and light fields is checked at other angles. At least two field sizes (e.g. $10 \times 10\text{cm}^2$ and $20 \times 20\text{cm}^2$) and four different gantry angles (e.g. 0° , 90° , 180° , 270°) should be tested. These may be carried out on a rotational basis. Annually, this check should also be carried out at an additional SSD (other than reference SSD) at one gantry angle and one field size.

Frequency and tolerance:

| | |
|--------------------------------------|---|
| m (1 field per week at standard SSD) | 2 mm for field sizes $< 20 \times 20 \text{ cm}^2$ 1% for field sizes $> 20 \times 20 \text{ cm}^2$ 2 mm (deviation between the radiation field centre and the crosshair) |
| a (at additional SSD) | 2 mm for field sizes $< 20 \times 20 \text{ cm}^2$ 1% for field sizes $> 20 \times 20 \text{ cm}^2$ 2 mm (deviation between the radiation field centre and the crosshair) |

2.6 Mechanical isocentre check

A general note on checks of the isocentre position: Checking the mechanical isocentre position, the radiation isocentre position and the optical indication of the isocentre and their relative alignment is a complex procedure with many aspects being inter-related. Thus, it does not lend itself easily to independent checks of the separate components as appears to be implied by tests listed below. In practice, a combination of a few complementary checks are usually performed.

2.6.1 Rotation axis of the collimator

Aim:

To verify that the crosshairs are aligned with the collimator rotation axis.

How to perform the test:

This test should be performed prior to other tests of the mechanical isocentre, which are based on the assumption of correctly aligned crosshairs. With the gantry and treatment table angles set to zero, and at two distances (one of which should be at the SAD), the crosshair position is marked as the collimator is rotated to 0°, 90° and 270° in order to establish the maximum deviation with collimator rotation.

Frequency and tolerance:

m 2 mm (all points should be located within a 2 mm diameter circle containing the isocentre.)

2.6.2 Treatment table rotation

Aim:

To verify that the table rotation axis lies within the isosphere.

How to perform the test:

With the gantry and collimators angles set to zero, and using graph paper on the treatment table, the crosshair position should be marked as the table is rotated to 0°, 90° and 270° such as to establish the maximum deviation.

Frequency and tolerance:

m 2 mm (all points should be located within a 2 mm diameter circle containing the isocentre.)

2.6.3 Rotation axis of the gantry

Aim:

To verify that the gantry rotation axis lies in the isocentre sphere.

How to perform the test:

The position of an isocentre indicator (either the crosshairs, or an indicator attached to the gantry), is measured relative to a fixed point marking the isocentre position, as the gantry is rotated.

For example: a plate mounted such that it can be rotated about a cross marked on its surface, is set so that the cross is at the indicated isocentre distance and aligned with the crosshairs. The alignment of the crosshairs to the marked cross on the plate is checked as the gantry is rotated. A variety of such tools is commercially available.

An alternative method is to use a sharp pointer attached to the gantry (in the same manner as the front pointer). This is aligned on the collimator rotation axis and with the tip at the isocentre distance. A second rigid pointer is mounted on the treatment table or the floor so as to mark the isocentre. The deviation of the tips of the two pointers is measured as the gantry is rotated.

Frequency and tolerance:

m 2 mm (all points should be located within a 2 mm diameter circle containing the isocentre.)

2.7 Radiation isocentre check

Aim:

To confirm that the radiation beam axes intersect within a 2 mm sphere (isocentre sphere) and that the radiation isocentre is coincident with the mechanical isocentre.

2.7.1 'Star film'

Aim:

To confirm that, in the plane of the gantry rotation, the radiation beam axes intersect within a 2 mm sphere (isocentre sphere) and that the radiation isocentre is coincident with the mechanical isocentre.

How to perform the test:

A film is placed vertically in the plane of gantry rotation. The indicated isocentre position should be marked on the film. The film is exposed at different gantry angles, with the narrowest possible field setting. The image on the film will be a star shape. The intersection of all beams marks the radiation isocentre established in the plane of the film.

Frequency and tolerance:

- a 2 mm (all beams should be centred within a 2 mm diameter circle containing the marked isocentre.)

2.7.2 Alignment of opposing fields

Aim:

As the star film is only sensitive to errors in the plane of the gantry rotation, this test is suggested to detect errors in the perpendicular direction.

How to perform the test:

A film is set up and marked at the field centre and field edges with the gantry at 0° in the identical manner as for the light/radiation coincidence test (2.5). Then the film is exposed with the gantry at 180°. By comparing this film with that taken for test 2.5 any relative movement of the radiation fields and hence a movement of the radiation isocentre can be detected.

Frequency and tolerance:

- a 2 mm

2.8 Laser alignment

Aim:

To check that all laser beams correctly indicate the isocentre and that opposing laser beams are congruent.

How to perform the test:

Indication of the isocentre:

A rotatable plate is adjusted in such a way that a point marked on its rotation axis is coincident with the light field crosshair at SAD. It is checked that the lateral and longitudinal lasers are coincident with this mark.

Congruence of lasers:

A piece of paper is put into the lateral laser beam at a distance further than 20 cm from the isocentre. The maximum deviation between the projections of the right and the left lateral lasers is recorded. The projection of the longitudinal laser is compared to a reference mark, for example on the floor, (that is made at the time of acceptance of the laser system).

Quick daily check:

This should ensure that the lasers correctly indicate the isocentre, either using the method described above, or by checking that the lasers coincide with appropriate marks made on the opposing walls.

Frequency and tolerance:

d 2 mm Quick daily check

w 1 mm Indication of the isocentre and congruence of the lasers

(Note that for the congruence the tolerance is valid for deviations recorded at a distance of at least 20 cm from the isocentre).

2.9 Field size indicators

Aim:

To check that the read out of the field size indicators agrees with the measured field size.

How to perform the test:

The size of the light field is measured at the reference SSD in a plane perpendicular to the central axis. The chosen field size should be collimated starting from a larger field size as well as starting from a smaller field size. The width and length of the light field should be measured at the centre of the field. The measured field size is compared with the numerical field size indication. At least three different symmetrical field sizes and at least one additional asymmetric jaw setting should be checked. The field size may be chosen according to a weekly rotation scheme, to include at least one field size per week. For independent collimators it may be preferred to check predefined collimator settings against the measured collimator position for each jaw independently. The maximum over travel and the zero position should be checked for each of the four jaws.

If the light field is used clinically for electrons, then these checks should also be performed for electron fields.

Frequency and tolerance:

m 2 mm for field sizes $< 20 \times 20 \text{ cm}^2$
 1% for field sizes $> 20 \times 20 \text{ cm}^2$

2.10 Non-divergent asymmetric field check

Aim:

To check the overlap or gap at the junction of non-divergent asymmetric fields.

How to perform the test:

A film may be exposed four times in succession, with the four field quadrants, by setting the opposing jaws to the zero position. The maximum and minimum junction dose (ignoring the central axis region where all 4 fields abut), should be determined using a densitometer.

Frequency and tolerance:

m 2 mm overlap. For a penumbra fall-off of 10% per mm (80-20% penumbra width of 6 mm), this equates to a minimum/maximum junction of between 80% and 120% of the nominal dose.

3 Radiation checks: X-Rays

3.1 Beam output: definitive calibration, routine beam output check, constancy check

Aim:

To verify the machine output and the dose monitor calibration.

How to perform the test:

Definitive calibration:

This should be carried out annually for all available beam qualities following the procedures described in the appropriate SSRMP recommendations [14].

Routine beam output check using a recommended dosimeter:

This should be carried out for all available beam qualities using one of the dosimeters suggested in the appropriate SSRMP recommendations [14], or with a similar dosimeter and under similar conditions. However, a solid water equivalent phantom may be used to replace the water phantom, with a hole drilled at a suitable depth, (e.g. 10 cm).

Beam output constancy check:

A variety of devices may be used, diodes, ionisation chambers, or one of the purpose built daily check dosimeters. A measurement for all beam qualities clinically in use is made under daily check conditions and is compared against the reference value established at the time of a calibration measurement.

Suggested set-up conditions:

$10 \times 10 \text{ cm}^2$ field, SDD = 100 cm or SSD = 100 cm, $d \geq d_{\text{max}}$

It is important to regularly check the constancy of the dosimeter systems against a reference measurement. This should be carried out at least every 6 months, or more frequently depending on the stability of the device. The deviation of the dosimeter system to the reference must be within 0.5%.

Frequency and tolerance:

a 2% Definitive calibration
w 2% Routine beam output check using a recommended dosimeter
d 3% Beam output constancy check

3.2 Output constancy with gantry angle

Aim:

To verify the stability of the machine output with gantry angle.

How to perform the test:

The machine output should be checked at different gantry angles for each beam quality. An ionisation chamber with build-up cap can be placed at the isocentre, or a dosimeter may be attached to the gantry along the beam axis. The values measured should be compared with the value at the gantry angle used for the machine calibration.

Suggested set-up conditions:

10 x 10 cm² field, SDD = 100 cm, $d \geq d_{\max}$, gantry angles 0°, 90°, 180° and 270°

Frequency and tolerance:

a 2%

3.3 Output constancy with dose rate

Aim:

To verify machine output constancy at different dose rates.

How to perform the test:

The beam output should be checked for each dose rate clinically used and for all available dose rates if dynamic wedges with varying dose rates are implemented.

Measurements should be compared with the output at the standard dose rate.

Suggested set-up conditions:

As for a routine beam output check.

Frequency and tolerance:

a 1%

3.4 Linearity of the dosimetry system

Aim:

To verify that the dose delivered per monitor unit is proportional to the number of monitor units given. (The start up and the end errors are checked at the same time.)

How to perform the test:

The dose delivered per monitor unit should be verified, for all energies, for a range of given monitor units (e.g. equivalent to approximately 0.2 Gy, 0.5 Gy, 1 Gy, 2 Gy, 4 Gy)

Suggested set-up conditions:

As for a routine beam output check.

Frequency and tolerance:

a 1%

3.5 Dose monitor leakage

Aim:

To verify that the dose monitor is not integrating dose when no radiation is present.

How to perform the test:

The beam is switched off. The dose monitor chambers are activated for a certain time, (which is dependent on the smallest dose rate used clinically at that machine). Verify that the dose monitors do not count any dose.

Suggested set-up conditions:

If for e.g. the lowest dose rate used clinically is 100 MU/min, the dose monitor should be activated for 1 minute to assure a 1% tolerance.

Frequency and tolerance:

a 1%

3.6 Output factors

Aim:

To verify that the output factors (machine output variation with field size), are in agreement with the values determined at the time of commissioning the machine.

How to perform the test:

Output factor measurements should be made in a water tank at d_{ref} for a few square and rectangular fields. The ratio of the dose at d_{ref} for the given field and the reference $10 \times 10 \text{ cm}^2$ field gives the output factor.

Suggested set-up conditions:

Field sizes: $6 \times 6 \text{ cm}^2$, $10 \times 10 \text{ cm}^2$, $20 \times 20 \text{ cm}^2$ and maximum, also $6 \times 30 \text{ cm}^2$ and $30 \times 6 \text{ cm}^2$, SDD = 100 cm, $d = d_{ref}$.

Frequency and tolerance:

a 2%

3.7 Tray transmission factors

Aim:

To verify the beam transmission through the tray.

How to perform the test:

The ratio of the ionisation chamber reading measured with the shadow tray in the beam to that without the tray is calculated and compared with the reference value. For a tray with holes, a weighted average of the transmission factor should be calculated taking the relative areas of hole and solid tray into account.

Suggested set-up conditions:

$10 \times 10 \text{ cm}^2$ field, SDD = 100 cm, $d = d_{ref}$.

Frequency and tolerance:

a 1%

3.8 Wedge factors (mechanical wedges)

Aim:

To verify the wedge transmission ratio on the central axis.

How to perform the test:

The dose should be measured in a wedged beam and also in an open field under the same conditions and then the ratio of the two doses is calculated. When making the wedged field dose measurement the ionisation chamber axis should be in the unwedged direction. Measurements should be made with the collimators rotated through 180° and for both wedge directions (e.g. “in” and “out”) if more than one direction is possible, and then the mean value is used to calculate the wedge factor.

Measurements must be compared to baseline data.

Suggested set-up conditions:

$10 \times 10 \text{ cm}^2$ field, SDD = 100 cm, $d = d_{ref}$.

Frequency and tolerance:

a 2% (for manual mechanical wedges)

m 2% (for motorised mechanical wedges)

Dynamic wedges are discussed separately in section 6.

3.9 Wedge factor constancy with gantry angle

Aim:

To verify that any backlash in the wedge position is minimal.

How to perform the test:

The checks should be carried out as described in paragraph 3.8, but also with the gantry at 90° and 270° and the collimator in both directions. The values measured should be compared with the value at the reference gantry angle (paragraph 3.8).

Suggested set-up conditions:

10 x 10 cm² field, SDD = 100 cm, d = d_{ref}.

Frequency and tolerance:

a 3%

3.10 Beam energy

Aim:

To verify through the beam penetration the stability of the incoming photon spectrum.

How to perform the test:

Extensive check:

Perform a depth dose measurement on the central axis in a water phantom. Determine the depth of d_{max}. Measurement of TPR_{20/10} (or, alternatively, the J₁₀/J₂₀ ratio,) in a water phantom, or solid phantom.

Quick check:

Measure the dose at two different depths in a (solid) phantom (e.g. at 10 and 20 cm depth or 5 and 15 cm) and compute the ratio between the two readings.

Devices: ion chamber, diode, diamond detector.

Suggested set-up conditions:

10 x 10 cm² field, SSD = reference for calibration or 100 cm, SDD = 100 cm for TPR_{20/10}.

Frequency and tolerance:

| | | |
|---|------|--|
| a | 2% | expected TPR _{20/10} (or J ₁₀ /J ₂₀) |
| a | 2% | expected depth dose (for depths greater than d _{max}) |
| a | 2 mm | expected d _{max} |
| w | 2% | expected ratio of dose at two depths (quick check) |

3.11 Dose profiles at reference gantry position

Aim:

A suitably flattened beam is established at commissioning, where after quality control checks should ensure that the dose profile retains the same shape as for the beam data measurements.

How to perform the test:

Extensive checks:

Measure dose profiles along the major beam axes for all beam qualities. Compare the dose profiles with the reference dose profiles.

Quick checks:

'In phantom' or 'in air' profiles may be measured. The relative dose can be measured at a minimum of 5 points, one on the central axis and two on each of the major field axes (paired dose points located symmetrically about the central axis). Compare the profiles with the reference profiles, alternatively, evaluate the flatness and symmetry parameters.

Suggested set-up conditions:

Extensive checks:

Field sizes: 5 x 5 cm², 10 x 10 cm², 20 x 20 cm² and maximum field size, SDD = 100 cm, d = d_{ref}, gantry 0°.

Devices: ion chamber, diamond detector, diode and linear array in a water phantom.

Quick checks:

Field sizes: 10 x 10 cm² and maximum field size (as limited by the linac or the measuring device used).

Devices: ion chamber, diode, linear array in a water phantom, or film in a slab phantom. Measurements could be performed in air with an ion chamber or diode attached to an air scanner, or with an EPID.

Frequency and tolerance:

| | | |
|---|----|--|
| w | 3% | <i>Quick checks:</i> deviation from base line measurements (within the flattened area) |
| a | 2% | <i>Extensive checks:</i> deviation from profiles measured at commissioning (within the flattened area) |

3.12 Dose profile constancy with gantry angle

Aim:

To verify the stability of the dose across a homogeneous radiation field at different gantry angles with respect to that at the reference gantry angle.

How to perform the test:

Measure profiles along the major beam axes at different gantry positions for all energies. Evaluate the variations in the profile with respect to the baseline measurements at reference gantry angle.

Devices: ion chamber, diode, linear array attached to an air scanner, film in a slab phantom, EPID or devices measuring the dose at the centre and two (four) symmetric points on the beam profiles.

Suggested set-up conditions:

Field size: maximum field size (as limited by the linac or the measuring device used).

SDD = 100 cm, $d = d_{\text{ref}}$ (or d_{max} if 'in air' measurements are performed), gantry angles 0° , 90° , 180° and 270° .

Frequency and tolerance:

| | | |
|---|----|---|
| a | 3% | deviation from base line measurements (within the flattened area) |
|---|----|---|

3.13 Gantry rotation speed / MU delivered per unit angle interval

Aim:

To check that the MU delivered per unit angle interval is correct. (The dose rate does not necessarily remain constant during the rotation, however the gantry rotation speed should be altered to compensate for this). It is only necessary to perform this test if rotational irradiation is clinically implemented.

How to perform the test:

Check that the MU delivered during gantry rotation is as expected for various angle intervals throughout 360° . Alternatively, a film may be exposed around a cylindrical phantom, producing a resultant uniform dose distribution.

Frequency and tolerance:

| | |
|---|----|
| m | 2% |
|---|----|

3.14 Radiation leakage

Aim:

Check the integrity of the shielding system.

How to perform the test:

Dose measurements (e.g. using film) are made around the gantry head. The leakage dose is specified at 1m from the beam focus.

Frequency and tolerance:

| | |
|---|---|
| a | 0.5% of the dose in the reference point |
|---|---|

3.15 Radiation survey

Aim:

Check that the ambient dose equivalent at relevant points around the treatment areas, (e.g. at the console, by the treatment room doors), lies within the limits specified at acceptance.

Frequency and tolerance:

a as at acceptance

4 Radiation checks: Electrons

4.1 Beam output: definitive calibration, routine beam output check, constancy check

Aim:

To verify the machine output and the dose monitor calibration.

How to perform the test:

Definitive calibration:

This should be carried out annually for each electron energy following the procedures described in the SSRMP recommendations, [15].

Routine beam output check using a recommended dosimeter:

This should be carried out for each electron energy using one of the dosimeters recommended by the relevant SSRMP recommendations, or a similar dosimeter and under similar conditions. However, a solid water equivalent phantom may be used to replace the water phantom, with a hole drilled at a depth suitable for each electron energy (e.g. d_{max}). A cylindrical ion chamber may be used instead of a parallel-plate chamber if the set-up conditions are reproducible.

Beam output constancy check:

A variety of devices may be used, diodes, ionisation chambers, or one of the purpose designed daily check dosimeters. A measurement is made for all electron energies, clinically in use, under daily check conditions and is compared to the reference value established at the time of a calibration measurement.

Suggested set-up conditions:

Applicator size $10 \times 10 \text{ cm}^2$ or greater, SSD = 100 cm, $d = d_{max}$.

Frequency and tolerance:

| | | |
|---|----|---|
| a | 2% | Definitive calibration |
| w | 2% | Beam output check using a recommended dosimeter |
| d | 3% | Beam output constancy check |

4.2 Output constancy with gantry angle

Aim:

To verify the stability of the machine output with gantry angle.

How to perform the test:

The machine output should be checked at different gantry angles for each electron energy. An ionisation chamber with build-up cap can be placed at the isocentre, or a dosimeter may be attached to the gantry along the beam axis. The values measured should be compared with the value at the gantry angle used for the machine calibration.

Suggested set-up conditions:

Applicator size $10 \times 10 \text{ cm}^2$ or greater, SDD = 100 cm, $d = d_{max}$, gantry angles 0° , 90° , 180° and 270° .

Frequency and tolerance:

a 2%

4.3 Output constancy with dose rate

Aim:

To verify machine output constancy at different dose rates.

How to perform the test:

The beam output should be checked for each dose rate clinically used. Measurements should be compared with the output at the standard dose rate.

Suggested set-up conditions:

As for a routine beam output check.

Frequency and tolerance:

a 1%

4.4 Linearity of the dosimetry system

Aim:

To verify that the dose delivered per monitor unit is independent of the number of monitor units given and so ensure that end errors in switching off the beam are negligible.

How to perform the test:

The dose delivered per monitor unit should be verified, for all electron energies, for a range of given monitor units (e.g. equivalent to approximately 0.2 Gy, 0.5 Gy, 1 Gy, 2 Gy, 4 Gy).

Suggested set-up conditions:

As for a routine beam output check.

Frequency and tolerance:

a 1% variation in dose per monitor unit

4.5 Output factors for different applicators

Aim:

To verify that the output factors (machine output variation with different applicators using standard inserts) are in agreement with the values determined at the time of commissioning the machine.

How to perform the test:

Measurements should be made in a water tank or water equivalent phantom at d_{\max} for all applicators and all electron energies. The ratio of the dose at d_{\max} for the given applicator and the 'standard' applicator gives the output factor.

Suggested set-up conditions:

All applicators, SSD = 100 cm, $d = d_{\max}$. If adjustable applicators are available, a set of at least 5 field sizes, representative of those used clinically, should be used for tests (e.g. 5 x 5 cm², 10 x 10 cm², 15 x 15 cm², 20 x 20 cm², maximum allowed).

Frequency and tolerance:

a 2%

4.6 Virtual source position

Aim:

To verify the constancy of the virtual source position.

How to perform the test:

The ratio between the dose measurements at the reference SSD and at another SSD should be verified for all applicators (using standard inserts) and all electron energies, relative to the value at time of commissioning the machine.

Suggested set-up conditions:

All applicators, SSD = 100 cm and 110 cm, $d = d_{\max}$.

Frequency and tolerance:

a 1%

4.7 Beam energy

Aim:

To verify the stability of the electron beam energy by measurement of the beam penetration.

How to perform the test:

Extensive check:

Perform a depth dose measurement on the central axis in a water phantom. Determine the shift in the position of for e.g. the d_{80} or d_{50} values established at commissioning.

Additionally, determine the x-ray contamination and its variation relative to the commissioning value.

Quick check:

Measure the dose, or ionisation, at two different depths in a (solid) phantom (ideally one of the depths should be close to the maximum ionisation depth and the other on the descending part of the depth dose curve. The deviation of the measured ratio from the baseline measurement should be converted into a range shift.

Devices: ion chamber, diode, diamond detector.

Suggested set-up conditions:

Applicator size $10 \times 10 \text{ cm}^2$ or $15 \times 15 \text{ cm}^2$, SSD = 100 cm, gantry angle 0° , all electron energies.

Frequency and tolerance:

| | | |
|---|------|---------------------------------|
| a | 2 mm | for extensive check |
| a | 1% | of expected X-ray contamination |
| w | 2 mm | for quick check |

4.8 Dose profiles at reference gantry angle

Aim:

A suitably flattened beam is established at commissioning, where after quality control checks should ensure that the dose profile retains the same shape as for the beam data measurements.

How to perform the test:

Extensive checks:

Measure dose profiles along the major beam axes for all beam qualities.

Compare the dose profiles with the reference dose profiles.

Quick checks:

'In phantom' or 'in air' profiles may be measured. The relative dose can be measured at a minimum of 5 points, one on the central axis and two on each of the major field axes (paired dose points located symmetrically about the central axis). Compare the profiles with the reference profiles, alternatively, evaluate the flatness and symmetry parameters.

Suggested set-up conditions:

Extensive checks:

Field sizes: 5×5 , 10×10 , $20 \times 20 \text{ cm}^2$ and maximum field size, SDD = 100 cm, $d = d_{\text{ref}}$, gantry 0° .

Devices: ion chamber, diamond, diode and linear array in a water phantom.

Quick checks:

Field sizes: $10 \times 10 \text{ cm}^2$ or $15 \times 15 \text{ cm}^2$ and maximum field size (as limited by the linac or the measuring device used).

Devices: ion chamber, diode, linear array in a water phantom, or film in a slab phantom. Measurements could be performed in air with an ion chamber or diode attached to an air scanner, or with an EPID.

Frequency and tolerance:

| | | |
|---|----|--|
| w | 3% | <i>Quick checks:</i> deviation from base line measurements (within the flattened area) |
| a | 3% | <i>Extensive checks:</i> deviation from profiles measured at commissioning (within the flattened area) |

4.9 Dose profile constancy with gantry angle

Aim:

To verify the stability of the dose across a homogeneous radiation field at different gantry angles with respect to that at the reference gantry angle.

How to perform the test:

Measure profiles along the major beam axes at different gantry positions for all energies. Evaluate the variations in the profile with respect to the baseline measurements at reference gantry angle.

Devices: ion chamber, diode, linear array attached to an air scanner, film in a slab phantom, EPID or devices measuring the dose at the centre and two (four) symmetric points on the beam profiles.

Suggested set-up conditions:

Field size: maximum field size (as limited by the linac or the measuring device used).

SDD = 100 cm, $d = d_{\text{ref}}$ (or d_{max} if 'in air' measurements are performed), gantry angles 0° , 90° , 180° and 270° .

Frequency and tolerance:

a 3% deviation from base line measurements (within the flattened area)

5 Multileaf collimator (MLC)

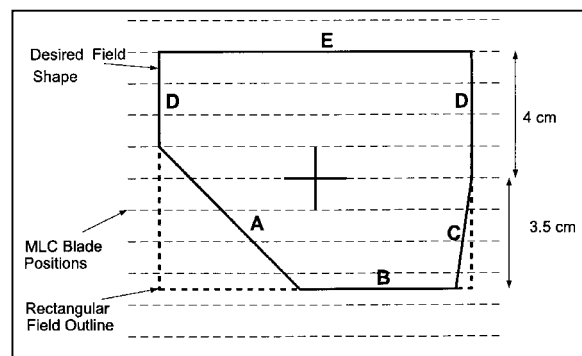
5.1 Shape of MLC fields

Aim:

To check the field shape of the MLC and by examination at different gantry angles ensure that gravitational effects are insignificant.

How to perform the test:

A printed template (see example on right taken from Figure 5.9 on p.140 in IPEM report number 81 [7], copyright Institute of Physics and Engineering in Medicine 1998, reproduced with permission) can be used to compare the contour with the optical field shape and with the shape of the radiation field. Turn the gantry to 90° , reset the field shape and compare the optical and radiation field shapes. Repeat at 270° . For the comparisons made at gantry angles of 90° and 270° , the collimator angle should be chosen such as to produce a worst case situation.



Suggested set-up conditions:

Set template at SSD = 100 cm and gantry to 0° , 90° and 270° .

Frequency and tolerance:

m 1 mm per leaf

5.2 Alignment of leaf positions

Aim:

To check the alignment of the individual leaves relative to each other.

How to perform the test:

Analyse the edges of a long rectangular MLC field (for which the long field edges are perpendicular to the direction of leaf movement) by comparing to a straight line.

Suggested set-up conditions:

Set film at SSD = 100 cm and Gantry to 0° .

Frequency and tolerance:

m 1 mm per leaf

5.3 Alignment of opposing leaves

Aim:

To check the relative position of opposite leaf pairs.

How to perform the test:

Perform a double exposure on film with one leaf bank and then the other set to the central axis. Then check for gaps or overlaps.

Suggested set-up conditions:

Set film at SSD = 100 cm and Gantry to 0°.

Frequency and tolerance:

m 1 mm per leaf

5.4 Interlocks

Aim:

To check the interlocks for the safety of the patient and the equipment, e.g. prevent the use of electrons with the MLC in the wrong position and/or prevent collisions between leaves.

How to perform the test:

Set the equipment into appropriate state to challenge an interlock situation.

Frequency and tolerance:

a functional.

5.5 Leakage between leaves

Aim:

To check the radiation leakage between the leaves.

How to perform the test:

Expose a film with the MLC set to a long rectangular field (for which the long field edges are perpendicular to the direction of leaf movement). Measure the transmission between the leaves.

Frequency and tolerance:

a max transmission 5% of the unblocked central axis dose

6 Dynamic wedges

6.1 Dynamic wedge factors

Aim:

To verify the dynamic wedge 'transmission' ratio on the central axis.

How to perform the test:

A phantom with an ionisation chamber (or equivalent dosimeter) should be used with its effective measurement point located at a depth greater than d_{\max} on the central beam. The output is measured for a fixed number of monitor units and is recorded and compared to baseline data.

Suggested set-up conditions:

Measurements should be made in a near water equivalent phantom with an ionisation chamber (or equivalent dosimeter). SSD = 100 cm. The field size should be as large as possible. Different wedge angles and/or orientations should be checked alternately.

Frequency and tolerance:

d 2%

6.2 Interrupted dynamic wedge exposures

Aim:

To verify the dynamic wedge transmission and the dynamic wedge dose profile resulting from an interrupted dynamic wedge irradiation.

How to perform the test:

A phantom comparable with that used in 6.1 should be used. During irradiation in the “clinical mode” the beam is switched off and on and the resulting output is determined and compared as in 6.1. Additionally, the irradiation should be repeated and a film (located at approximately d_{\max}), is also exposed with an interruption of the beam. The film is compared to an un-interrupted film exposure.

Suggested set-up conditions:

Measurements should be made in a near water equivalent phantom with an ionisation chamber (or equivalent dosimeter). SSD = 100 cm. The field size should be as large as possible, (the same as used in 6.1). Different wedge angles and/or orientations should be checked alternately.

Frequency and tolerance:

m 2% (for the wedge factor)

The film can be compared manually or digitally to the reference film.

6.3 Dynamic wedge profiles

Aim:

To verify the dynamic wedge profile.

How to perform the test:

A phantom comparable with that used in 6.1 should be used. Alternatively, an air-scanner may be used or a film may be exposed. The profile should be measured in the direction of the dynamic wedge for the largest possible field size in at least 3 points including the central ray location.

Suggested set-up conditions:

Measurements should be made in a near water equivalent phantom with ionisation chambers (or equivalent dosimeter). Alternatively a film may be exposed (the film should be analysed digitally). SSD should be set to 100 cm. The field size should be as large as possible. The gantry angle should be set to 0° . Different wedge angles and/or orientations should be checked alternately.

Frequency and tolerance:

m 3%

6.4 Dynamic wedge factor variation with gantry angle

Aim:

The wedge factor should be measured and examined at different gantry angles to ensure that gravitational effects are insignificant.

How to perform the test:

A phantom comparable with that used in 6.1 should be used. The phantom should be fixed at the gantry arm. The output is measured for a fixed number of monitor units and is recorded and compared to the value from 6.1.

Suggested set-up conditions:

Measurements should be made in a nearly water equivalent phantom with ionisation chambers (or equivalent dosimeter) fixed at the gantry arm so that it rotates with the gantry. The SSD can be chosen arbitrarily. The largest wedge angle for all possible wedge orientations should be used. The measurement should be done at gantry angles 0° , 90° and 270° .

Frequency and tolerance:

a 2%

7 Checks relating to the mechanical integrity and safety of the machine

Since practical aspects of safety checks tend to vary from one centre to another, depending on the installed devices, the sub-paragraph “how to perform the test” is skipped for this section. Tests to be performed on several devices serving the same function could be performed on a rotational basis provided that all are tested at least once per year.

7.1 Room entrance interlock

Aim:

To ensure that in the case of a person attempting to enter the treatment room whilst the treatment is running, the beam is switched off.

Frequency and tolerance:

d functional

7.2 Manual door opening

Aim:

To ensure the treatment room door can be opened manually in any instance, for example in case of power failure.

Frequency and tolerance:

a functional

7.3 Audio video monitor

Aim:

To ensure the systems allowing audio and video contact with the patient in the treatment room are functioning correctly.

Frequency and tolerance:

d functional

7.4 Beam on indicators

Aim:

To ensure that the beam on indicator lights during irradiation.

Frequency and tolerance:

d functional

7.5 Emergency off switches

Aim:

To check that the linear accelerator is switched off, on pushing one of the emergency off switches.

Frequency and tolerance:

d functional (in rotation)

7.6 Touch guards

Aim:

To ensure that activation of any patient collision touch guard causes the machine movement to be halted. As well as ensuring that contact with the touch guard stops machine movement, it must be checked that the touch guard operation can be cleared to re-enable machine movement.

Frequency and tolerance:

w functional

7.7 Brakes

Aim:

Check the correct function of the brakes.

Frequency and tolerance:

w functional

7.8 Deadman's switches

Aim:

Check that releasing any deadman's switch disables the machine movement being controlled by that operator.

Frequency and tolerance:

w functional

7.9 Accessory (tray and wedge) interlocks

Aim:

To check that the interlock correctly indicates if an accessory (block tray or wedge) is in place and in the case of a machine with multiple mechanical wedges, which wedge is in place and in which orientation. The machine should not run if the interlock indication does not match the selection at the console.

Frequency and tolerance:

m functional

7.10 Trays, wedges, blocks and electron applicators

Aim:

Check that these are fixed correctly, such that they cannot fall off.

Frequency and tolerance:

w functional

(The electron applicators may be checked on a rotational basis)

7.11 Backup Dose Monitor Interlock

Aim:

Check that the backup monitor can switch off the beam.

Frequency and tolerance:

a functional

7.12 Timer function

Aim:

Check that the timer can switch off the beam.

Frequency and tolerance:

m functional

7.13 Patient retrieval in case of power failure

Aim:

Check the function of any special equipment used to retrieve patient in case of power failure.

Frequency and tolerance:

a functional, but monthly in case of systems using an independent power supply.

8 Special treatment techniques

Special treatment techniques are being clinically implemented in many Swiss centres, they include for example:

- Total/half body photon irradiation
- Total skin electron irradiation
- Electron arc therapy
- Intra-operative radiotherapy
- Stereotactic radiosurgery or radiotherapy
- Intensity Modulated Radiation Therapy
- Dynamic MLC arc therapy

All these techniques require dedicated quality assurance procedures, which are considered beyond the aim of the present recommendations. Dedicated SSRMP recommendations will perhaps cover these aspects of accelerator usage for patient treatment, otherwise specific quality assurance protocols are, for the time being, left to the responsibility of local medical physicists.

9 Tables: frequencies and tolerances

Table 1: Tests ordered by contents

| Ref. Test | Frequency | Tolerance |
|---|-----------|----------------------|
| 2 Mechanical checks | | |
| 2.1 Check of optical SSD indicators | w | 2 mm |
| 2.2 Rotation scales: | | |
| Collimator rotation | m | 1° |
| Gantry rotation | m | 1° |
| Treatment table rotation | m | 1° |
| 2.3 Treatment table movement scales | m | 2 mm |
| 2.4 Treatment table top deflection under load | a | 2 mm |
| 2.5 Light and radiation field coincidence at the reference SSD and at an additional SSD | m a | |
| Field size < 20 x 20 cm ² | | 2 mm |
| Field size > 20 x 20 cm ² | | 1% of the field size |
| 2.6 Mechanical isocentre check | | |
| Rotation axis of collimator | m | 2 mm |
| Treatment table rotation | m | 2 mm |
| Rotation axis of the gantry | m | 2 mm |
| 2.7 Radiation isocentre check | | |
| Star film | a | 2 mm |
| Alignment of opposing fields | a | 2 mm |
| 2.8 Laser alignment | w | 1 mm |
| Quick check | d | 2 mm |
| 2.9 Field size indicators | m | |
| Field size < 20 x 20 cm ² | | 2 mm |
| Field size > 20 x 20 cm ² | | 1% of the field size |
| 2.10 Non-divergent asymmetric field check | m | 2 mm |
| 3 Radiation checks: X-Rays | | |
| 3.1 Beam output: | | |
| Beam output constancy check | d | 3% |
| Beam output check using a recommended dosimeter | w | 2% |
| Definitive calibration | a | 2% |
| 3.2 Output constancy with gantry angle | a | 2% |
| 3.3 Output constancy with dose rate | a | 1% |
| 3.4 Linearity of the dosimetry system | a | 1% |
| 3.5 Dose monitor leakage | a | 1% |
| 3.6 Output factors | a | 2% |
| 3.7 Tray transmission factors | a | 1% |
| 3.8 Wedge factors (mechanical wedges): | | |
| Manual mechanical wedges | a | 2% |
| Motorised mechanical wedges | m | 2% |
| 3.9 Wedge factor constancy with gantry angle | a | 3% |

| | | | |
|----------|---|---|-----------------------------------|
| 3.10 | Beam energy: | | |
| | Quick check: ratio of dose at two depths | w | 2% |
| | TPR _{20/10} (or J ₁₀ /J ₂₀) | a | 2% |
| | Depth dose curve | a | 2% |
| | Depth of d _{max} | a | 2 mm |
| 3.11 | Dose profiles at reference gantry angle: | | |
| | Quick check | w | 3% |
| | Extensive check | a | 2% |
| 3.12 | Dose profile constancy with gantry angle | a | 3% |
| 3.13 | Gantry rotation speed/MU delivered per unit angle interval | m | 2% |
| 3.14 | Radiation leakage | a | 0.5% |
| 3.15 | Radiation survey | a | - |
| 4 | Radiation checks: Electrons | | |
| 4.1 | Beam output: | | |
| | Beam output constancy check | d | 3% |
| | Beam output check using a recommended dosimeter | w | 2% |
| | Definitive calibration | a | 2% |
| 4.2 | Output constancy with gantry angle | a | 2% |
| 4.3 | Output constancy with dose rate | a | 1% |
| 4.4 | Linearity of the dosimetry system | a | 1% |
| 4.5 | Output factors for different applicators | a | 2% |
| 4.6 | Virtual source position | a | 1% |
| 4.7 | Beam energy: | | |
| | Quick check: ratio of dose at two depths | w | 2 mm |
| | Depth dose curve | a | 2 mm |
| | X-ray contamination | a | 1% |
| 4.8 | Dose profiles at reference gantry angle: | | |
| | Quick check | w | 3% |
| | Extensive check | a | 3% |
| 4.9 | Dose profile constancy with gantry angle | a | 3% |
| 5 | Multileaf collimators (MLC) | | |
| 5.1 | Shape of the fields | m | 1 mm |
| 5.2 | Alignment of leaf positions | m | 1 mm |
| 5.3 | Alignment of opposing leaves | m | 1 mm |
| 5.4 | Interlocks | a | functional |
| 5.5 | Leakage between leaves | a | 5% of unblocked central axis dose |
| 6 | Dynamic wedges | | |
| 6.1 | Dynamic wedge factors | d | 2% |
| 6.2 | Interrupted dynamic wedge exposures | m | 2% |
| 6.3 | Dynamic wedge profiles | m | 3% |
| 6.4 | Dynamic wedge factor variation with gantry angle | a | 2% |
| 7 | Machine integrity and safety | | |
| 7.1 | Room entrance interlock | d | functional |
| 7.2 | Manual door opening | a | functional |
| 7.3 | Audio video monitor | d | functional |
| 7.4 | Beam on indicators | d | functional |
| 7.5 | Emergency off switches | d | functional |
| 7.6 | Touch guards | w | functional |
| 7.7 | Brakes | w | functional |
| 7.8 | Deadman's switch | w | functional |

| | | | |
|------|--|---|------------|
| 7.9 | Accessory (tray and wedge) interlocks | m | functional |
| 7.10 | Trays, wedges blocks and electron applicators | w | functional |
| 7.11 | Backup dose monitor | a | functional |
| 7.12 | Timer function | m | functional |
| 7.13 | Patient retrieval in case of power failure | a | functional |
| | In case of systems using an independent power supply | m | functional |

Table 2: Tests ordered by frequency

| Test and frequency | Reference | Tolerance |
|--|-----------|----------------------|
| Daily | | |
| Room entrance interlock | 7.1 | functional |
| Audio video monitor | 7.3 | functional |
| Beam on indicators | 7.4 | functional |
| Emergency off switches | 7.5 | functional |
| Laser alignment - quick check | 2.8 | 2 mm |
| Beam output: Beam output constancy check: | | |
| Photons | 3.1 | 3% |
| Electrons | 4.1 | 3% |
| Dynamic wedge factors | 6.1 | 2% |
| Weekly | | |
| Touch guards | 7.6 | functional |
| Brakes | 7.7 | functional |
| Deadman's switch | 7.8 | functional |
| Trays, wedges, blocks and electron applicators | 7.10 | functional |
| Check of optical SSD indicators | 2.1 | 2 mm |
| Laser alignment | 2.8 | 1 mm |
| Routine beam output check using a recommended dosimeter | | |
| Photons | 3.1 | 2% |
| Electrons | 4.1 | 2% |
| Beam energy: Quick check, ratio of dose at two depths | | |
| Photons | 3.10 | 2% |
| Electrons | 4.7 | 2 mm |
| Dose profiles: Quick check | | |
| Photons | 3.11 | 3% |
| Electrons | 4.8 | 3% |
| Monthly | | |
| Accessory (tray and wedge) interlocks | 7.9 | functional |
| Timer function | 7.12 | functional |
| Rotation scales (collimator, gantry and table rotation) | 2.2 | 1° |
| Treatment table movement scales | 2.3 | 2 mm |
| Light and radiation field coincidence: | 2.5 | |
| Field size < 20 x 20 cm ² | | 2 mm |
| Field size > 20 x 20 cm ² | | 1% of the field size |
| Mechanical isocentre check | 2.6 | |
| Rotation axis of collimator | 2.6.1 | 2 mm |
| Treatment table rotation | 2.6.2 | 2 mm |
| Rotation axis of the gantry | 2.6.3 | 2 mm |
| Field size indicators: | 2.9 | |
| Field size < 20 x 20 cm ² | | 2 mm |
| Field size > 20 x 20 cm ² | | 1% of the field size |
| Non-divergent asymmetric field check | 2.10 | 2 mm |
| Wedge factors (motorised mechanical wedges) | 3.8 | 2% |
| Gantry rotation speed / MU delivered per unit gantry angle | 3.13 | 2% |
| Interrupted Dynamic Wedge Exposures | 6.2 | 2% |
| Dynamic Wedge Profiles | 6.3 | 3% |
| Shape of the MLC fields | 5.1 | 1 mm |
| Alignment of MLC leaf positions | 5.2 | 1 mm |

| | | |
|---|-------|--|
| Alignment of opposing MLC leaves | 5.3 | 1 mm |
| Annually | | |
| Manual door opening | 7.2 | functional |
| Backup dose monitor | 7.11 | functional |
| Patient retrieval in case of power failure | 7.13 | functional |
| Treatment table top deflection under load | 2.4 | 2 mm |
| Light and radiation field coincidence at non-reference SSD: | 2.5 | |
| Field size < 20 x 20 cm ² | | 2 mm |
| Field size > 20 x 20 cm ² | | 1% of the field size |
| Radiation isocentre check | 2.7 | |
| Star film | 2.7.1 | 2 mm |
| Alignment of opposing fields | 2.7.2 | 2 mm |
| Beam output: Definitive calibration | | |
| Photons | 3.1 | 2% |
| Electrons | 4.1 | 2% |
| Output constancy with gantry angle | | |
| Photons | 3.2 | 2% |
| Electrons | 4.2 | 2% |
| Output constancy with dose rate | | |
| Photons | 3.3 | 1% |
| Electrons | 4.3 | 1% |
| Linearity of the dosimetry system | | |
| Photons | 3.4 | 1% |
| Electrons | 4.4 | 1% |
| Dose monitor leakage | 3.5 | 1% |
| Output factors for different field sizes | | |
| Photons | 3.6 | 2% |
| Electrons (for different applicators) | 4.5 | 2% |
| Tray transmission factors | 3.7 | 1% |
| Wedge factors (manual mechanical wedges) | 3.8 | 2% |
| Wedge factor constancy with gantry angle | 3.9 | 3% |
| Beam energy photons: | | |
| TPR _{20/10} (or J ₁₀ /J ₂₀) | 3.10 | 2% |
| Depth dose | 3.10 | 2% |
| Depth of d _{max} | 3.10 | 2 mm |
| Beam energy electrons: | | |
| Depth dose curve | 4.7 | 2 mm |
| X-ray contamination | 4.7 | 1% |
| Dose profiles: Extensive checks | | |
| Photons | 3.11 | 2% |
| Electrons | 4.8 | 3% |
| Dose profile constancy with gantry angle | | |
| Photons | 3.12 | 3% |
| Electrons | 4.9 | 3% |
| Virtual source position (electrons) | 4.6 | 1% |
| Radiation leakage | 3.14 | 0.5% |
| Radiation survey | 3.15 | - |
| MLC interlocks | 5.4 | functional |
| Leakage between the MLC leaves | 5.5 | 5% of the unblocked central axis dose |
| Dynamic wedge factor variation with gantry angle | 6.4 | 2% |

10 References to Quality Assurance protocols

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11 Definitions and Glossary

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| TPR_{20/10}: | tissue phantom ratio between 20 cm and 10 cm depth. |
| J₁₀/J₂₀: | ratio between ionisation at 10 cm and 20 cm depth in the same conditions. |
| d: | measurement depth. |
| d_{max}: | depth of the maximum dose. |
| d_{ref}: | reference depth. |
| Field size: | distance between the 50% dose level in profiles normalised to 100% at the beam central axis. |
| Flattened area: | For photons the area inside the 80% of the field size along the main axes. For electrons the flattened area should be defined as the central 80% of the field width at the phantom surface. |
| Flatness: | percentage dose difference (AAPM TG 45, IEC): $\left(\frac{P_{\max} - P_{\min}}{P_{\max} + P_{\min}} \right) \cdot 100$ percentage dose ratio (IPEM81, IEC): $\left(\frac{P_{\min}}{P_{\max}} \right) \cdot 100$ |
| SDD: | Source to Detector Distance |
| SSD: | Source to Surface Distance |
| Symmetry: | (AAPM, IPEM, DIN, IEC): $\left(\frac{D(x)}{D(-x)} \right) \cdot 100$ |
| Isocentre: | The definition of the term isocentre by the IEC is "the centre of the smallest sphere through which the axis of the radiation beams pass in all conditions". |
| Baseline data: | Original data measured with the quality control device, that can be traced back to the reference data taken, for example, at the time of commissioning. |

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