Canadian Association of Provincial Cancer Agencies

Standards for Quality Control at Canadian Radiation Treatment Centres

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Major Dosimetry Equipment

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Developed, revised and approved by THE CANADIAN ORGANIZATION OF MEDICAL PHYSICS and THE CANADIAN COLLEGE OF PHYSICISTS IN MEDICINE

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Document development and review process: The quality control documents in this series originated from one of two sources. Some of the source documents were commissioned by CAPCA specifically for the purpose of developing national standards. Others had been previously developed for provincial use by the Physics Professional Affairs Committee of Cancer Care Ontario (formerly the Ontario Cancer Treatment and Research Foundation). The source documents were developed over an extended period of time from 1989 to 2001. Each source document was reviewed in 2003 by one or more independent Canadian medical physicists and the reviews accepted by the task group as they became available. The primary and secondary task group reviewers then examined the source document, the external review(s) and any appropriate published literature to propose quality control standards, objectives and criteria to the full task group. The full task group met in November 2003 and, by a consensus approach, developed the present document. The task group gratefully acknowledges the effort contributed by the author(s) of the source document and the reviewer(s) whose work forms the basis of this document. Extensive review, updating and reformatting have been performed and, for any errors or omissions introduced in this process, the task group takes full responsibility.

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Acronyms, Synonyms and Definitions

AAPM	American Association of Physicists in Medicine
ADCL	Accredited Dosimetry Calibration Laboratory
Al	Aluminum
ANSI	American National Standards Institute
BSF	Back scatter factor
CAPCA	Canadian Association of Provincial Cancer Agencies
CCO	CancerCare Ontario
CCPM	Canadian College of Physicists in Medicine
CNSC	Canadian Nuclear Safety Commission (Successor to the Atomic Energy Control Board - AECB)
COMP	Canadian Organization of Medical Physics
CSA	Canadian Standards Association
CTV	Clinical target volume
Cu	Copper
EPI(D)	Electronic Portal Imaging (Device)
HVL	Half value layer
IAEA	International Atomic Energy Agency
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission (Geneva, Switzerland)
IMRT	Intensity Modulated Radiation Therapy
INMS-NRCC	Institute for National Measurement Standards of the National Research Council of Canada
IPEM	Institution of Physics and Engineering in Medicine
IPSM	Institute of Physical Sciences in Medicine
ISO	International Organization for Standardization
Isocentre	The intersection of the axes of collimator and gantry rotation
Linac	Electron linear accelerator
MLC	Multileaf Collimator
MPPAC	Medical Physics Professional Advisory Committee
MU	Monitor unit

NCRP	National Council on Radiation Protection and Measurements
NIST	National Institute of Standards and Technology
NRCC	National Research Council of Canada
NTD	Normal treatment distance
ODI	Optical distance indicator
PMMA	Polymethyl methacrylate
PDD	Percentage depth dose
PTV	Planning target volume
QA	Quality assurance (the program)
QC	Quality Control (specific tasks)
SSD	Source-to-surface distance
STP	Standard temperature and pressure
TBI	Total body irradiation
TG-	Publications of various AAPM Quality Assurance Task Groups
TLD	Thermoluminescence dosimeter
WHO	World Health Organization
σ	Standard deviation
ε_T	Timer/(monitor) end error

Frequencies:

Daily:	Once during every treatment day and separated by at least 12 hours.
Weekly:	On average once every 7 days and at intervals of between 5 and 9 days
Monthly:	On average once every four weeks and at intervals of between 3 and 5 weeks
Annually	On average once every 12 months and at intervals of between 10 and 14 months.

Output:

Output constancy check: a daily instrument reading (corrected for temperature and pressure) taken under reproducible geometrical conditions designed to check that the radiation output (e.g. cGy/MU) values in clinical use are not grossly in error.

Output Measurement: a determination of the absorbed dose to water (cGy) at a reference point in the photon beam for a chosen field size and beam quality.

Introduction

Patients receiving treatment in a Canadian cancer centre have a reasonable expectation that the quality of their treatment is independent of their geographic location or the centre they are attending. Insofar as medical physicists contribute to treatment quality, this expectation will be more closely met through the harmonisation of quality control protocols across the country. The Canadian Association of Provincial Cancer Agencies (CAPCA) has initiated the process of standardisation of treatment quality in Canada through its draft document "Standards for Quality Assurance at Canadian Radiation Treatment Centres". This present document is an appendix to the CAPCA document and is concerned with quality control measures for use with major dosimetry equipment.

A quality control program on equipment used for radiotherapy in a Canadian cancer centre must be carried out by, or under the direct supervision of, a qualified medical physicist. Here, a qualified medical physicist is a physicist who is a member or fellow of the Canadian College of Physicists in Medicine or who holds equivalent certification. This individual, known as the supervising physicist, is responsible for ensuring compliance with the quality control protocol, appropriate documentation, appropriate remedial actions and communication with other relevant parties on the operational state of the equipment. Depending on local circumstances and organisational structure, one physicist may supervise quality control on all equipment or the responsibilities may be dispersed. However, the supervising physicist for a particular piece of equipment must have a direct line of communication to the Quality Assurance Committee for the Radiation Treatment Program.

This document examines the quality assurance necessary for the proper functioning of major dosimetry equipment used in the acceptance testing, commissioning and routine monitoring of radiation therapy devices. This dosimetry equipment ranges from the very simple (rulers and thermometers) to sophisticated computer controlled beam acquisition devices. A brief description of the equipment and its role in the radiotherapy clinic is given. Commissioning, acceptance testing and periodic QC tests and measurements on the major dosimetry equipment are discussed. Recommendations on how often these QC tests should be performed and what tolerance levels should be used are provided. A final section discusses the risks associated with the failure of the various tests described, and recommends actions to be taken when tolerances are not met. This section also addresses the qualifications of personnel carrying out these tests, and describes the resources required to implement the quality control program. References used in the preparation of this document are listed at the end of the document.

This document contains specific criteria which the equipment should meet in order to assure an acceptable level of treatment quality. However, it does not recommend how the tests should be carried out. It is the responsibility of the supervising physicist to ensure that the locally available equipment and procedures are

sufficiently sensitive to establish compliance or otherwise with the criteria specified here.

A successful quality assurance program is critically dependent upon adequately trained staff and a culture of continuous quality improvement. Educational opportunities to be offered to quality control staff must include new staff orientation, in-house continuous education, conference participation and manufacturer's courses as appropriate. All such educational activities must be documented as part of the quality assurance program. Continuous quality improvement embodies the concepts of documentation, monitoring, review and feedback.

The standards promoted in this document are based on the experience of the authors and reviewers and are broadly consistent with recommendations from other jurisdictions (AAPM 1994, IPEM 1999). Although this document has undergone extensive review it is possible that errors and inaccuracies remain. It is hoped that the users of these standards will contribute to their further development through the identification of shortcomings and advances in knowledge which could be incorporated in future versions.

Performance Objectives and Criteria

Objectives and criteria for the evaluation of the performance of radiotherapy equipment fall into several categories.

1. Functionality. Systems for which the criterion of performance is "Functional" are either working correctly or not. Such systems are commonly associated with the safety features of the equipment or installation. Operating a facility which has failed a test of functionality has the potential to expose patients and staff to hazardous conditions.

2. Reproducibilty. The results of routine quality control tests, for which reproducibility is the criterion, are assessed against the results obtained at installation from the accepted unit. Tolerances and action levels may be set for parameters that can be quantified. For characteristics which are not amenable to quantification, criteria have to be developed locally to reflect the test equipment available and inter or intra-observer variability as appropriate.

3. Accuracy. Accuracy is the deviation of the measured value of a parameter from its expected or defined value. Examples are

4. Characterisation and documentation. In some cases it is necessary to make measurements to characterise the performance of a piece of equipment before it can be clinically. An example would be the measurement of the ion collection efficiency.

5. Completeness. The use of this term is restricted to the periodic review of quality control documentation.

For quantities that can be measured, tolerance and action levels may be defined.

i. Tolerance Level. For a performance parameter which can be measured, a tolerance level is defined. If the difference between the measured value and its expected value is at or below the stated tolerance level then no further action is required as regards that performance parameter.

ii Action Level. If the difference between the measured value and its expected or defined value exceeds the action level then a response is required immediately. The ideal response is to bring the system back to a state of functioning which meets all tolerance levels. If this is not immediately possible, then the use of the equipment must be restricted to clinical situations in which the identified inadequate performance is of no or acceptable and understood clinical significance. The decision on the most appropriate response is made by the supervising physicist in conjunction with the users of the equipment and others as appropriate. If the difference between the measured value and its expected or defined value lies between the tolerance and action levels,

several courses of action are open. If the problem is easily and quickly rectifiable then remedial action should be taken at once. An alternative course of action is to delay remedial intervention until the next scheduled maintenance period. Finally, the decision may be made to monitor the performance of the parameter in question over a period of time and to postpone a decision until the behaviour of the parameter is confirmed. Once again, this will be a decision made by the supervising physicist in consultation with the users of the equipment and others as appropriate.

Documentation of equipment performance is essential and is discussed later. However, at the conclusion of a series of quality control tests it is essential to inform the users of the equipment of its status. If performance is within tolerance verbal communication with the users is sufficient. If one or more parameters fails to meet Action Level criteria, and immediate remedial action is not possible, then the users of the equipment must be informed in writing of the conditions under which the equipment may be used. Compliance with Action Levels but failure meet Tolerance Levels for one or more parameters may be communicated verbally or in writing depending on the parameters and personnel involved. The judgement of those involved will be required to make this decision.

System Description

Ionization chambers and electrometers used for reference dosimetry

The absorbed dose to water from radiation therapy devices is determined through the use of a chamber/electrometer combination at the reference point under reference conditions, as specified in the appropriate dosimetry protocols (e.g., AAPM TG-51, or AAPM TG-61). Local or secondary standards are chamber/electrometer combinations which have a calibration coefficient in terms of air-kerma or absorbed dose directly traceable to a primary standards dosimetry laboratory or an accredited secondary standards dosimetry laboratory (NRCC, NIST, or ADCL). Redundancy for these devices is recommended to assure the maintenance of the calibration between, and following, calibration at the standards laboratory. These standards, which comprise a unique chamber/electrometer combination, are the basis of accurate dose delivery and are generally removed from routine clinical use. Routine calibration of radiation therapy devices in the clinical setting is typically performed with field grade chambers and electrometers which have a combined calibration coefficient transferred from the secondary standard.

Devices for relative dosimetry

Devices may be used for determining the relative dose of a radiation device as a method of ensuring the stability of the device on a routine basis. Similar equipment may be used to determine the dose received by a patient. Some of the devices in use include ionization chambers, diodes, thermoluminescent dosimeters and film.

Basic measurement devices

Most secondary standards are vented well or thimble type ionization chambers, and as such are subject to local atmospheric conditions. Therefore thermometers, barometers and hygrometers will be used during reference dosimetry measurements. Basic distance checks will be achieved with a quality ruler or caliper. A quality stopwatch will be used for accurate time measurement.

Automated beam scanning devices

Automatic remotely controlled water scanners are the principal devices used to perform beam data acquisition for acceptance testing and commissioning of radiation therapy units. They are also used for periodic checks of beam parameters such as flatness, symmetry, depth dose, off-axis ratios and energy. They comprise a water tank, and a mechanism for moving a radiation detector through the beam. They range in sophistication from single axis motion with hardcopy output, to sophisticated computer-controlled multi-axis motion with software tools for beam analysis and conversion. Capabilities for real-time isodose tracking, and dynamic beam measurement are also available.

Quality assurance devices

Megavoltage beam parameters such as flatness, symmetry, beam energy and constancy can be measured on a routine basis with a variety of devices that are more convenient to use than the water scanner. These devices may consist of an array of diodes or ionization chambers and may have software for data manipulation. These devices are easy to set-up and use, and the multi-detector construction makes them useful in the monitoring of technologies such as the dynamic wedge and Intensity Modulated Radiation Therapy.

Phantom Materials

Whereas water is the reference phantom material for clinical reference dosimetry, solid phantoms are used for routine measurement. These materials may have radiation absorption properties and interaction coefficients similar to water or may be available in other tissue-equivalent materials such as bone, lung or muscle. The phantom may have "slab" geometry, or be anthropomorphic. Anthropomorphic or "humanoid" phantoms are often constructed so as to accommodate TLD measurement.

Acceptance Testing and Commissioning

Most major dosimetry equipment requires little commissioning and acceptance testing. The exception to this is the automated beam scanning device which usually comes with a manufacturers' acceptance testing procedure. Acceptance testing serves three purposes:

- to ensure that the unit meets stated specifications,
- to establish baseline parameters for a future quality assurance program,
- to familiarize the customer with operation of the unit.

In addition, acceptance testing of the equipment and facility will include establishing compliance with applicable radiation safety codes. These are included in federal and provincial regulations and it is the supervising physicist or designate's responsibility to be familiar with these requirements and to demonstrate compliance. Decommissioning of radiotherapy equipment and facilities may also be regulated by federal and/or provincial authorities. For the purpose of this document, an example of this would be the decommissioning of the check source.

Acceptance tests are customarily described in a document prepared by the vendor, although the purchaser may wish to specify additional tests. The document is signed by the purchaser upon satisfactory completion of testing, before which formal purchase of the unit should not be completed. The references and bibliography provide a comprehensive list of mechanical, electrical and software tests for water scanner and film densitometers.

The standards for dosimetry equipment acceptance testing should be consistent with routine quality control standards. In particular, there is no reason why new or upgraded dosimetry equipment should not meet the tolerance values detailed later in this document (Table 1). The tests should be performed by, or under the supervision of, a qualified medical physicist.

Adherence to these standards (Table 1) must be demonstrated and documented, in or outside of the vendor' s acceptance testing protocol, before a new piece of dosimetry equipment is accepted, and put into clinical service. Also, an appropriate subset of acceptance tests must be performed after any repair of the equipment. The extent of testing required must be judged by a qualified medical physicist.

Commissioning generally refers to the acquisition of additional measured data or characteristics after most acceptance testing is completed, with two purposes:

- for subsequent calculations, for example, involving radiation dose,
- to establish baseline parameters for a future quality control program.

For dosimetry equipment, the former purpose dominates commissioning and an example would be the acquisition, for an ionization chamber, of a calibration coefficient from a standards dosimetry laboratory. Clearly all the tests listed in Table 1 must be

performed at this time with the intended local test equipment and protocols if meaningful baselines are to be established.

Quality Control of Equipment

The purpose of a quality control program is to assure that operational standards for a piece of dosimetry equipment that were considered acceptable at time of purchase continue to be maintained, as closely as possible, over its life time. Thus, quality control tests typically are periodic repetitions, partial or full, of acceptance and commissioning tests.

The standards for dosimetry equipment quality control are listed in Table 1. These minimum standards consist of tests to be performed, along with their minimum frequencies. The tests are derived from the published literature and, in particular, the standards laid out in the AAPM document, TG-40 (AAPM, 1994) and the IPEM document, Report 81 (IPEM, 1999). Where a tolerance level is specified it is typically set at 50-75% of the action level.

The tests should be performed by a qualified medical physicist, or a suitably trained individual working under the supervision of a qualified medical physicist. Independent verification of the results of quality control tests is an essential component of any quality control program. To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis and interpretation of the quality control tests at least annually. This independent check must be documented.

Daily tests must be scheduled at the beginning of each working day. For other tests, testing at less than the minimum frequency is permissible only if experience has established that the parameters of interest are highly stable. Documentary evidence supporting this decision is essential. It is unlikely that a frequency of less than half that specified here could be justified.

In the event that the equipment does not meet the stated performance objectives and criteria an adjustment or repair should be effected. If it is not immediately possible to restore the equipment to full performance, then the use of the equipment must be restricted to clinical situations in which the identified inadequate performance is of no or acceptable and understood clinical significance. The decision on the most appropriate response is made by the supervising physicist in conjunction with the users of the equipment and others as appropriate.

Preventive maintenance schedules and interventions are recommended by the manufacturer of the equipment and should be adhered to diligently. Following preventive maintenance or repair, the appropriate quality control tests selected from those listed in Table 1 must be performed before the unit is returned to clinical service. The extent of testing required must be judged by a qualified medical physicist. Frequently, device repair and quality control testing are performed by different persons. In such cases, good communication and reporting between the various staff involved are essential.

As pointed out previously, radiation safety activities are beyond the scope of this report. However, such activities may be integrated into routine quality control programs of equipment.

An inspection of Table 1 indicates that the majority of tests are to be done on initial receipt of the equipment, or following repair. With the exception of automated beam scanning devices, there are very few specific commissioning tests required for major dosimetry equipment. However the tests listed as part of the on-going QC program may also be used as a guide for tests to be carried out upon receipt of new equipment.

There are several tests described here which have a critical impact upon the quality of radiation therapy given to patients, and as such should only be carried out by a qualified medical physicist. Of primary importance is the maintenance of the secondary standard and its standards lab traceable calibration coefficient. Next is the transfer and maintenance of calibration factors for field grade chambers used routinely in the clinic. Finally, the assessment of energy determining devices, and software related to the calculation of photon and electron beam parameters are critical and require verification by a qualified medical physicist.

The remaining tests are important in ensuring the accurate measurement and functioning of devices in radiation therapy, but may be carried out either by, or under the supervision of, a qualified medical physicist.

Since many of the tests described are carried out on an initial basis, or following repair, there is not expected to be an undue increase in the workload for a medical physics department. In fact, as the tests in Table 1 constitute a minimum requirement for safe operation, it is possible that many departments are already performing at least the quality control work described in this document with their current staff levels. There should be no major increase in staff requirements when implementing the recommendations of this quality control document.

Documentation

Appropriate documentation is an essential component of a quality assurance program. All documents associated with the program should contain, as a minimum, the following information:

1. the name of the institution
2. the name of the originating department
3. the name of the developer of the document
4. the name of the individual or group who approved the document for clinical use
5. the date of first issue
6. the number and date of the current revision

Further guidelines on the design of appropriate documentation may be found elsewhere (ISO 2000)

Documents for use in a quality control program may be conveniently separated into two major categories: protocols and records. The protocols must be included in the Policy and Procedure Manual of the Radiation Treatment Quality Assurance Committee.

The quality control protocol contains the standards, or performance objectives and criteria, to be applied to the piece of equipment. Such standards are based on documents such as this. In addition to the specification of standards, the protocol should provide sufficient detail on the test equipment and procedures to be followed that there can be no residual ambiguity in the interpretation of the test results.

The quality control record contains the results of the tests, the date(s) on which they were performed and the signatures and qualifications of the tester and the supervising physicist. When the number of tests to be performed on a particular occasion is limited and the test procedure is simple it may be advantageous to combine the protocol and record into a single document.

In addition to the protocol and record, it is essential to have a means of documenting any corrective action that takes place together with any subsequent tests. Deviations from the locally approved protocol, such as those resulting from clinical pressure to access the equipment, must, of course, also be documented.

Finally, all documentation related to the quality control program must be retained for at least ten years.

Table 1: Quality Control Tests

(a) Reference Dosimetry: Secondary Standard			
Designator	**Test**	**Performance**	
		Tolerance	**Action**
Initial use and following calibration			
ISS1	Extra-cameral signal (stem effect)	0.5%	1.0%
ISS2	Ion collection efficiency	Characterize	
ISS3	Linearity	0.5%	1.0%
ISS4	Leakage	0.1%	0.2%
ISS5	Collection Potential Reproducibility	1.0%	2.0%
At each use			
ESS1	Reproducibility	0.2%	0.5%
Bi-annual (i.e., every two years)			
BSS1	Calibration at standards lab		

(b) Reference Dosimetry: Field Standard			
Designator	**Test**	**Performance**	
		Tolerance	**Action**
Initial use or following malfunction and repair			
IFS1	Extra -cameral signal (stem effect)	0.5%	1.0%
IFS2	Ion collection efficiency	Characterize	
IFS3	Linearity	0.5%	1.0%
IFS4	Leakage	0.1%	0.2%
IFS5	Collection Potential Reproducibility	1.0%	2.0%
IFS6	Cross calibration		
Semi-annual			
SFS1	Signal Reproducibility	0.2%	0.5%
SFS2	Collection Potential Reproducibility	1.0%	2.0%
Annual			
AFS1	Cross calibration	Characterize	

(c) Devices for relative dosimetry			
Designator	**Test**	**Performance**	
		Tolerance	**Action**
Thermoluminescent dosimeter (TLD) systems			
Initial use or following malfunction and repair			
IRD1	Linearity or supralinearity	Characterize	
At each use			
ERD1	Individual calibration of each chip	Characterize	
Film dosimetry systems			
Initial use or following malfunction and repair			
IRD2	Dose response curve	Characterize	
IRD3	Film reader linearity	Characterize	
Weekly			
WRD1	Sensitometric curve	Characterize	
Annual			
ARD1	Film reader linearity	Characterize	
Ionization chambers **Initial use or following malfunction and repair**			
IRD5	Linearity (dose and dose rate)	0.5%	1.0%
IRD6	Extra-cameral signal (stem effect)	0.5%	1.0%
Annual			
ARD2	Signal reproducibility	0.5%	1.0%
Diode systems **Initial use or following malfunction and repair**			
IRD7	Linearity	Characterize	
IRD8	Energy Dependence	Characterize	
IRD9	Angular Dependence	Characterize	
IRD10	Temperature Dependence	Characterize	

(d) Basic measurement devices			
Designator	**Test**	**Performance**	
		Tolerance	**Action**
Reference thermometer, Barometer, Hygrometer, Linear rule, Stopwatch			
Initial use or following malfunction and repair			
IBM1	Calibration certificate	Characterize	
Field thermometer, Barometer, Hygrometer, Linear rule, Stopwatch			
Initial use or following malfunction and repair			
IBM2	Cross calibration	Characterize	
Annual			
ABM1	Cross calibration	Characterize	

(e) Automated beam scanning devices and detector arrays			
Designator	**Test**	**Performance**	
		Tolerance	**Action**
Mechanical components			
Initial use or following malfunction and repair			
IBS1	Alignment	Characterize	
IBS2	Hysteresis	Characterize	
IBS3	Orthogonality	Characterize	
Annual			
ABS1	Positional Accuracy	1 mm	2 mm
Detectors			
Initial use or following malfunction and repair			
IBS4	Extracameral signal (stem effect)	0.5%	1.0%
Annual			
ABS4	Reproducibility of collection potential	0.5%	1.0%
ABS5	Leakage	0.5%	1.0%
ABS6	Linearity	0.5%	1.0%
Data acquisition / analysis			
Initial use or following malfunction and repair			
IBS5	Scan speed insensitivity	Characterize	
IBS6	Symmetry / Flatness calculations	1.0%	2.0%
IBS7	Energy / Bremsstrahlung calculations	1.0%	2.0%
IBS8	Ionization-to-dose calculations	1.0%	2.0%
IBS9	Accuracy of output (soft & hardcopy)	1.0 mm	2.0 mm
At each use			
EBS1	Agreement with static measurements	1.0%	2.0%

(f) Quality assurance devices			
Designator	**Test**	**Performance**	
		Tolerance	**Action**
Diode Arrays			
Initial use or following malfunction and repair			
IQD1	Accuracy	1.0 mm	2.0 mm
IQD2	Linearity (Dose & Dose-rate)	Characterize	
IQD3	Agreement with static measurements	1.0%	2.0%
IQD4	Symmetry and Flatness calculations	1.0%	2.0%
IQD5	Accuracy of Output (soft & hardcopy)	1.0 mm	2.0 mm
Annual			
AQD1	Energy Dependence	Characterize	
Electron and photon energy verification devices			
Annual			
AQD2	Energy Dependence Calibration	Characterize	

(g) Phantom materials		
Initial use or following malfunction and repair		
IPM1	Physical density, composition, electron density	Characterize
IPM2	Dimensions of slabs or pieces	Characterize
IPM3	Homogeneity, internal defects	Characterize

Notes

(a) Reference Dosimetry: Secondary Standard

ISS1 to ISS5:	Tolerances based on AAPM TG-40. Action levels are suggested and may be modified based on experience. Suggested methods for measurement may be found in AAPM TG-51.
ESS1:	Based on AAPM TG-40.
BSS1:	Based on AAPM TG-40.

(b) Reference Dosimetry: Field Standard

IFS1 to IFS5:	Tolerances based on TG-40. Action levels are suggested and may be modified based on experience. Suggested methods for measurement may be found in AAPM TG-51.
IFS6:	Based on local experience.
SFS1 / 2:	Based on local experience and AAPM TG-40.
AFS1:	Modified frequency from AAPM TG-40 based on local experience.

(c) Devices for relative Dosimetry

IRD1 & ERD1:	Based on AAPM TG-40.
IRD2,3,WRD1:	Can be established using classic H&D curve at initial use. Effects of batch film changes should be routinely assessed.
ARD1	Based on AAPM TG-40.
IRD5 & IRD6 & ARD2:	Based loosely on AAPM TG-40 and local experience.
IRD7 to IRD10:	Based on AAPM TG-40.

(d) Basic measurement devices

IBM1:	Certificates are retained for reference devices.
IBM2:	Field devices are compared to reference devices prior to initial use.
IBM3 & ABM1:	Field devices are checked against reference devices every year except for barometers. Barometers are checked every 3 months (see AAPM TG-40).

(e) Automated beam scanning devices and detector arrays

IBS1 to IBS3:	Based on clinical experience. Tolerances on the order of 0.5 mm are probably acceptable. Acceptance test criteria may be provided by the vendor as a guideline.
ABS1:	Based on local experience. Users may adapt and document criterion to local needs.

IBS4: Based on IFS1 with looser criteria.
ABS4: Based on similar criteria for IFS5.
ABS5 & 6: Based on similar criteria for IFS4 and IFS3.

IBS5-9,EBS1: Tests based on clinical experience and may be modified to meet the user criteria. Tests may also be modified to follow the vendors' acceptance test criteria.

(f) Quality assurance devices

IQD1 to IQD5: Based loosely on IBS5 to IBS10 and AAPM TG-40. In addition the manufacturers' acceptance test procedures may be used to modify the users' criteria.

AQD1 & 2 If devices are used across a range of beam energies, care must be taken to ensure the correct calibration factors are applied. Verification and inspection once a year based loosely on AAPM TG-40.

(g) Phantom materials

IPM1 to IPM3 Visual inspection and radiographic verification prior to use is recommended. The tolerance depends on the intended use of the material and may be appropriately chosen by the user.

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