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PAKISTAN STANDARD

MEDICAL DIAGNOSTIC X-RAY EQUIPMENT - RADIATION CONDITIONS FOR USE IN THE DETERMINATION OF CHARACTERISTICS

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(1st Revision)

PAKISTAN STANDARD SPECIFICATION

FOR

MEDICAL DIAGNOSTIC X-RAY EQUIPMENT – RADIATION CONDITIONS FOR USE IN THE DETERMINATION OF CHARACTERISTICS.

0 FOREWORD

0.1 This Pakistan Standard was adopted by the authority of the Board of Directors of Pakistan Standards and Quality Control Authority (PSQCA), after the draft prepared by the Technical Committee for **"Electromedical Equipment (ESTC – 14)"** had been approved and endorsed by the National Standards Committee for Electronics on 12-01-2009.

0.2 This Pakistan Standard PS: IEC 61267-2009 was adopted in the year 1998 based on IEC 61267-1994 "Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics". Since IEC has revised this standard in 2005, hence it deemed necessary to revise this Pakistan Standard also on IEC basis.

0.3 This Standard replaces the previous Standard adopted in 1998. This Standard constitutes a technical revision.

0.4 This Standard includes the following significant technical changes with respect to the previous edition:

a) Introduction of "practical peak voltage" for measuring X-ray tube voltage;

b) Introduction of a new procedure for establishing the radiation qualities;

c) Inserting of an informative Annex B "Determination of the amount of additional filtration" and a normative Annex C "Measurement of the practical peak voltage";

d) Revision of radiation qualities and radiation conditions;

e) Addition of term definitions.

This Standard is an adoption of IEC Publication 61267-2005 “Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics” (1st Revision).

0.5 This Standard has been prepared and finalized after taking into consideration the view and suggestions put forward by the representative section of technologists, manufacturers and utilizing agencies.

0.6 This Standard is subject to periodical review in order to keep pace with the changing requirements and latest developments in the industry. Any suggestion for improvement will be recorded and placed before the revising committee in due course.

0.7 This Standard covers the technical provisions and it does not purport to include all the necessary provisions of a contract.

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INTRODUCTION

To establish characteristics, aspects or properties of ASSOCIATED EQUIPMENT or to have available RADIATION BEAMS for physical and medical investigations, sets of well-defined RADIATION CONDITIONS can offer an important tool in many situations.

From a regulation and standardization point of view there is a need:

– to have available well-defined RADIATION CONDITIONS that can be used internationally to specify standards of operation of X-RAY EQUIPMENT;
– to provide a basis for the harmonization of existing national standards;
– to provide uniform sets of RADIATION CONDITIONS (a dictionary of RADIATION CONDITIONS) to describe and judge the performance of X-RAY EQUIPMENT for the benefit of MANUFACTURERS, USERS, PATIENTS and health protection authorities;
– to solve communication problems between MANUFACTURERS, USERS and regulatory authorities, stemming from a lack of internationally accepted definitions and test methods.

From an application point of view, commonly accepted sets of RADIATION CONDITIONS would in general find use in:

– QUALITY CONTROL tests by MANUFACTURERS;
– installation and ACCEPTANCE TESTS;
– calibration of test instrumentation;
– type approval tests (where required);
– inspection and tests by regulatory authorities and testing institutes;
– physical and medical studies in physical laboratories and medical facilities;
– determination of characteristics of ASSOCIATED EQUIPMENT.

Standard RADIATION CONDITIONS can benefit a number of potential users, such as:

– MANUFACTURERS of X-RAY EQUIPMENT;
– MANUFACTURERS of X-ray test instrumentation;
– research laboratories;
– testing institutes;
– USERS;
– government regulatory authorities;
– service organizations;
– standardization organizations.

Some provisions and statements in the body of this International Standard require additional information. Such information is presented in Annex A called "Rationale". An asterisk in the left-hand margin of a clause or subclause indicates the presence of such additional information.

In this standard the X-RAY TUBE VOLTAGE is measured as the PRACTICAL PEAK VOLTAGE. The rationale behind using this quantity is given in Annex C. A description of how the quantity PRACTICAL PEAK VOLTAGE is measured is given in Annex C.

In the development of this edition of this standard efforts were made to set up procedures that give a high degree of equivalence of standard RADIATION QUALITIES realized on different X-ray machines. In the first edition the RADIATION QUALITIES were established by adjusting, within given limits the X-RAY TUBE VOLTAGE to such a value that the required HALF-VALUE LAYER was achieved. Depending on the total INHERENT FILTRATION an X-RAY TUBE VOLTAGE had to be selected which could differ from the nominal value by as much as ±5 %. If the INHERENT FILTRATION of the X-RAY TUBE was relatively strong this could be compensated by choosing a lower X-RAY TUBE VOLTAGE and vice versa. For the example of a radiation quality with a nominal X-RAY TUBE VOLTAGE of 100 kV this procedure meant that the tube voltage could be set as low as 95 kV for a moderately filtered RADIATION QUALITY and as high as 105 kV for a heavily filtered X-RAY TUBE. These two RADIATION QUALITIES were considered to be equivalent as long as they both had the required HALF-VALUE LAYER.

This solution was not considered to be an ideal one. However, due to the lack of a suitable and agreed definition of what is usually termed peak voltage no alternative was available. With the arrival of the PRACTICAL PEAK VOLTAGE the situation has changed: With this quantity it is possible by means of an electrical measurement to set the tube voltage of the x-ray generator in question with any arbitrary shape of the ripple to a value that a radiograph taken with a tube connected to this generator has the same low level contrast as a radiograph taken with the same x-ray tube connected to a true constant potential generator operating at the 'correct' voltage.

Given the possibility of setting the tube voltage of any generator to the 'correct' value, irrespective of the shape of the ripple, it becomes difficult to justify the deliberate selection of a 'wrong' tube voltage to compensate for a below or an above average filtration of the x-ray tube. The procedure, by which the radiation qualities are realized in this second edition, consists of setting the X-RAY TUBE VOLTAGE to the 'correct' value and determining the amount of filtration needed to produce the required HALF-VALUE LAYER. The nature of this process implies that there is a certain maximum total INHERENT FILTRATION beyond which a given X-RAY TUBE may no longer be used to produce a given RADIATION QUALITY. This is not new in principle, but it is clearly expressed in this edition. In order not to exclude what are considered as standard X-RAY TUBES, the HALF-VALUE LAYERS of some of the RADIATION QUALITIES have been increased. The new HALF-VALUE LAYERS have been chosen in such a way that it is possible to establish all RADIATION QUALITIES in this standard with an X-RAY TUBE with 2,5 mm Al hardening-equivalent filtration and with ANODE ANGLES down to 9°.

The procedure to be followed according to this edition for producing the RADIATION QUALITIES of the RQR series does require a certain amount of additional effort. This additional effort is largely compensated when the more heavily filtered radiation qualities are realized. The great advantage of the new method lies in a much higher degree of equivalence of a given RADIATION QUALITY with X-RAY TUBES having different INHERENT FILTRATIONS.

MEDICAL DIAGNOSTIC X-RAY EQUIPMENT – RADIATION CONDITIONS FOR USE IN THE DETERMINATION OF CHARACTERISTICS

1 Scope and object

This International Standard applies to test procedures which, for the determination of characteristics of systems or components of medical diagnostic X-RAY EQUIPMENT, require well-defined RADIATION CONDITIONS.

Except for mammography, this standard does not apply to conditions where discontinuities in radiation absorption of elements are deliberately used to modify properties of the RADIATION BEAM (for example by rare earth filters).

RADIATION CONDITIONS as used for screen-film sensitometry are not covered in this standard.

NOTE Screen-film sensitometry is the subject of the ISO 9236 series.

This standard deals with methods for generating RADIATION BEAMS with RADIATION CONDITIONS which can be used under test conditions typically found in test laboratories or in manufacturing facilities for the determination of characteristics of medical diagnostic X-RAY EQUIPMENT.

Examples of such RADIATION QUALITIES are RADIATION BEAMS emerging through the filtration from the X-RAY SOURCE ASSEMBLY. RADIATION CONDITIONS represent the more general case, where SCATTERED RADIATION emerges from an EXIT SURFACE of a PATIENT or a PHANTOM. This requires a well defined geometrical arrangement.

The most complete specification of RADIATION FIELDS is given by the spectral distribution of the photon fluence. Since the measurement of X-RAY SPECTRA is a demanding task, this standard expresses RADIATION QUALITIES in terms of the X-RAY TUBE VOLTAGE, the first and second HALF-VALUE LAYER. In the case of RADIATION CONDITIONS, specifications are performed additionally in terms of PHANTOM properties and geometry.

The attempt to characterize a spectral distribution just by means of the X-RAY TUBE VOLTAGE, the first and possibly the second HALF-VALUE LAYER is thus a compromise between the mutually conflicting requirements of avoiding excessive efforts for establishing a RADIATION QUALITY and of the complete absence of any ambiguity in the definition of a RADIATION QUALITY. Due to differences in the design and the age of X-RAY TUBES in terms of anode angle, anode roughening and INHERENT FILTRATION, two RADIATION QUALITIES produced at a given X-RAY TUBE VOLTAGE having the same first HALF-VALUE LAYER can still have quite different spectral distributions. Given the inherent ambiguity in the characterization of RADIATION QUALITY, it is essential that further tolerances introduced by allowing certain ranges of values, e.g. for X-RAY TUBE VOLTAGE and first HALF-VALUE LAYER, must be sufficiently small not to jeopardise the underlying objective of this standard. This standard is to ensure that measurements of the properties of medical diagnostic equipment should produce consistent results if RADIATION QUALITIES or RADIATION CONDITIONS in compliance with this standard are used.

To achieve this objective, certain degrees of freedom in the way in which a RADIATION CONDITION could be established in the framework of the first edition of this standard have been removed. The essential restriction introduced in this second edition is that the X-RAY TUBE VOLTAGE is measured and set to its 'correct' value. The second step is to attempt to establish the prescribed first HALF-VALUE LAYER by adding into the beam the necessary amount of ADDITIONAL FILTRATION. If the INHERENT FILTRATION provided by the X-RAY TUBE alone is so strong that the HALF-VALUE LAYER of the RADIATION BEAM emerging from the X-RAY TUBE ASSEMBLY as such is larger than that to be established, the X-RAY TUBE ASSEMBLY used is not suited for producing the desired RADIATION CONDITION. This may occur if the anode angle of the X-RAY TUBE ASSEMBLY is too small and/or in the case of excessive anode roughening due to tube ageing.

In the approach outlined in the two preceding paragraphs the X-RAY TUBE VOLTAGE plays a decisive role. It is therefore essential that the 'correct' X-ray tube voltage is chosen irrespective of the type of high voltage generator connected to the X-RAY TUBE. The way in which this is realized in this standard is by measuring the X-RAY TUBE VOLTAGE in terms of the PRACTICAL PEAK VOLTAGE. This quantity is a weighted mean of all values of the X-RAY TUBE VOLTAGE occurring during an exposure. The weighting is done in such a way that identical values of the PRACTICAL PEAK VOLTAGE give identical values of the low level contrast on a radiograph irrespective of the waveform supplied by the generator.

Although the PRACTICAL PEAK VOLTAGE can be measured non-invasively, the level of uncertainty required in this standard demands the use of invasive techniques. The design and age of the X-RAY TUBE ASSEMBLY influence the result of non-invasive measurements. When PRACTICAL PEAK VOLTAGE is measured invasively, tube design and age have no influence on the result of such a measurement.

In the framework of what is physically feasible, differences in tube design and ageing are taken into account by adding the appropriate amount of ADDITIONAL FILTRATION.

In Annex C further explanations with regard to the PRACTICAL PEAK VOLTAGE are given.

This standard describes both primary RADIATION QUALITIES, which to a good approximation are free of SCATTERED RADIATION (RQR, RQA, RQC, RQT, RQR-M and RQA-M) and, for PATIENT simulation, RADIATION CONDITIONS containing SCATTERED RADIATION (RQN, RQB, RQN-M and RQB-M).

It is crucial to be aware that in the presence of SCATTERED RADIATION the characteristics of X-radiation in terms of fractions of AIR KERMA associated with the PRIMARY RADIATION and the SCATTERED RADIATION depend on the position and nature of any ADDED FILTER or PHANTOM. It is therefore obvious that AIR KERMA measurements in such RADIATION BEAMS need careful consideration.

Clauses 5 to 9 deal with RADIATION CONDITIONS which are essentially free of SCATTERED RADIATION. Due to the spatial homogeneity of these RADIATION CONDITIONS, the APPLICATION DISTANCE does not influence the RADIATION CONDITIONS to a significant extent. These RADIATION CONDITIONS are called RADIATION QUALITIES.

- Clause 5 deals with RADIATION QUALITIES of the RADIATION BEAM emerging from the X-RAY SOURCE ASSEMBLY. Such RADIATION QUALITIES can be used for determining ATTENUATION properties of ASSOCIATED EQUIPMENT.
- Clause 6 deals with RADIATION QUALITIES of the RADIATION BEAM emerging from an irradiated object, that simulates a PATIENT under the conditions that:

– the contribution of SCATTERED RADIATION in the RADIATION BEAM is not significant;

– exact simulation of the spectral distribution of the RADIATION BEAM emerging from the PATIENT is not a prerequisite

- Clauses 7 and 8 deal with RADIATION QUALITIES derived from those dealt with in Clause 6 in view of special applications like automatic exposure and automatic brightness control systems and computed tomographs. The radiation transmitted through the irradiated object has properties similar to those of the radiation transmitted through a PATIENT under the conditions that:

  – the contribution of SCATTERED RADIATION in the RADIATION BEAM is not significant;

  – exact simulation of the spectral distribution of the RADIATION BEAM emerging from the PATIENT is not a prerequisite.

- Clauses 9 and 10 deal with RADIATION CONDITIONS where SCATTERED RADIATION is taken into account. This is done either by limiting the amount of SCATTERED RADIATION by appropriate means and/or providing specific additional information.
- Clause 9 deals with measuring arrangements primarily intended in combination with RADIATION CONDITIONS RQB of Clause 10 to be used for those measurements where the contribution of SCATTERED RADIATION to the detected signal is minimal and is known as NARROW BEAM CONDITION.
- Clause 10 deals with RADIATION CONDITIONS to be used for measurements where the contribution of SCATTERED RADIATION to the detected signal is significant and is known as BROAD BEAM CONDITION.

For the RADIATION QUALITIES specified in Clauses 5 to 10 it is assumed that an X-RAY TUBE is available with an anode angle of not less than about 9 degrees. For x-ray tubes with smaller anode angles it may not be possible to realize some or all RADIATION QUALITIES of Clause 5. If some or all RADIATION QUALITIES of the RQR series cannot be realized with a given X-RAY TUBE due to a too strong INHERENT FILTRATION, some special provisions have been made to establish nevertheless the more heavily filtered RADIATION QUALITIES in Clauses 6 to 10 which are in principle based on the RADIATION QUALITIES of the RQR series.

In order to make allowance for the use of X-RAY TUBES with ANODE ANGLES down to 9°, the HALF-VALUE LAYERS of RADIATION QUALITIES RQR 4 to RQR 10 have been increased with respect to the values specified in the first edition of this standard (1994).

Clauses 11 to 14 deal with RADIATION CONDITIONS applicable to mammography.

- Clause 11 deals with RADIATION QUALITIES of the RADIATION BEAM emerging from the X-RAY SOURCE ASSEMBLY. Such RADIATION QUALITIES can be used for determining ATTENUATION properties of ASSOCIATED EQUIPMENT.
- Clause 12 deals with RADIATION QUALITIES transmitted through an irradiated object, that simulates a PATIENT under the conditions that:

  – the contribution of SCATTERED RADIATION in the RADIATION BEAM is not significant;

  – exact simulation of the spectral distribution of the RADIATION BEAM emerging from the PATIENT is not a prerequisite.

- CLAUSE 13 deals with RADIATION CONDITIONS to be used for studies in mammography under NARROW BEAM CONDITION. These RADIATION CONDITIONS are achieved by applying a special tissue-equivalent PHANTOM.

- CLAUSE 14 deals with RADIATION CONDITIONS to be used for studies in mammography under BROAD BEAM CONDITION. These RADIATION CONDITIONS are achieved by applying a special tissue-equivalent PHANTOM.

The test instrumentation as required in this standard partly comprises SPECIFIC components or a series of equivalent components out of which the most suitable should be chosen in order to provide test conditions required to achieve prescribed test parameters. However, these provisions in terms of hardware may not be available at USER facilities. As an example, clinical mammography units are not suited for producing the RADIATION QUALITIES in Clauses 11 to 14 without modification. In order to adapt them the PATIENT SUPPORT needs to be removed.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61674:1997, *Medical electrical equipment – Dosimeters with ionization chambers and/or semi-conductor detectors as used in X-ray diagnostic imaging*

IEC 61676:2002, *Medical electrical equipment – Dosimetric instruments used for non-invasive measurement of X-ray tube voltage in diagnostic radiology*

ISO 4037-1:1996, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61674 and IEC 61676 (two of which have been repeated here for convenience) and the following definitions apply.

3.1
APPLICATION DISTANCE
distance from the EFFECTIVE FOCAL SPOT to the APPLICATION PLANE

3.2
APPLICATION PLANE
plane perpendicular to the CENTRAL BEAM AXIS, where the standard RADIATION CONDITION is defined

3.3
CENTRAL BEAM AXIS
line from the FOCAL SPOT through the centre of the DIAPHRAGM

3.4
EXIT SURFACE
<RADIOLOGY> plane or curved surface through which the RADIATION BEAM emerges from an irradiated object

3.5
HALF-VALUE LAYER TEST DEVICE
device, normally shaped as foil or plate, which, when applied under NARROW BEAM CONDITIONS, attenuates AIR KERMA RATE to one half of the value that is measured without the device

3.6
HOMOGENEITY COEFFICIENT
ratio of first to second HALF-VALUE LAYER

NOTE The first HVL gives the thickness of a SPECIFIED material which reduces the AIR KERMA RATE to half the value without this material; the second HVL gives the additional thickness to reduce the AIR KERMA RATE to a quarter.

3.7
PRACTICAL PEAK VOLTAGE
$\hat{U}$

weighted average of the X-RAY TUBE VOLTAGE according to $\hat{U} = \frac{\sum_i w(U_i) U_i}{\sum_i w(U_i)}$, where U_i is the sequence of measured X-RAY TUBE VOLTAGES in kV and the weighting function $w(U_i)$ given by

$w(U_i) = 0$ for $U_i < 20$ kV and

$w(U_i) = \exp\{a \cdot U_i^2 + b \cdot U_i + c\}$ for 20 kV< $U_i \leq$36 kV and

$w(U_i) = d \cdot U_i^4 + e \cdot U_i^3 + f \cdot U_i^2 + g \cdot U_i + h$ for 36 kV < $U_i \leq$ 150 kV with

a = –8,646855*10^-3, b = 8,170361*10^-1, c = –2,327793*10^+1 and
d = 4,310644*10^-10, e = –1,662009*10^-7, f = 2,308190*10^-5, g = 1,030820*10^-5,
h = –1,747153*10^-2

for applications other than mammography and

$w(U_i) = 0$ for $U_i < 20$ kV and

$w(U_i) = \exp\{k \cdot U_i^4 + l \cdot U_i^3 + m \cdot U_i^2 + n \cdot U_i + o\}$ for 20 kV < $U_i \leq$ 50 kV with

k = –2,142352*10^-6, l = 2,566291*10^-4, m = –1,968138*10^-2, n = 8,506836*10^-1,
o = –1,514362*10^+1

for mammography

3.8
RADIATION CONDITION
description of RADIATION FIELDS by a set of electrical and geometrical parameters like X-RAY TUBE VOLTAGE, TOTAL FILTRATION and geometrical arrangements

3.9
RADIATION QUALITY
radiation condition whereby the RADIATION FIELD includes only an insignificant amount of SCATTERED RADIATION

NOTE This definition takes precedence over that given in IEC TR 60788.

3.10
REFERENCE POINT
point of a RADIATION DETECTOR which, during the calibration of the DETECTOR, is brought to coincidence with the point at which the CONVENTIONAL TRUE VALUE is specified

[IEC 61674:1997, définition 3.17, modifiée]

3.11
X-RAY TUBE VOLTAGE
potential difference applied to an X-RAY TUBE between the anode and the cathode. The unit of this quantity is the volt (V)

[IEC 61676:2002, definition 3.25]

NOTE The X-RAY TUBE VOLTAGE may vary as a function of time. The PRACTICAL PEAK VOLTAGE is a weighted value of the X-RAY TUBE VOLTAGE over a time period.

3.12
REFERENCE DIRECTION
specified direction to which characteristics such as target angle, radiation field and specifications with respect to the imaging quality of the radiation source are referenced

4 Common aspects – Adjustment procedures

4.1 Standard RADIATION CONDITIONS

The standard RADIATION CONDITIONS are characterized by a letter code.

They are described, as applicable, in terms of:

– the material of the emitting TARGET;
– the X-RAY TUBE VOLTAGE;
– a specific TOTAL FILTRATION consisting of that of
  • the X-ray source assembly, and
  • an added filter or phantom of specific material and thickness;
– the first half-value layer;
– homogeneity coefficient
– an application distance.

4.2 RADIATION DETECTOR

The RADIATION DETECTOR to be used for measurements of AIR KERMA or AIR KERMA RATE to determine the attenuation curve shall comply with IEC 61674. Additionally,

– its energy dependence of response shall not exceed ±3 % over the range of radiation qualities N15 to N200 of ISO 4037-1;
– the dimensions of the entrance surface of its SENSITIVE VOLUME shall be such that it will be fully covered by the RADIATION BEAM;
– its sensitivity shall be such that measurements can (still) be carried out, when applying ADDED FILTERS or PHANTOMS described in this standard;
– the RADIATION DETECTOR shall be applicable for the AIR KERMA RATES involved (with and without application of ADDED FILTERS or PHANTOMS).

4.3 PERCENTAGE RIPPLE of the X-RAY TUBE VOLTAGE

PERCENTAGE RIPPLE of the X-RAY TUBE VOLTAGE shall not exceed 10 %, apart from the case of mammography, where a limit of 4 % shall not be exceeded.

4.4 Anode material

Requiring tungsten as target material does not refer to pure tungsten but to a “tungsten-rich” target material. For technological reasons, for example, alloys are used containing up to 10 % of rhenium.

5 RQR – RADIATION QUALITIES in RADIATION BEAMS emerging from the X-RAY SOURCE ASSEMBLY

5.1 Object

This clause deals with RADIATION QUALITIES, which are used for measurements in the RADIATION BEAM as emerging from the X-RAY SOURCE ASSEMBLY. Such RADIATION QUALITIES are, for example, applied for determining characteristics of PATIENT SUPPORTS in case the PATIENT SUPPORT is situated in between the X-RAY SOURCE ASSEMBLY and the PATIENT.

5.2 Characterization

The standard RADIATION QUALITIES, characterized by the letter code given in the first column of Table 1, are referred to as follows:

RQR x IEC 61267:200y,

where x is, according to Table 1, a number between 2 and 10, and y represents the year of publication of the revision of this standard.

5.3 Description

The standard RADIATION QUALITIES RQR are described by the set of parameters given below:

– an emitting TARGET of tungsten;
– an X-RAY TUBE VOLTAGE adjusted to the values given in column 2 of Table 1;
– an adjusted TOTAL FILTRATION of the X-RAY SOURCE ASSEMBLY;
– the first HALF-VALUE LAYER as given in column 3 of Table 1.
– the HOMOGENEITY COEFFICIENT within ± 0,03 to that given in column 4 of Table 1

The method of production of RADIATION QUALITIES RQR according to the description specified in this subclause is given in 5.4 and 5.6.

Table 1 – Characterization of standard RADIATION QUALITIES RQR 2 to RQR 10

Standard RADIATION QUALITY	X-RAY TUBE VOLTAGE kV	First HALF-VALUE LAYER in mm of aluminium	HOMOGENEITY COEFFICIENT
RQR 2	40	1,42	0,81
RQR 3	50	1,78	0,76
RQR 4	60	2,19	0,74
RQR 5	70	2,58	0,71
RQR 6	80	3,01	0,69
RQR 7	90	3,48	0,68
RQR 8	100	3,97	0,68
RQR 9	120	5,00	0,68
RQR 10	150	6,57	0,72

5.4 X-RAY TUBE VOLTAGE adjustment

The X-RAY TUBE VOLTAGE shall be specified in terms of the PRACTICAL PEAK VOLTAGE. The X-RAY TUBE VOLTAGE shall be set to the prescribed value with an uncertainty of 1,5 % or 1,5 kV (coverage factor k = 2), whatever is larger.

5.5 ADDITIONAL FILTRATION

Using the setting of the X-RAY TUBE VOLTAGE determined in the previous subclause, an ATTENUATION curve shall be measured with aluminium ATTENUATION layers. The ATTENUATION curve shall cover at least an ATTENUATION of a factor 6.

For all cases except for those of mammography, the amount of ADDITIONAL FILTRATION required in order to establish the first HALF-VALUE LAYER and to approximate the HOMOGENEITY COEFFICIENT given in the appropriate tables shall be determined. If the first HALF-VALUE LAYER of the X-RAY TUBE ASSEMBLY is larger than the value to be obtained, the X-RAY TUBE ASSEMBLY shall not be used for establishing the desired RADIATION QUALITY.

An example of determining the amount of ADDITIONAL FILTRATION required is described in Annex B.

Add the amount of ADDITIONAL FILTRATION as determined above. Verify the HALF-VALUE LAYER with the modified filtration by means of the HALF-VALUE LAYER TEST DEVICE. The correct standard RADIATION QUALITY is obtained, when the quotient of the measured values of AIR KERMA or AIR KERMA RATE – obtained in measurements with and without the HALF-VALUE LAYER TEST DEVICE in the RADIATION BEAM – is between 0,485 and 0,515.

NOTE Since the establishment of the correct HALF VALUE LAYER is a non-linear procedure, it may be necessary to repeat the steps described in this subclause starting with the measurement of the ATTENUATION curve. Alternatively, when the INDICATED VALUES of AIR KERMA or AIR KERMA RATE – obtained in measurements with and without the HALF-VALUE LAYER TEST DEVICE in the RADIATION BEAM –are just marginally outside the range between 0,485 and 0,515 the added filtration may be varied by trial and error. If the ratio of the AIR KERMA is below 0,485, the ADDITIONAL FILTRATION needs to be increased and vice versa. The ATTENUATION curve can be determined with a set of seven Al-filters starting with a thickness of 0,5 mm, where the thickness increases by a factor of two from one filter to the next until and including a filter thickness of 32 mm).

5.6 Test equipment

5.6.1 X-RAY TUBE VOLTAGE measuring device

The X-RAY TUBE VOLTAGE shall be measured with a voltage divider connected parallel to the X-RAY GENERATOR and the X-RAY TUBE.

NOTE Non-invasive X-RAY TUBE VOLTAGE measuring devices are not appropriate for the purposes of this standard.

5.6.2 Auxiliary filter

Auxiliary filters of thin layers of aluminium shall be available and shall be suitable for mounting on the X-RAY SOURCE ASSEMBLY to enable the first HALF-VALUE LAYER given in Table 1 to be obtained.

The material of these layers shall be aluminium of a purity of at least 99,9 %.

5.6.3 ATTENUATION layers

To produce the nominal HALF-VALUE LAYER, as required in 5.3 in order to achieve a standard RADIATION QUALITY RQR, an ATTENUATION curve shall be measured by means of a series of aluminium ATTENUATION layers. By combining the aluminium ATTENUATION layers it shall be possible to establish a total ATTENUATION layer thickness up to 25 mm in steps not larger than 0,5 mm. The thickness of each ATTENUATION layer shall be known to within ±0,01 mm.

The material of these ATTENUATION layers shall be aluminium of a purity of at least 99,9 %.

The size of the ATTENUATION layers shall be large enough to intercept the full RADIATION BEAM intended to be used for the test (see Figure 1).

5.6.4 DIAPHRAGM

A DIAPHRAGM shall be available to limit the extent of the RADIATION BEAM immediately after the EXIT SURFACE of the ATTENUATION layer to not more than 50 mm x 50 mm (see Figure 1).

5.6.5 RADIATION DETECTOR

See 4.2.

5.6.7 HALF-VALUE LAYER TEST DEVICES

To produce the nominal HALF-VALUE LAYER, as required in 6.3.1 in order to achieve a standard RADIATION QUALITY RQR, a HALF-VALUE LAYER TEST DEVICE of aluminium shall be available. This HALF-VALUE LAYER TEST DEVICE, consisting preferably of a single layer, shall have a thickness equal to the nominal first HALF-VALUE LAYER given in the third column of Table 1 within a total tolerance of ± 0,1 mm.

The material of these layers shall be aluminium of a purity of at least 99,9 %.

The size of the HALF-VALUE LAYER TEST DEVICE shall be large enough to intercept the full RADIATION BEAM intended to be used for the test (see Figure 1).

5.7 Generation and verification of the standard RADIATION QUALITIES RQR

5.7.1 Geometry

The RADIATION DETECTOR shall be placed with its REFERENCE POINT on the REFERENCE AXIS in the APPLICATION PLANE. The APPLICATION PLANE shall be at a distance from the FOCAL SPOT of not less than 550 mm or not less than twice the distance between the FOCAL SPOT and the HALF-VALUE LAYER TEST DEVICE, whichever is the larger.

To minimize backscatter effects, only those objects required for measurement purposes shall be placed in the volume inside the RADIATION BEAM, which is limited by the APPLICATION PLANE and the plane normal to the RADIATION BEAM AXIS containing a point 450 mm beyond the APPLICATION PLANE in the REFERENCE DIRECTION (see Figure 1).

5.7.2 Establishing one standard RADIATION QUALITY RQR

The steps described in 5.4 shall be carried out using the parameters given in Table 1. As a result of these measurements it may be necessary to modify the TOTAL FILTRATION by mounting an auxiliary filter on the X-RAY SOURCE ASSEMBLY.

5.7.3 Establishing a series of RADIATION QUALITIES RQR

The amount of ADDITIONAL FILTRATION required for establishing each of the RADIATION QUALITIES RQR will not be identical for each RADIATION QUALITY. If the difference between the largest and smallest value of the ADDITIONAL FILTRATION is not larger than 0,5 mm, one single ADDED FILTER with a thickness close to the arithmetic mean of all values of ADDITIONAL FILTRATION may be used for establishing all RADIATION QUALITIES RQR with one single filter.

6 RQA – RADIATION QUALITIES based on a PHANTOM made up of an aluminium ADDED FILTER

6.1 Object

This clause deals with RADIATION QUALITIES, which are used for the determination of characteristics, when

- measurements are made in the RADIATION BEAM emerging from the irradiated object simulating the PATIENT;
- the amount of SCATTERED RADIATION in the detected RADIATION BEAM is not significant (low-scatter condition);
- close simulation of the spectral distribution of the RADIATION BEAM emerging from the PATIENT is not a prerequisite.

6.2 Characterization

The standard RADIATION QUALITIES characterized by the letter code given in the first column of Table 2, are referred to as follows:

RQA x IEC 61267:200y,

where x is, according to Table 2, a number between 2 and 10, and y represents the year of publication of the revision of this standard.

6.3 Description

6.3.1 Description of RADIATION QUALITIES RQA for a known X-RAY TUBE VOLTAGE

The standard RADIATION QUALITIES RQA are described by the following parameters:

– an emitting TARGET of tungsten;
– an X-RAY TUBE VOLTAGE identical to that of the corresponding RADIATION QUALITY RQR
– a TOTAL FILTRATION consisting of:
  - the TOTAL FILTRATION realised according to Subclauses 5.4 and 5.5
  - an ADDED FILTER as described in 6.3.2 with a thickness given in column 3 of Table 2;
– the nominal first HALF-VALUE LAYER as given in column 4 of Table 2.

The method of production of RADIATION QUALITIES RQA according to the descriptions specified in this subclause is given in 6.4.

6.3.2 ADDED FILTER

For simulating the PATIENT in order to achieve the standard RADIATION QUALITIES RQA 2 to RQA 10, layers of aluminium of suitable thicknesses to obtain the values of the ADDED FILTER given in Table 2, shall be available. The thickness of each filter layer shall be known to within ±0,01 mm.

The material of these layers shall be aluminium of a purity of at least 99,9 %.

The size of the layers shall be large enough to intercept the full RADIATION BEAM intended to be used for the test (see Figure 2).

Table 2 – Characterization of standard RADIATION QUALITIES RQA 2 to RQA 10

Standard RADIATION QUALITY	X-RAY TUBE VOLTAGE kV	ADDED FILTER thickness of aluminium mm	Nominal first HALF-VALUE LAYER in thickness of aluminium mm
RQA 2	40	4	2,2
RQA 3	50	10	3,8
RQA 4	60	16	5,4
RQA 5	70	21	6,8
RQA 6	80	26	8,2
RQA 7	90	30	9,2
RQA 8	100	34	10,1
RQA 9	120	40	11,6
RQA 10	150	45	13,3

6.4 Generation of the standard RADIATION QUALITIES RQA

Starting from the standard RADIATION QUALITIES RQR as established according to 5.4 and 5.6, add the filter given in column 3 of Table 2.

NOTE By establishing RADIATION QUALITIES RQA on the basis of RADIATION QUALITIES RQR the X-RAY TUBE VOLTAGE and the TOTAL FILTRATION are adjusted in the way described. This does not leave any further degree of freedom for adjusting the HVL. Therefore, the HVLs given in column 4 of Table 2 represent nominal values.

6.5 Alternative method for generating standard RADIATION QUALITIES RQA

RADIATION QUALITIES RQA may also be established directly by the procedures described in Clause 5, i.e. without having previously established RADIATION QUALITIES RQR. When the procedures described in Clause 5 are applied to the generation of RADIATION QUALITIES RQA the HALF-VALUE LAYERS in column 4 of Table 2 are those to be established and hence no nominal ones.

7 RQC – RADIATION QUALITIES based on copper ADDED FILTER

7.1 Object

This clause deals with RADIATION QUALITIES, which are used for adjusting the automatic brightness control system for fluoroscopy under scatter free conditions.

7.2 Characterization

The standard RADIATION QUALITIES characterized by the letter code given in the first column of Table 3, are referred to as follows:

RQC x IEC 61267:200y

where x is, according to Table 3, one of the numbers 3, 5, 8, and y represents the year of publication of the revision of this standard.

7.3 Description

The standard RADIATION QUALITIES RQC are described by the parameters given in 7.3.1.

7.3.1 Description

The standard RADIATION QUALITIES RQC are described in terms of:

– an emitting TARGET of tungsten;
– an X-RAY TUBE VOLTAGE identical to that of the corresponding RADIATION QUALITY RQR;
– a TOTAL FILTRATION consisting of
  • the total filtration realised according to Subclauses 5.4 and 5.6;
  • an ADDED FILTER of copper.

7.3.2 Added filter

For simulating the PATIENT in order to achieve the standard RADIATION QUALITIES RQC 3, RQC 5 and RQC 8, layers of copper of suitable thicknesses to obtain the values of the ADDED FILTER given in column 3 of Table 3, shall be available. The thickness of each filter layer shall be known to within ±0,01 mm.

The material of these layers shall be copper of a purity of at least 99,9 %.

The size of the layers shall be large enough to intercept the full RADIATION BEAM intended to be used for the test (see Figure 2).

Table 3 – Characterization of standard RADIATION QUALITIES RQC 3, RQC 5 and RQC 8

Standard RADIATION QUALITY Characterization	X-RAY TUBE VOLTAGE kV	ADDED FILTER for RQC thickness in copper mm	Nominal first HALF-VALUE LAYER in thickness of aluminium mm
RQC 3	50	0,5	4,5
RQC 5	70	1,5	8,4
RQC 8	100	2,0	11,5

7.4 Method of production RADIATION QUALITIES RQC

Standard RADIATION QUALITIES RQC shall be produced starting with the set-up established for the RADIATION QUALITIES RQA. The ADDED FILTER is then replaced by copper filters of thickness given in column 3 of Table 3. The HALF-VALUE LAYERS given in column 4 of Table 3 are nominal ones.

If the QUALITY EQUIVALENT FILTRATION of the X-RAY TUBE ASSEMBLY lies between 1,5 mm and 3,5 mm aluminium, the ADDED FILTER thickness of Table 3 shall be used as such, without modifications.

NOTE The RQC RADIATION QUALITIES are only marginally influenced by the exact amount of Al filtration.

8 RQT – RADIATION QUALITIES based on copper ADDED FILTER

8.1 Object

This clause deals with RADIATION QUALITIES, which are used for the determination of characteristics in CT applications.

8.2 Characterization

The standard RADIATION QUALITIES characterized by the letter code given in the first column of Table 4, are referred to as follows:

RQT x IEC 61267:200y

where x is, according to Table 4, a number between 8 and 10, and y represents the year of publication of the revision of this standard.

8.3 Description

The standard RADIATION QUALITIES RQT are described by the parameters given in 8.3.1.

8.3.1 Description of RADIATION QUALITIES RQT for a known X-RAY TUBE VOLTAGE

The standard RADIATION QUALITIES RQT are described in terms of:

- the first HALF-VALUE LAYER;
- an emitting TARGET of tungsten;
- an X-RAY TUBE VOLTAGE identical to that of the corresponding RADIATION QUALITY RQR;
- a TOTAL FILTRATION consisting of
  - the TOTAL FILTRATION realised according to Subclause 5.4 and 5.6;
  - an ADDED FILTER of copper.

8.3.2 ADDED FILTER

For simulating the PATIENT in order to achieve the standard RADIATION QUALITIES RQT 8 to RQT 10, layers of copper of suitable thicknesses to obtain the values of the first HALF-VALUE LAYER given in column 4 of Table 4, shall be available.

The material of these layers shall be copper of a purity of at least 99,9 %.

The size of the layers shall be large enough to intercept the full RADIATION BEAM intended to be used for the test (see Figure 2).

Table 4 – Characterization of standard RADIATION QUALITIES RQT 8, RQT 9 and RQT 10

Standard RADIATION QUALITY Characterization	X-RAY TUBE VOLTAGE kV	Nominal ADDED FILTER for RQT thickness in copper mm	First HALF-VALUE LAYER in thickness of aluminium mm
RQT 8	100	0,2	6,9
RQT 9	120	0,25	8,4
RQT 10	150	0,3	10,1

8.4 Method of production RADIATION QUALITIES RQT

Standard RADIATION QUALITIES RQT shall be produced starting with the set up established for the RADIATION QUALITIES RQR. The ADDED FILTER of the thickness given in column 3 of Table 4 is then introduced into the beam. This results in the nominal HALF-VALUE LAYER are given in column 4 of table 5.

NOTE By establishing RADIATION QUALITIES RQA on the basis of RADIATION QUALITIES RQR the X-RAY TUBE VOLTAGE and the TOTAL FILTRATION are adjusted in the way described. This does not leave any further degree of freedom for adjusting the HVL. Therefore, the HVLs given in column 4 of Table 2 represent nominal values.

8.5 Alternative method for generating standard RADIATION QUALITIES RQT

Standard RADIATION QUALITIES RQT may also be established directly, i.e. without having previously established standard RADIATION QUALITIES RQR. It is recommended to produce RADIATION QUALITIES RQT directly, i.e. without RQR radiation qualities, by means of a 'trial and error' method. Add the amount of ADDITIONAL FILTRATION of copper given in column 3 of Table 4. Verify the HALF-VALUE LAYER obtained in this way by means of the HALF-VALUE LAYER TEST DEVICE described in 8.6 (see below). The correct standard RADIATION QUALITY RQT is obtained, when the quotient of the measured values of AIR KERMA or AIR KERMA RATE – obtained in measurements with and without the HALF-VALUE LAYER TEST DEVICE in the RADIATION BEAM – is between 0,485 and 0,515. If the value is less than 0,485 the thickness of the added copper filter needs to be increased; if it is larger than 0,515 the thickness needs to be decreased. After having modified the thickness of the copper filter a new HALF-VALUE LAYER measurement should be made. Repeat this procedure until a ratio of the AIR KERMA or AIR KERMA RATE with and without the test device between 0,485 and 0,515 is achieved. When the standard RADIATION QUALITIES RQT are produced by the method described in this subclause the HALF-VALUE LAYERS in column 4 of Table 4 are those to be established and hence no nominal ones.

8.6 HALF-VALUE LAYER TEST DEVICE

To produce the nominal HALF-VALUE LAYER, as required in 8.3.2 in order to achieve a standard RADIATION QUALITY RQT, a HALF-VALUE LAYER TEST DEVICE of aluminium shall be available. This HALF-VALUE LAYER TEST DEVICE, consisting preferably of a single layer, shall have a thickness equal to the nominal first HALF-VALUE LAYER given in column 4 of Table 4 within a total tolerance of ± 0,1 mm.

The material of these layers shall be aluminium of a purity of at least 99,9 %.

The size of the HALF-VALUE LAYER TEST DEVICE shall be large enough to intercept the full RADIATION BEAM intended to be used for the test (see Figure 1).

9 Standard RADIATION CONDITIONS RQN

9.1 Object

This clause deals with RADIATION CONDITIONS, which are used for the determination of characteristics, when the contribution of SCATTERED RADIATION to the detected signal has to be minimized in the results of relevant measurements (NARROW BEAM CONDITION).

NOTE A possible RQN 1, at an X-RAY TUBE VOLTAGE around 30 kV, would be applicable for mammography studies. Because of the special conditions of such studies, this RADIATION CONDITION is dealt with in Clause 13 under the characterization of RQN-M.

9.2 Characterization

The standard RADIATION CONDITIONS characterized by the letter code RQN 2 to RQN 10 are referred to as follows:

RQN x IEC 61267:200y

where x is a number between 2 and 10, as appropriate, and y represents the year of publication of the revision of this standard.

If the APPLICATION DISTANCE is xxx rather than 1 000 mm, the RADIATION CONDITION is expressed and referred to as follows:

RQN x – xxx IEC 61267:200y

where xxx is the APPLICATION DISTANCE in millimetres.

9.3 Description

The standard RADIATION CONDITIONS RQN are related to the standard RADIATION QUALITIES RQR 2 to RQR 10 specified in Clause 5.

After having achieved the corresponding standard RADIATION QUALITY RQR, the PHANTOM described below is placed in the RADIATION BEAM.

To achieve standard RADIATION QUALITIES RQN 2 to RQN 10, a cylindrical container filled with water shall be available as a PHANTOM.

The container shall have:

– an outside diameter of 50 mm;

– a height of 200 mm ± 1 mm;

– top, bottom and walls made of polymethylmethacrylate, each being 10 mm ± 2 mm thick; and

– the interior filled with water.

9.4 Test equipment (DIAPHRAGMS)

DIAPHRAGMS shall be available to be placed close to the X-RAY SOURCE ASSEMBLY as shown in Figure 3 to limit the RADIATION BEAM both at the ENTRANCE SURFACE and at the EXIT SURFACE of the ADDED FILTER. The first DIAPHRAGM shall be placed in a distance of 300 mm from the FOCAL SPOT, the DIAPHRAGM at the EXIT SURFACE (500 mm from the FOCAL SPOT) shall have an aperture not exceeding 40 mm in diameter.

A third DIAPHRAGM with an aperture of 11 mm in diameter shall be placed at a distance of 550 mm from the FOCAL SPOT, so that the total RADIATION BEAM is adjusted to a diameter of 20 mm ± 2 mm at the APPLICATION DISTANCE.

The DIAPHRAGMS shall be made of lead of a minimum thickness of 5 mm.

NOTE If the DIAPHRAGMS are large enough (> 275 mm x 275 mm or > 390 mm in diameter), the phantom (added filter) shown in Figure 4 can be used instead of the added filter in Figure 3.

9.5 Generation of the standard RADIATION CONDITIONS RQN

To establish conditions for the generation of standard RADIATION CONDITIONS RQN, the full procedure by which the corresponding RQR is established is carried out. Having established the RQR RADIATION QUALITY, the PHANTOM specified in 9.3 shall be placed so that its ENTRANCE SURFACE is between 200 mm and 300 mm from the FOCAL SPOT.

The DIAPHRAGMS mentioned in 9.4 shall be placed according to Figure 3.

10 Standard RADIATION CONDITIONS RQB

10.1 Object

This clause deals with RADIATION CONDITIONS, which are used for the determination of characteristics, when the contribution of SCATTERED RADIATION to the detected signal is significant in the results of relevant measurements (BROAD BEAM CONDITION).

NOTE A possible RQB 1, at an X-RAY TUBE VOLTAGE around 30 kV, would be applicable for mammography studies. Because of the special conditions of such studies, this RADIATION CONDITION is dealt with in Clause 14 under the characterization of RQB-M.

10.2 Characterization

The standard RADIATION CONDITIONS characterized by the letter code RQB 2 to RQB 10 are referred to as follows:

RQB x IEC 61267:200y

where x is a number between 2 and 10, as appropriate, and y represents the year of publication of the revision of this standard.

If the APPLICATION DISTANCE is xxx rather than 1 000 mm, the RADIATION CONDITION is expressed and referred to as follows:

RQB x – xxx IEC 61267:200y

where x is a number between 2 and 10, as appropriate, and xxx is the APPLICATION DISTANCE in millimetres.

10.3 Description

The standard RADIATION CONDITIONS RQB are related to the standard RADIATION QUALITIES RQR 2 to RQR 10 specified in Clause 5.

After having achieved the corresponding standard RADIATION QUALITY RQR, the PHANTOM described below is placed in the RADIATION BEAM.

To achieve standard RADIATION CONDITIONS RQB 2 to RQB 10, the PHANTOM to be used shall be a water-filled container.

The container shall have:

– sides of outside dimensions of 300 mm ± 1 mm and height 200 mm ± 1 mm;

– top, bottom and walls made of polymethylmethacrylate, each being 10 mm ± 2 mm thick; and

– the interior filled with water.

10.4 Test equipment (DIAPHRAGMS)

DIAPHRAGMS shall be available to be placed close to the X-RAY SOURCE ASSEMBLY and close to the ENTRANCE SURFACE of the PHANTOM as shown in Figure 4, and to limit the RADIATION BEAM so that the total RADIATION BEAM is adjusted to 275 mm x 275 mm in the plane of the EXIT SURFACE of the PHANTOM.

The DIAPHRAGM shall be made of lead of a minimum thickness of 5 mm.

10.5 Generation of the standard RADIATION CONDITIONS RQB

To establish conditions for the generation of standard RADIATION CONDITIONS RQB, the full procedure by which the corresponding RQR is established is carried out. Having established the RQR RADIATION QUALITY, the EXIT SURFACE of the PHANTOM according to 10.3 shall be situated at 20 mm less than the APPLICATION DISTANCE.

The DIAPHRAGMS mentioned in 10.4 shall be placed according to Figure 4.

11 Standard RADIATION CONDITION RQR-M

11.1 Object

This clause deals with RADIATION QUALITIES, which are used for the determination of characteristics in unattenuated mammography beams of X-RAY EQUIPMENT operating at X-RAY TUBE VOLTAGES essentially below 40 kV, such as in mammography, and when the contribution of SCATTERED RADIATION to the detected signal has to be minimized in the result of relevant measurements.

11.2 Characterization

The standard RADIATION QUALITIES, characterized by the letter code RQR-M, are referred to as follows:

RQR-M x IEC 61267:200y

where x is, according to Table 5, a number between 1 and 4 and y represents the year of publication of the revision of this standard.

11.3 Description

The standard RADIATION QUALITIES RQR-M are described in terms of:

– emitting TARGET of molybdenum;

– X-RAY TUBE VOLTAGE with a PERCENTAGE RIPPLE of not more than 4 %;

– TOTAL FILTRATION of 0,032 mm ± 0,002 mm molybdenum in the X-RAY SOURCE ASSEMBLY.

Table 5 – Characterization of standard RADIATION QUALITIES RQR-M 1 to RQR-M 4

Standard RADIATION QUALITY Characterization	X-RAY TUBE VOLTAGE (nominal value) kV	Nominal first HALF-VALUE LAYER in mm of aluminium
RQR-M 1	25	0,28
RQR-M 2	28	0,31
RQR-M 3	30	0,33
RQR-M 4	35	0,36

11.4 Generation of the standard radiation qualities RQR-M

The nominal X-RAY TUBE VOLTAGE shall be selected and the first aluminium HALF-VALUE LAYER shall be measured using a HALF-VALUE LAYER TEST DEVICE. The value determined experimentally should be within ± 0,02 of the value given in column 3 of Table 5.

12 Standard RADIATION CONDITION RQA-M

12.1 Object

This clause deals with RADIATION QUALITIES, which are used for the determination of characteristics, when:

– measurements are made in the RADIATION BEAM emerging from the irradiated object simulating the PATIENT;

– the amount of SCATTERED RADIATION in the detected RADIATION BEAM is not significant (low-scatter condition);

– close simulation of the spectral distribution of the RADIATION BEAM emerging from the PATIENT is not a prerequisite.

12.2 Characterization

The standard RADIATION QUALITIES, characterized by the letter code RQA-M, are referred to as follows:

RQA-M x IEC 61267:200y

where x is, according to Table 6, a number between 1 and 4, and y represents the year of publication of the revision of this standard.

12.3 Description

The standard RADIATION CONDITION RQA-M is described in terms of:

– emitting TARGET of molybdenum;

– X-RAY TUBE VOLTAGE with a PERCENTAGE RIPPLE of not more than 4 %;

– TOTAL FILTRATION of 0,032 mm ± 0,002 mm molybdenum in the X-RAY SOURCE ASSEMBLY;

– ADDED FILTER of 2 mm ± 0,01 mm aluminium.

Table 6 – Characterization of standard RADIATION QUALITIES RQA-M 1 to RQA-M 4

Standard RADIATION QUALITY Characterization	X-RAY TUBE VOLTAGE (nominal value) kV	ADDED FILTER in mm aluminium	Nominal first HALF-VALUE LAYER mm aluminium
RQA-M 1	25	2	0,56
RQA-M 2	28	2	0,60
RQA-M 3	30	2	0,62
RQA-M 4	35	2	0,68

12.4 Generation of the standard RADIATION CONDITION RQA-M

After having established the RQR-M RADIATION QUALITY the ADDED FILTER shall be placed so that its ENTRANCE SURFACE is between 200 mm and 300 mm from the FOCAL SPOT.

13 Standard RADIATION CONDITIONS RQN-M

13.1 Object

This clause deals with a RADIATION CONDITION, which is used for the determination of characteristics of X-RAY EQUIPMENT operating at X-RAY TUBE VOLTAGES essentially below 40 kV, such as in mammography, and when the contribution of SCATTERED RADIATION to the detected signal has to be minimized in the result of relevant measurements (NARROW BEAM CONDITION).

13.2 Characterization

The standard RADIATION CONDITIONS, characterized by the letter code RQN-M, are referred to as follows:

RQN-M x IEC 61267:200y

where x is, according to Table 7, a number between 1 and 4, and y represents the year of publication of the revision of this standard.

13.3 Description

The standard RADIATION CONDITIONS RQN-M are described in terms of:

– emitting TARGET of molybdenum;
– X-RAY TUBE VOLTAGE with a PERCENTAGE RIPPLE of not more than 4 %;
– TOTAL FILTRATION of 0,032 mm ± 0,002 mm molybdenum in the X-RAY SOURCE ASSEMBLY;
– PHANTOM.

Table 7 – Characterization of standard RADIATION CONDITIONS RQN-M 1 to RQN-M 4

Standard RADIATION QUALITY Characterization	X-RAY TUBE VOLTAGE (nominal value) in kV	Nominal first HALF-VALUE LAYER in mm aluminium
RQN-M 1	25	0,37
RQN-M 2	28	0,61
RQN-M 3	30	0,63
RQN-M 4	35	0,70

For simulating the PATIENT in order to achieve the standard RADIATION CONDITION RQN-M, a PHANTOM shall be available, and is of a thickness of 45 mm.

The outer dimensions of the PHANTOM shall be:

– length: 120 mm ± 1 mm;
– width : 80 mm ± 1 mm;
– height: 45 mm ± 0,5 mm.

The phantom material shall be polymethylmethacrylate (PMMA).

13.4 Test equipment (DIAPHRAGMS)

DIAPHRAGMS shall be available to be placed close to the X-RAY SOURCE ASSEMBLY as shown in Figure 5, to limit the RADIATION BEAM at the ENTRANCE SURFACE and at the EXIT SURFACE of the PHANTOM.

The second DIAPHRAGM shall limit the RADIATION BEAM to a diameter of 20 mm in the APPLICATION PLANE.

The DIAPHRAGMS shall be made of lead of a minimum thickness of 1 mm.

13.5 Generation of the standard RADIATION CONDITIONS RQN-M

Starting from the configuration appropriate to the RQR-M RADIATION QUALITY the PHANTOM shall be placed so that its ENTRANCE SURFACE is between 200 mm and 300 mm from the FOCAL SPOT.

The DIAPHRAGMS shall be placed according to Figure 5.

14 Standard RADIATION CONDITION RQB-M

14.1 Object

This clause deals with a RADIATION CONDITION, which is used for the determination of characteristics of X-RAY EQUIPMENT operating at X-RAY TUBE VOLTAGES essentially below 40 kV, such as in mammography, and when the contribution of SCATTERED RADIATION to the detected signal is significant in the result of relevant measurements (BROAD BEAM CONDITION).

14.2 Characterization

The standard RADIATION CONDITION, characterized by the letter code RQB-M, is referred to as follows:

RQB-M x IEC 61267:200y

where x is, according to Table 8, a number between 1 and 4, and y represents the year of publication of the revision of this standard.

14.3 Description

The standard RADIATION CONDITIONS RQB-M are described in terms of:

- emitting TARGET of molybdenum;
- X-RAY TUBE VOLTAGE with a PERCENTAGE RIPPLE of not more than 4 %;
- TOTAL FILTRATION of 0,032 mm ± 0,002 mm molybdenum in the X-RAY SOURCE ASSEMBLY;
- PHANTOM.

Table 8 – Characterization of standard RADIATION CONDITIONS RQB-M 1 to RQB-M 4

Standard RADIATION QUALITY Characterization	X-RAY TUBE VOLTAGE (nominal value) in kV
RQB-M 1	25
RQB-M 2	28
RQB-M 3	30
RQB-M 4	35

For simulating the PATIENT in order to achieve the standard RADIATION CONDITIONS RQB-M, a PHANTOM shall be available, which simulates breast tissue of a mean composition of 50 % adipose and 50 % glandular tissue and is of a thickness of 45 mm.

The outer dimensions of the PHANTOM shall be:

– length: 120 mm ± 1 mm;
– width : 80 mm ± 1 mm;
– height: 45 mm ± 0,5 mm.

The PHANTOM shall be made of polymethylmethacrylate (PMMA).

14.4 Test equipment (DIAPHRAGM)

A DIAPHRAGM shall be available limiting the RADIATION BEAM, so that the latter:

– covers the total ENTRANCE SURFACE of the PHANTOM;
– exceeds the total EXIT SURFACE of the PHANTOM for about 10 mm at the three sides different from the side corresponding to the chest wall side during a normal PATIENT examination.

The overlap at the side corresponding to the chest wall side shall be as small as possible.

14.5 Generation of the standard RADIATION CONDITIONS RQB-M

Establish the standard RADIATION QUALITIES RQR-M according to Subclause 11.4.

The PHANTOM shall be placed so that its EXIT SURFACE is at a distance of 10 mm from the APPLICATION PLANE in the REFERENCE DIRECTION. The APPLICATION DISTANCE shall be 600 mm.

The DIAPHRAGM shall be placed to fulfil the requirements of 14.4, and shall be placed according to Figure 6.

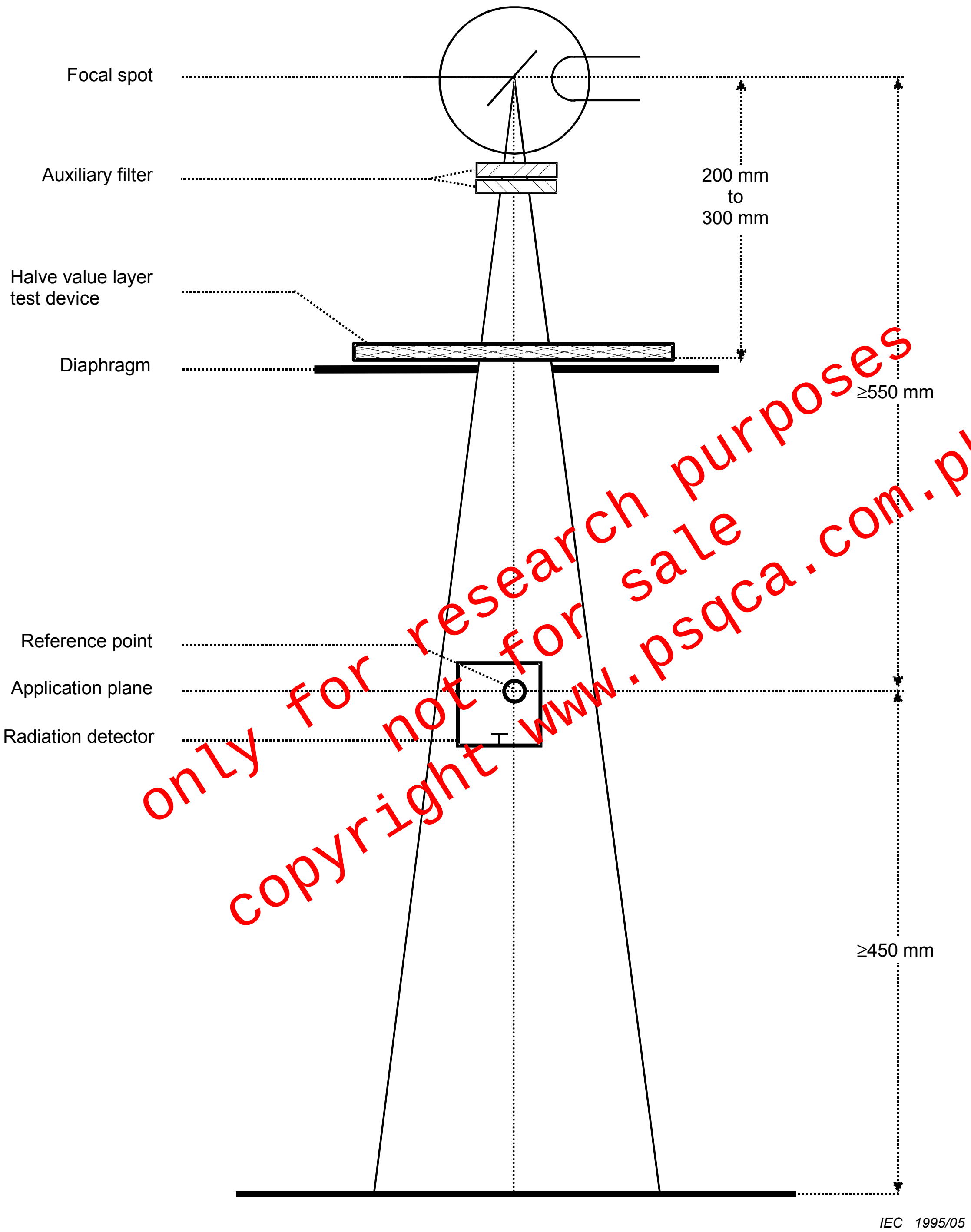


Figure 1 – Measuring arrangement for achieving standard RADIATION QUALITIES RQR 2 to RQR 10

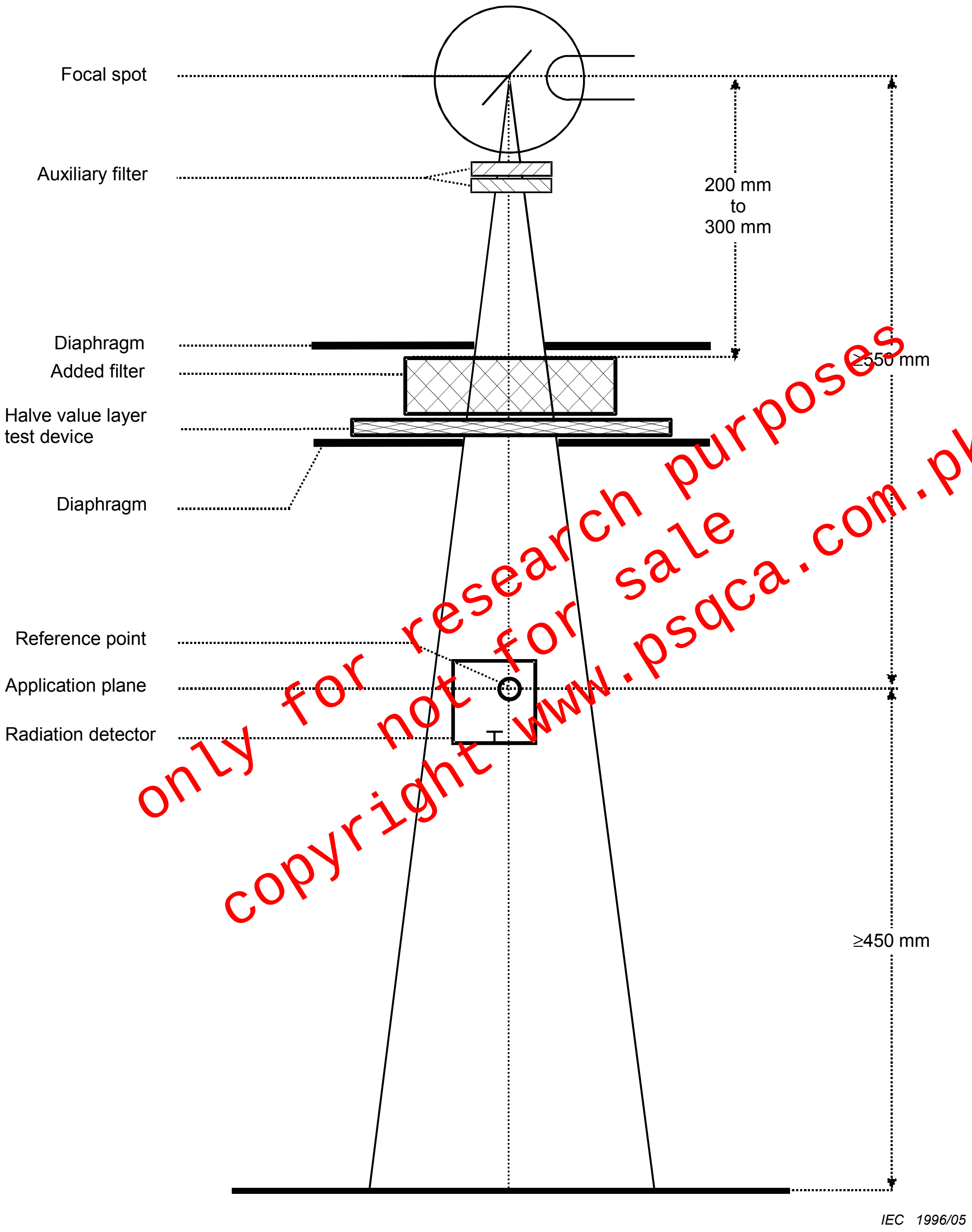


Figure 2 – Measuring arrangement for achieving standard RADIATION QUALITIES RQA 2 to RQA 10

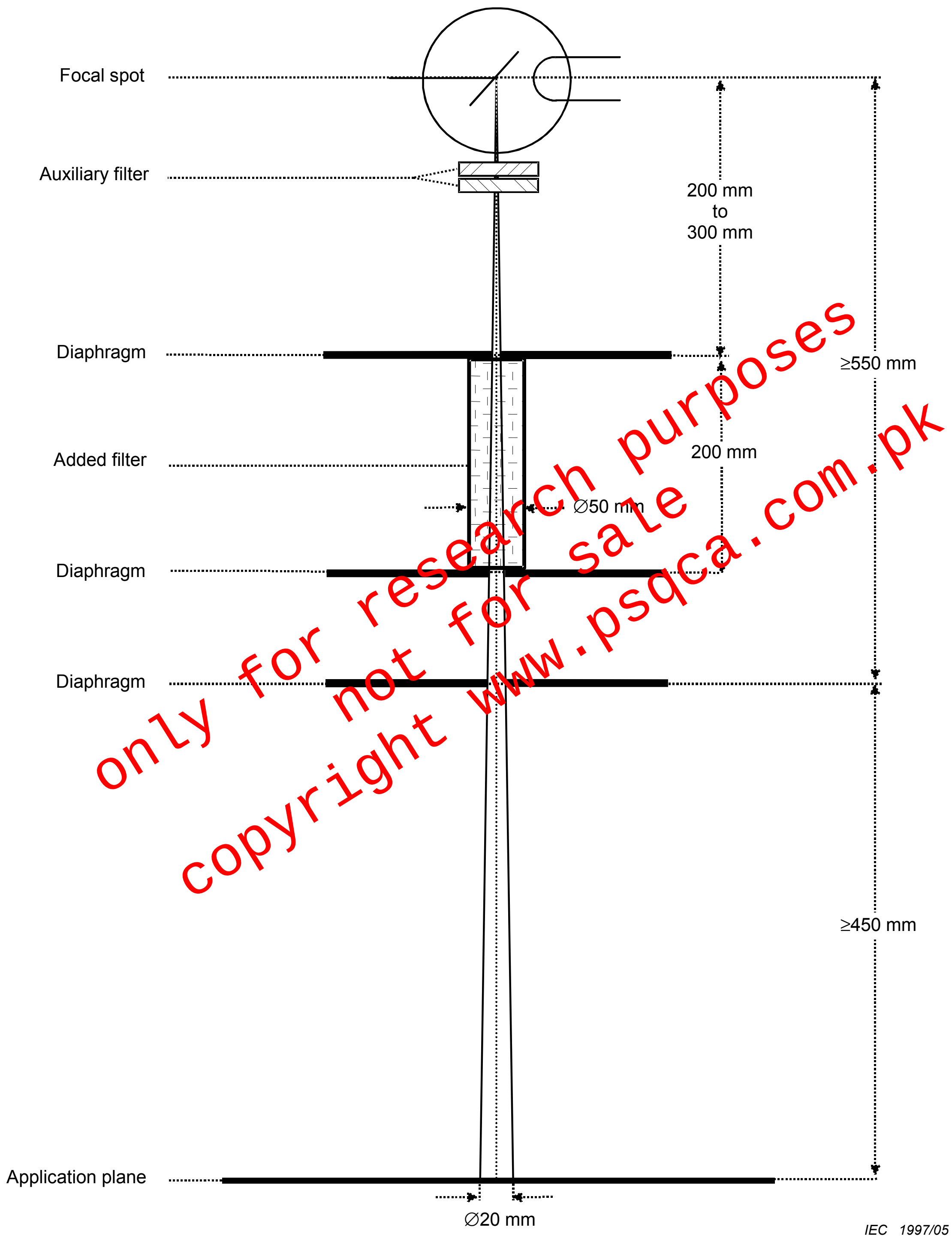


Figure 3 – Measuring arrangement for applying RADIATION CONDITIONS RQN 2 to RQN 10

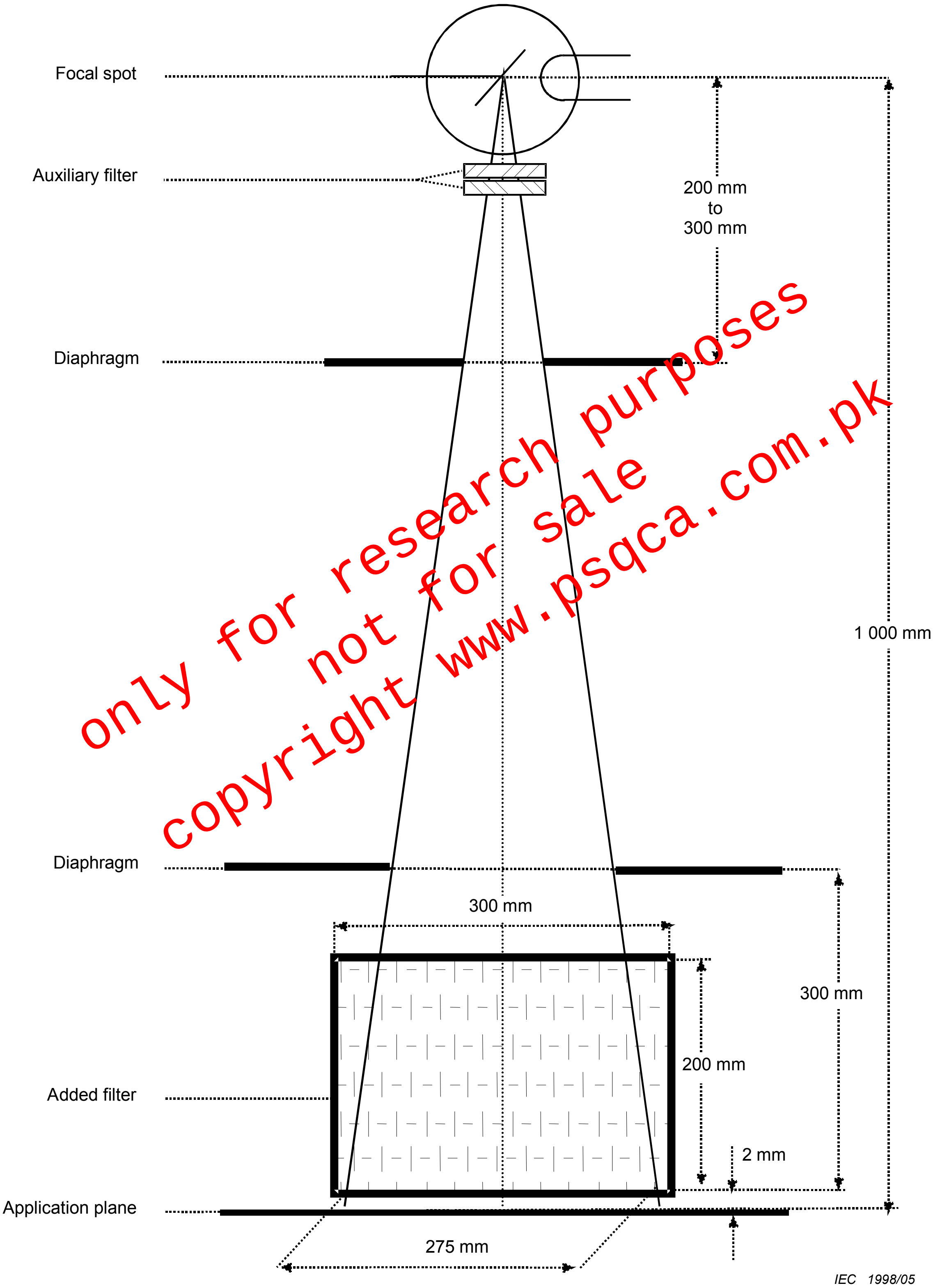


Figure 4 – Measuring arrangement for applying RADIATION CONDITIONS RQB 2 to RQB 10

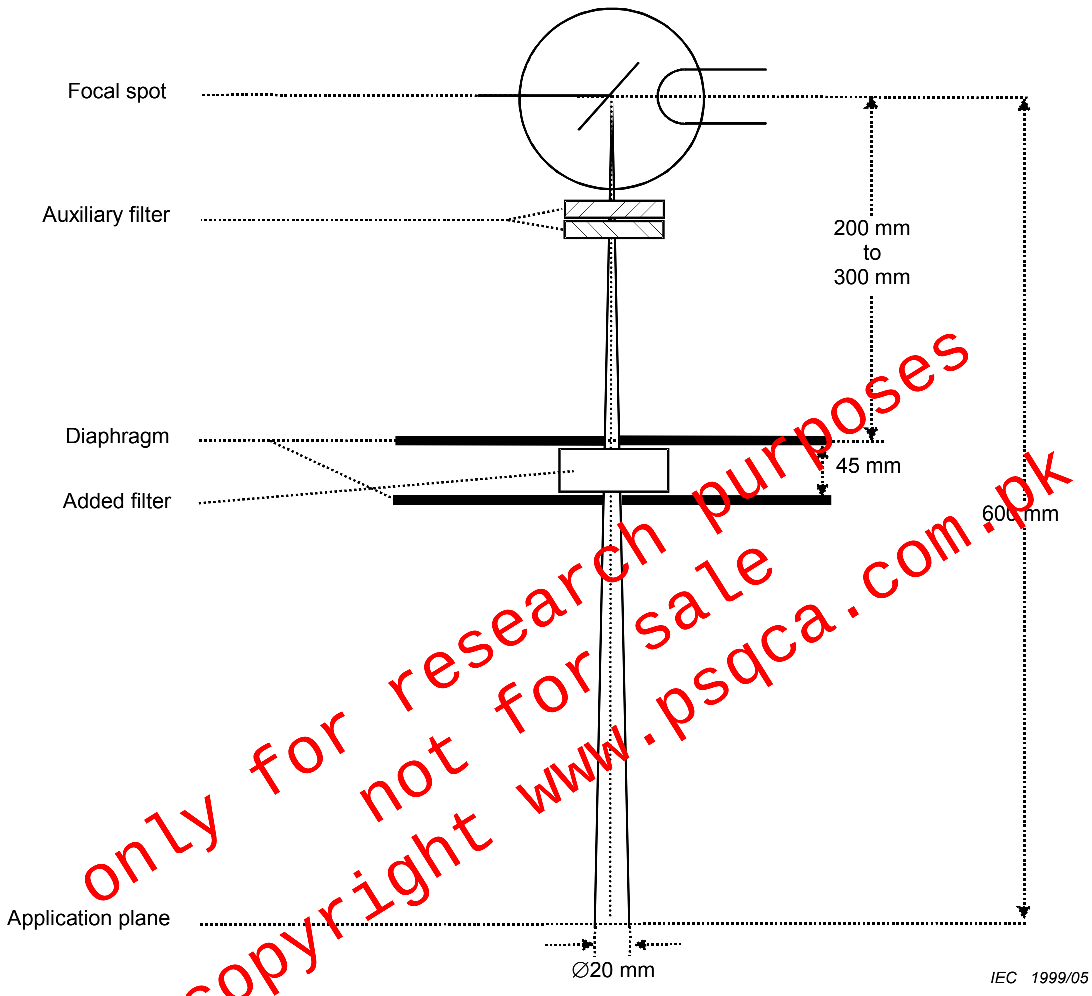
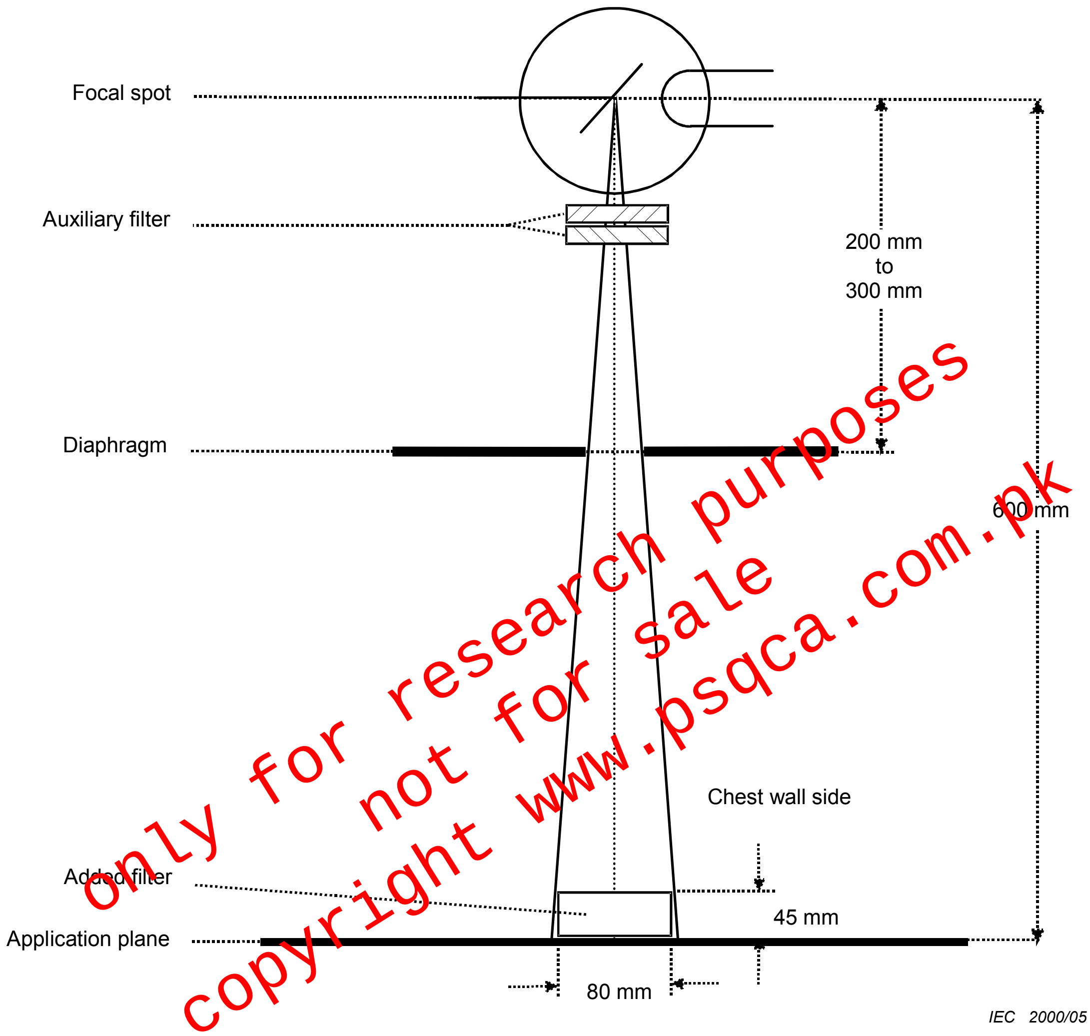


Figure 5 – Measuring arrangement for applying radiation condition RQN-M



For clinical machines the whole arrangement (filter, diaphragm and application plane) has to be tilt up to 10° in order to achieve the symmetrical conditions shown in this figure.

Figure 6 – Measuring arrangement for applying radiation condition RQB-M

Annex A
(informative)

Rationale

Concerning 1.1 Scope

The term RADIATION CONDITION refers to a description of RADIATION FIELDS and should not be confused with a description of a particular set-up for testing of equipment; see definition 3.8.

It should be noted that two similar terms are used in this standard, namely RADIATION CONDITION and RADIATION QUALITY. The respective definitions 3.8 and 3.9 indicate that the RADIATION QUALITY is used for RADIATION CONDITION if SCATTERED RADIATION does not play a significant role in specifying a RADIATION FIELD.

Concerning 4.1 Standard RADIATION CONDITIONS

In the context of this standard, RADIATION CONDITIONS are achieved by ADDED FILTERS or PHANTOMS and adjustment of X-RAY TUBE VOLTAGE in the range of about 30 kV up to 150 kV. Because of the materials of the ADDED FILTERS or PHANTOMS and the type of application of the RADIATION CONDITIONS (as reflected in Clauses 5, 6, 7, 8, 9 and 10) a RADIATION CONDITION at an X-RAY TUBE VOLTAGE of about 30 kV is only defined in Clauses 9 and 10, covering a PHANTOM for mammographic examinations.

Concerning
5.7 Generation and verification of the standard RADIATION QUALITIES RQR,
6.4 Generation and verification of the standard RADIATION QUALITIES RQA,
9.5 Generation of the standard RADIATION CONDITION RQN and
10.5 Generation of the standard RADIATION CONDITION RQB

In 5.7, 6.4, 9.5 and 10.5, the APPLICATION PLANE usually coincides with the ENTRANCE SURFACE of the component, ACCESSORY or device to be tested.

Annex B
(informative)

Determination of the amount of additional filtration

A simple way of determining the additional filtration necessary for achieving the desired radiation quality is the following. Make a plot of the attenuation curve. Use a linear scale on the abscissa for the attenuation layer thickness and a logarithmic scale on the ordinate for the attenuation factor. Prepare a – preferentially transparent – rectangular template whose height and width, both in the respective units of the diagram, are given by a factor of four and by the first half-value layer of the standard radiation quality to be realised multiplied with (1+1/*h*), respectively, where *h* is the HOMOGENEITY COEFFICIENT of the standard RADIATION QUALITY. Make an auxiliary horizontal line on the template dividing it into two parts of equal size and another vertical line at a distance from the left edge of the template corresponding to the first half-value layer. Try to position this template on the attenuation curve in such a way that the edges of the template are parallel to the axes of the diagram and that the upper left and the point of intersection of the two auxiliary lines coincide with points on the attenuation curve (see Figure B.1). The difference between the position of the left edge of the template and the ordinate gives the amount of additional filtration required to establish the radiation quality RQR.

The algorithm described above has a meaningful solution only as long as the total filtration of the X-ray tube is too small. If the filtration is too large the template cannot be positioned on the attenuation curve in the required way. In this case a match between the attenuation curve and the template can theoretically be achieved by shifting the left edge of the template to the left side of the ordinate and by simultaneously imagining an extrapolation of the attenuation curve to negative values of attenuation layer thicknesses. This corresponds to a removal of a fraction of the total filtration of the X-RAY SOURCE ASSEMBLY, a procedure which usually cannot be carried out.

K_a/K_{a0} is the quotient of the air kerma K_a behind an additional aluminium layer of thickness d to the air kerma K_{a0} without additional filtration.

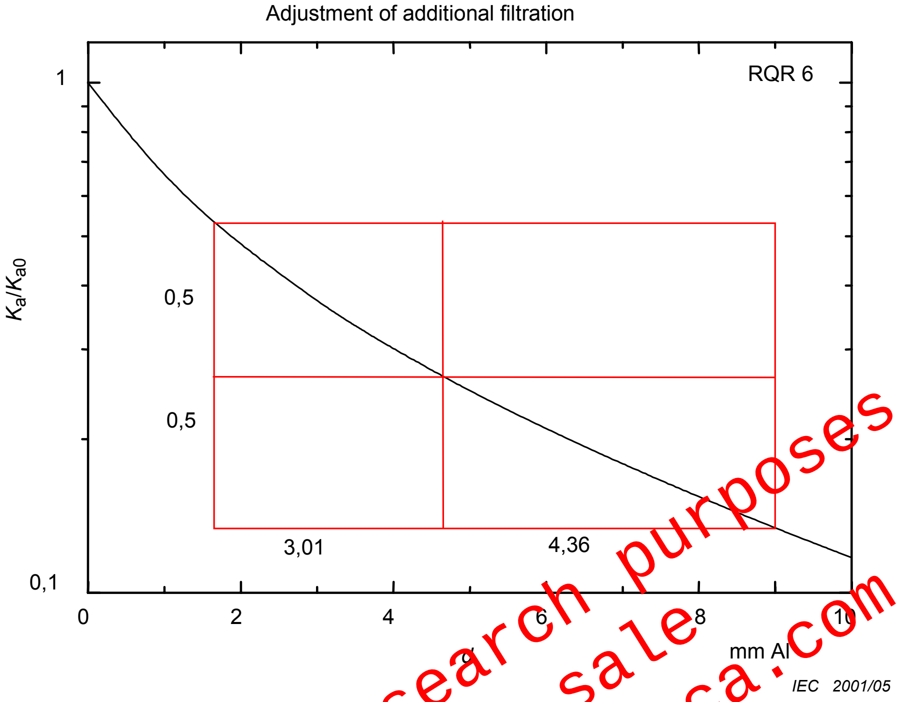


Figure B.1 – Determination of additional filtration required for adjusting the total filtration to the prescribed value (see 5.5)

Annex C
(normative)

Measurement of the PRACTICAL PEAK VOLTAGE

C.1 Introduction

The PRACTICAL PEAK VOLTAGE is based on the concept that the radiation generated by a high voltage of any waveform produces the same AIR KERMA contrast behind a specified PHANTOM as a radiation generated by an equivalent constant potential. The constant potential producing the same contrast as the waveform under test is defined as PRACTICAL PEAK VOLTAGE.

For the determination of the PRACTICAL PEAK VOLTAGE for a specified waveform, the X-ray spectrum produced by an X-RAY TUBE supplied with this non-constant potential has to be calculated. Using this spectrum, the ratio of AIR KERMA behind a PHANTOM and the AIR KERMA behind the PHANTOM plus a contrast material can then be calculated (for the application range "conventional diagnostic" a PHANTOM of 10 cm PMMA and a contrast material of 1,0 mm Al is used). Then, in a corresponding way, a constant potential giving the same AIR KERMA ratio for the same contrast configuration can be found. This is the PRACTICAL PEAK VOLTAGE for the given waveform. This complex procedure is only necessary for the correct determination of the quantity PRACTICAL PEAK VOLTAGE. For practical use it can be substituted for all waveforms by a simplified formalism described below.[1)]

C.2 Simplified formalism for the determination of the PRACTICAL PEAK VOLTAGE $\hat{U}$

For a given probability distribution $p(U_i)$ for the occurrence of a value of the voltage in the interval $[U_i - \Delta U/2, U_i + \Delta U/2]$ the PRACTICAL PEAK VOLTAGE $\hat{U}$ can be directly calculated by:

$$\hat{U} = \frac{\sum_{i=1}^{n} p(U_i) \cdot w(U_i) \cdot U_i}{\sum_{i=1}^{n} p(U_i) \cdot w(U_i)} \qquad \text{(C.1)}$$

When U_i is in units of kV, the weighting function $w(U_i)$ can be approximated with sufficient accuracy by the following formulas:

in the voltage region of U_i < 20 kV, by

$$w(U_i) = 0 \qquad \text{(C.2)}$$

1) Detailed information about the whole concept and the computational methods can be found in KRAMER, H-M., SELBACH H-J., ILES, WJ. The PRACTICAL PEAK VOLTAGE of diagnostic X-RAY generators. *British Journal of Radiology*, 1998, 77, p.200-209

in the voltage region of 20 kV $\leq U_i <$ 36 kV, by

$$w(U_i) = \exp\left\{a \cdot U_i^2 + b \cdot U_i + c\right\} \tag{C.3}$$

where

a = – 8,646855E-03

b = + 8,170361E-01

c = – 2,327793E+01

and for the voltage region of 36 kV $< U_i \leq$ 150 kV, by

$$w(U_i) = d \cdot U_i^4 + e \cdot U_i^3 + f \cdot U_i^2 + g \cdot U_i + h \tag{C.4}$$

where

d = +4,310644E-10

e = –1,662009E-07

f = +2,308190E-05

g = +1,030820E-05

h = –1,747153E-02

For the definition (see Equation C.1), the formula for $\hat{U}$ is generalized by using integral expressions instead of the summations, which however does not affect the values for the weighting function.

The above formula and the given values for the parameters a to h are valid for the application ranges "conventional diagnostic", "CT", "dental" and "fluoroscopic".

Annex D
(informative)

Overview of radiation qualities and radiation conditions

Clause	RADIATION QUALITY	Origin	PHANTOM simulating a PATIENT	Indications for possible applications	Conditions
5	RQR	X-RAY SOURCE ASSEMBLY		Determination of ATTENUATION properties of ASSOCIATED EQUIPMENT	
6	RQA	RADIATION BEAM from an ADDED FILTER	Aluminium layers	Measurement in the plane of the X-RAY IMAGE RECEPTOR	• Contribution of SCATTERED RADIATION is not significant • Close simulation of spectral distribution of RADIATION BEAM, emerging from PATIENT is not a prerequisite
7	RQC	RADIATION BEAM from an ADDED FILTER	Copper layer	• Adjustment of X-RAY IMAGE INTENSIFIER TUBES • AUTOMATIC EXPOSURE CONTROL	
8	RQT	RADIATION BEAM from an ADDED FILTER	Copper layer	Studies in CT applications	
9	RQN	RADIATION BEAM from a small water PHANTOM	Water-filled cylindrical box of PMMA	10 and 11 combined as a differential test for ANTI-SCATTER GRIDS	NARROW BEAM CONDITION
10	RQB	RADIATION BEAM from a large water PHANTOM	Water-filled box of PMMA	10 and 11 combined as a differential test for ANTI-SCATTER GRIDS	BROAD BEAM CONDITION
11	RQR-M	X-RAY SOURCE ASSEMBLY		Studies in mammography	NARROW BEAM CONDITION
12	RQA-M	RADIATION BEAM from an ADDED FILTER	Aluminium layers	Studies in mammography	NARROW BEAM CONDITION
13	RQN-M	RADIATION BEAM from a PHANTOM	Breast-tissue equivalent material	Studies in mammography	NARROW BEAM CONDITION
14	RQB-M	RADIATION BEAM from a PHANTOM	Breast-tissue equivalent material	Studies in mammography	BROAD BEAM CONDITION

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Index of defined terms