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Specification for a secondary standard dosemeter for diagnostic or mammographic radiology

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ABSTRACT

A performance specification for dosemeters intended for use as secondary standards for the measurement of X-ray air kerma for diagnostic or mammographic beam qualities is proposed. Important influence quantities are listed and the performance requirements given for ionisation chamber, measuring assembly and stability check device. Consideration is also given to the "useability" of the secondary standard and the security of any external computer software used operationally with the instrument.

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1. INTRODUCTION

The National Measurement System has a requirement for a nationally available service for calibrating secondary standard diagnostic dosemeters traceable to validated UK national primary standards. As part of the traceability requirement a performance specification for a diagnostic secondary standard needs to be established. The following specification is based on the International Electrotechnical Commission (IEC)[1] and American Association of Physicists in Medicine (AAPM)[2] specifications for a general diagnostic instrument but has taken into consideration the performance specification proposed by a working party of the Institute of Physical Sciences in Medicine (IPSM) Diagnostic Radiology Topic Group[3], the Physikalisch-Technische Bundesanstalt (PTB) diagnostic dosemeter requirements[4] and the IEC therapy level performance specification[5]. The performance requirements outlined are for a Secondary Standard Dosemeter intended for measurement of air kerma, or air kerma rate, in diagnostic and mammography radiation fields.

The specific influence quantities selected are those which can lead to the greatest measurement uncertainty. The limits set have been chosen to meet conditions found in the clinical environment and the overall uncertainty needed for a SECONDARY STANDARD.

2. SCOPE AND OBJECT

2.1 SCOPE

2.1.1 A complete dosemeter contains the following components:

- one or more ionisation chambers;
- a measuring assembly including any preamplifier or other signal conditioning components;
- and may possibly include one or more stability check devices.

Ionisation chambers used separately must comply with the requirements set out in Section 5.

2.1.2 Dosemeters to which this specification applies are REFERENCE CLASS dosemeters intended for the calibration of FIELD CLASS dosemeters.

2.1.3 Unless otherwise indicated, the requirements of this specification apply equally to instruments intended for the dosimetry of mammographic as well as conventional diagnostic beam qualities.

2.2 OBJECT

2.2.1 The object of this specification is to establish requirements for a satisfactory level of performance for Diagnostic and Mammographic Secondary Standard Dosemeters.

3. DEFINITIONS

Throughout this document words or phrases in upper case are defined in Appendix A. The definitions given are generally in agreement with those published by the IEC[6] and Organisation Internationale de Métrologie Légale (OIML)[7] except that some definitions have been made more restrictive. Any such special definitions shall be regarded as only applying to this document. Any terms not defined in Appendix A have the meanings defined in the above publications or are assumed to be in general scientific usage.

4. GENERAL REQUIREMENTS

For a complete dosemeter to comply fully with this specification, each of its components shall comply with the appropriate individual requirements. When the chamber and measuring assembly are used in conjunction with each other and a given effect is common to both then the higher value of the limit of variation specified shall be used.

The manufacturer must specify the ranges of influence quantities with which the instrument is intended to be used.

The general requirements of the IEC specification[1] should be adopted; where the requirements of this specification differ they are detailed below.

USEABILITY

It is desirable that a secondary standard is simple to use and that any corrections, modifications or other adjustments that are made to instrument readings are unambiguous, apparent to and under the control of the user. These amending factors should be capable of being disabled or removed and their status should be apparent to the user. It is not possible to be prescriptive about this requirement but its application can be best illustrated with a number of examples, (see Appendix B); the principles may be extended to other features.

UNCERTAINTIES

Confidence level

Throughout this report uncertainties are given at the 95% confidence level.

Overall uncertainty

The overall uncertainty for the combined chamber and instrument, obtained by summing the individual components in quadrature, shall not exceed ± 3%.

5. IONISATION CHAMBER

5.1 LONG-TERM STABILITY

Over a number of years the RESPONSE of an IONISATION CHAMBER can change owing to changes in dimensions and the nature of the surfaces surrounding the sensitive volume; the latter may also cause the energy dependence of the ionisation chamber to change with time. The method of construction and choice of materials shall therefore be such as to provide long-term stability at all radiation qualities within the RATED RANGE for the chamber.

Requirement

A change in RESPONSE with time for any beam quality in the RATED RANGE shall not be greater than ± 0.5% per year.

5.2 LEAKAGE CURRENT

Without radiation

LEAKAGE CURRENT can arise through inadequate chamber insulation or ineffective guarding of guarded chambers and through flexing of the cable.

Requirement

The LEAKAGE CURRENT shall not exceed ± 0.5% of the ionisation current produced by the minimum rated or effective dose rate.

Post-irradiation leakage

This effect arises in that part of the stem insulator or cable irradiated by the X-ray beam and causes a current to be produced which continues after the radiation has ceased and which usually decreases exponentially with time.

Requirement

Within 5 seconds of the end of a 10 minute irradiation with the dose rate set at any value in the RATED RANGE, the leakage current (of either polarity) shall not be greater than 0.5% of the ionisation current produced in the sensitive volume during the irradiation.

5.3 DOSE RATE DEPENDENCE

At low dose rates the RESPONSE of the chamber is influenced by leakage currents and must therefore comply with the requirements given in clauses 5.2.1 and 5.2.2. At high dose rates the RESPONSE of the chamber may vary due to ion recombination within the sensitive volume.

Requirement

The LIMIT OF VARIATION OF RESPONSE over the RATED RANGE or EFFECTIVE RANGE OF INDICATED VALUES of dose rate shall not exceed ± 1.0%.

5.4 RADIATION QUALITY

The ideal secondary standard should have a uniform response over a range of energies; in practice this is not likely so the uncertainty of any measurement with the chamber will be affected by any interpolation between discrete calibration points. To keep the interpolation errors to a minimum the secondary standard should have a maximum limit of variation of RESPONSE.

Requirement

This requirement refers to the qualities recommended by the IEC[8] and IPSM[3] which are summarised in Appendix C.

Over the RATED RANGE of beam qualities:

- the change in RESPONSE between adjacent mammography qualities recommended by the IPSM shall not exceed ± 2%.
- the change in RESPONSE between adjacent qualities in each of the quality sets RQR and RQA recommended by the IEC and those recommended by the IPSM shall not exceed ± 2%.

5.5 STEM SCATTER

The component of the ionisation current due to radiation scattered into the sensitive volume from the stem will depend on the length of stem irradiated and hence the beam size.

Requirement

Over the RATED RANGE of field sizes the LIMITS OF VARIATION of RESPONSE due to stem scatter shall not be greater than ± 1%.

5.6 STEM LEAKAGE

This arises from currents produced by the radiation within the stem due to air cavities and can have an overall effect on the RESPONSE .

Requirement

Over the RATED RANGE of field sizes the LIMITS OF VARIATION OF RESPONSE due to stem leakage shall be no greater than ± 0.5 %.

5.7 CHAMBER ORIENTATION

This requirement refers to the precision of alignment necessary when positioning the CHAMBER in the beam.

Requirement

For the RATED RANGE of beam qualities the LIMITS OF VARIATION IN RESPONSE for a change in the angle of incidence of the beam of ± 5° from the direction of incidence specified by the manufacturer shall not be greater than ± 0.5 %.

5.8 CHAMBER ROTATION

This requirement applies to cylindrical chambers and refers to the rotation of the chamber about its axis perpendicular to the incident radiation beam.

Requirement

For the RATED RANGE of beam qualities the LIMITS of VARIATION of RESPONSE for a complete rotation (360°) of the chamber shall be ± 0.5%.

5.9 OTHER INFLUENCE QUANTITIES

There are other influence quantities which can have an effect on the chamber performance; usually the effect is small and may be neglected.

Requirement

For each INFLUENCE QUANTITY not otherwise specified:

either the LIMITS OF VARIATION for the RATED RANGE shall be ± 0.1%.

or correction factors shall be provided with uncertainties not greater than ± 0.2%.

5.10 SUMMARY

For a summary of the LIMITS OF VARIATION for the effects of INFLUENCE QUANTITIES on ionisation chambers see Table 1.

Table 1 Limits of variation for effects of influence quantities on the ionisation chamber

Dependency	Limits of Variation %	Footnote
Long term stability	± 0.5	1
Leakage current	± 0.5	2
Dose rate	± 1.0	3
Radiation Quality Mammography Diagnostic	 ± 2.0 ± 2.0	4
Stem scatter	± 1.0	3
Stem leakage	± 1.0	5
Orientation	± 0.5	3
Rotation	± 0.5	3
Other influence quantities	± 0.1	-

[1] Of RESPONSE per year for any radiation quality in the RATED RANGE.
[2] Of ionisation current produced by minimum rated or effective dose rate.
[3] Percentage of RESPONSE within the EFFECTIVE RANGE for the respective quality.
[4] Percentage of change of CALIBRATION FACTOR over RATED RANGE.
[5] Percentage of RESPONSE over RATED RANGE of field sizes.

6. MEASURING ASSEMBLY

6.1 LONG-TERM STABILITY

Over a number of years the RESPONSE of a MEASURING ASSEMBLY to a given input current or charge can change due to changes in the material used in the construction of the device or the individual components used in the device.

Requirement

The change in RESPONSE with time to input charge or current in the RATED OR EFFECTIVE RANGE shall not be greater than ± 0.5 % per year.

6.2 NON-LINEARITY

Requirement

Within the EFFECTIVE RANGE of scale readings on each range:

either the LIMIT OF VARIATION OF RESPONSE due to the non-linearity of the measuring assembly shall be ± 0.5 % for a dose meter or ± 1 % for a dose-rate meter.

or correction factors shall be provided with uncertainties not greater than ± 0.5 % for a dosemeter or ± 1 % for a dose-rate meter.

6.3 READING DRIFT

When the MEASURING ASSEMBLY is in the integrate mode the indicated reading for any non-zero reading may change.

Requirement

With the instrument in the "measure" condition and no incident radiation the READING DRIFT shall not exceed ± 0.5 % of the indicated value produced by the minimum effective input current or charge.

6.4 ZERO DRIFT

With no incident radiation the instrument can experience a shift in the zero point.

Requirement

With the instrument in the "reset" or "set zero" condition or its equivalent, the ZERO DRIFT in 10 minutes shall not be greater than ± 0.5 % of the indicated value produced by the minimum effective input current or charge.

6.5 RESOLUTION

Requirement

The uncertainty of reading of the display is numerically equal to the RESOLUTION, and shall not be greater than ± 0.25% of the minimum effective scale reading for any range.

6.6 RANGE CHANGING

This applies to measuring assemblies incorporating a range switch which alters the scale factor of the instrument by stated ratios and/or switches between dose and dose-rate.

Requirement

For all ranges:

either the LIMITS OF VARIATION OF RESPONSE between ranges using an input signal to give the same scale reading for each range shall not be greater than ± 0.5% for a dose meter or ± 1% for a dose-rate meter,

or CORRECTION FACTORS shall be provided with uncertainties not exceeding ± 0.5% or ± 1% respectively.

6.7 OTHER INFLUENCE QUANTITIES

There are other influence quantities which can have an effect on measuring assembly performance; usually the effect is small and may be neglected.

Requirement

For each INFLUENCE QUANTITY not otherwise specified:

either the LIMITS OF VARIATION for the RATED RANGE shall be ± 0.1%.

or correction factors shall be provided with uncertainties not greater than ± 0.2%.

6.8 SUMMARY

The LIMITS OF VARIATION for the effects of influence quantities on the MEASURING ASSEMBLY are summarised in Table 2

Table 2 Limits of variation for effects of influence quantities on the measuring assembly

Dependency	Limits of Variation %	Footnote
Long-term Stability	± 0.5	1
Non-Linearity: Dosemeter Dose-rate meter	 ± 0.5 ± 1.0	2
Reading Drift	± 0.5	3
Zero Drift	± 0.5	4
Resolution	± 0.25	5
Range Changing: Dose meter Dose-rate meter	 ± 0.5 ± 1.0	6
Other influence quantities	± 0.1	-

[1] Of RESPONSE per year to input charge or current in the RATED or EFFECTIVE RANGE.
[2] Of RESPONSE at the REFERENCE SCALE READING.
[3] Of the minimum rated input current.
[4] Of rate of change of INDICATED VALUE produced by minimum rated or effective input current.
[5] Of minimum effective scale reading.
[6] Percentage of change of RESPONSE within the EFFECTIVE RANGE of the measured quantity.

7. STABILITY CHECK DEVICES

It is desirable that all secondary standards are supplied with a stability check device, usually a radioactive source, which can be used to verify the overall long-term stability and correct functioning of the ionisation chamber and the measuring assembly.

7.1 REPRODUCIBILITY

The essential feature of a check device is that it should give results which are reproducible from one occasion of use to another when the equipment is functioning correctly.

Requirement

For an instrument which is in full working order the standard deviation for a series of at least 10 independent check device measurements carried out on separate days over a period of not less than one month shall be less than 0.5% when the results are corrected for decay of any radioactive source, the effects of air density and any other appropriate influence quantity.

8. EXTERNAL COMPUTERS AND SOFTWARE

8.1 SOFTWARE SECURITY

Because of the risk that unauthorised or unvalidated changes to software might affect the calibration it is desirable that if the secondary standard incorporates an external computer and software for data manipulation or analysis then the program is fully protected against unauthorised changes.

Requirement

Any software required for the calibration process which is specifically written for the operation of the secondary standard or the manipulation or analysis of data generated in the course of measurements with the secondary standard must be supplied by the instrument manufacturer and must be fully protected against changes by anyone other than the manufacturer or his authorised agents.

8.2 SOFTWARE IDENTIFICATION

Requirement

The version number and source of any software required for the use of the secondary standard must be incorporated in the program and easily accessible to users of it. It is desirable that when measurement data have been processed and printed or otherwise stored only in the processed form that the software source and version number are stored with the data.

9. REFERENCES

1 International Electrotechnical Commission, IEC SC 62 WG 3 CD Draft 3 (August 1993): *Medical electrical equipment: Dosemeters with ionisation chambers and/or semi-conductor detectors as used in radiography, including mammography and fluoroscopy.*

2. Wagner, L K; Fontenla, D P; Kimme-Smith, C; Rothenberg, L N; Shepard, J and Boone, J M. 1992 Recommendations on performance characteristics of diagnostic exposure meters: Report of AAPM diagnostic X-ray imaging task group 6. *Med Phys* **19** 231 - 241

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4. Selbach H-J. Requirements for dosemeters used in diagnostic radiology: Proceedings of a Seminar, Dosimetry in Diagnostic Radiology. 1992 *Rad Prot Dosim* **43**, No 1/4, 25-29

5. International Electrotechnical Commission, IEC 731 (1991): *Medical electrical equipment: Dosemeters with ionisation chambers as used in radiotherapy*

6. International Electrotechnical Commission, IEC Publication 788 (1984): *Medical radiology*

7. Organisation Internationale de Métrologie Légale, OIML 1984 *International vocabulary of basic and general terms of metrology*

8. International Electrotechnical Commission, IEC 62B(Sec)144, January 1991. *Medical diagnostic X-ray equipment: Radiation conditions for use in the determination of characteristics of diagnostic X-ray equipment*

APPENDIX A Definitions

The definitions given are generally in agreement with those published by the IEC[6] and OIML[7] except that some definitions have been made more restricted. Any such special definitions shall be regarded as only applying to this document. Any terms not defined in Appendix A have the meanings defined in the above publications or are assumed to be in general scientific usage.

Correction Factor
Dimensionless factor which converts the INDICATED VALUE of an instrument from its value when operated under particular conditions to its value when operated under stated REFERENCE CONDITIONS.

Effective Range of Indicated Values
The range of INDICATED VALUES for which an instrument complies with a stated performance: the maximum (minimum) EFFECTIVE INDICATED VALUE is the highest (lowest) in this range.

The concept of EFFECTIVE RANGE may also be applied to scale readings and to related quantities that are not directly indicated by the instrument, for example the input signal.

Field Class Instrument
Instrument, whose performance and stability are sufficient for it to be used as a FIELD INSTRUMENT.

Field Instrument
Measuring instrument for ordinary routine measurements.

Indicated Value
The value of a quantity derived from the scale reading on an instrument together with any scale factors indicated on the control panel of this instrument.

Influence Quantity
Any quantity, usually external, that may affect the performance of an instrument (e.g. radiation quality etc.)

Ionisation Chamber
An ionisation detector consisting of a chamber filled with a suitable gas, in which an electric field insufficient to induce gas multiplication is provided for the collection at the electrodes of charges associated with the ions and the electrons produced in the sensitive volume of the detector by ionising radiation.

Leakage Current
Any current arising in the DETECTOR or MEASURING ASSEMBLY which is not produced by ionisation in the RADIATION DETECTOR.

Limits of Variation
The maximum VARIATION of a PERFORMANCE CHARACTERISTIC y, permitted by this standard. If LIMITS OF VARIATION are stated as ± L%, the VARIATION $\Delta y/y$ shall remain in the range - L% to + L%.

Measured Value
The best estimate of the TRUE VALUE of a quantity, being derived from the INDICATED VALUE of an instrument together with the application of all relevant CORRECTION FACTORS.

Measuring Assembly
The main purpose of this device is to measure the current from the IONISATION CHAMBER and convert it into a form suitable for display, control or storage. It may comprise a power supply for the IONISATION CHAMBER polarising voltage, amplifier, signal conditioning or processing circuits, a digital and/or analogue display device, data processing and/or storage circuits and in some cases functional output circuits, for example, to control X-ray equipment or for data transfer. Unless otherwise specified, it also includes the separate preamplifier, if any.

National Standard
STANDARD recognised by an official national decision as the basis for fixing the value in a country of all other STANDARDS of the given quantity.

Performance Characteristics
One of the quantities used to define the performance of an instrument (e.g. RESPONSE, LEAKAGE CURRENT).

Primary Standard
STANDARD of a particular quantity which has the highest metrological qualities in a given field.

Rated Range of Use
The range of values of an INFLUENCE QUANTITY or instrument parameter within which the instrument will operate within the LIMITS OF VARIATION. Its limits are the maximum and minimum RATED values.

The minimum RATED RANGE is the least range of an INFLUENCE QUANTITY or instrument parameter within which the instrument shall operate within the specified LIMITS OF VARIATION in order to comply with this standard.

Reference Class Instrument
Instrument, whose performance and stability are sufficient for it to be used as a REFERENCE INSTRUMENT.

Reference Conditions
Under REFERENCE CONDITIONS all INFLUENCE QUANTITIES and instrument parameters have their REFERENCE VALUES.

Reference Instrument
Measuring instrument used for calibrating other instruments.

Reference Value
Value of an INFLUENCE QUANTITY or an instrument parameter at which the CORRECTION FACTOR for dependence on that INFLUENCE QUANTITY has the value 1.0.

Resolution of the Display
The smallest change of scale reading to which a numerical value can be assigned without further interpolation. For an analogue display, this is the smallest fraction of a scale interval that can be determined by an observer under specified conditions. For a digital display, the RESOLUTION is ± 1 in the last digit.

Response
The quotient of the INDICATED VALUE divided by the CONVENTIONAL TRUE VALUE.

Secondary Standard
STANDARD, the value of which is fixed by direct or indirect comparison with a PRIMARY STANDARD.

Standard
Measuring instrument intended to define, to represent physically, to conserve or to reproduce the unit of measurement of a quantity (or a multiple or sub-multiple of that unit) in order to transmit it to other measuring instruments by comparison.

True Value
Value of the physical quantity to be measured by an instrument.

Variation
The relative difference $\Delta y/y$, between the values of a PERFORMANCE CHARACTERISTIC y, when one INFLUENCE QUANTITY assumes successively two specified values, the other INFLUENCE QUANTITIES being at STANDARD TEST VALUES, unless other values are specified.

Zero Drift
A continuous change in the scale reading of MEASURING ASSEMBLY, with

a) the setting control in the "set zero" condition, or
b) the setting control in the "measure" condition and the input disconnected from an IONISATION CHAMBER and shielded, or connected to an IONISATION CHAMBER with negligible leakage current.

APPENDIX B Examples of useability considerations

The following list is illustrative only, it is not intended to be a complete statement of all aspects of instrument use covered by the useability clause.

1 The quantity being measured and any multipliers applied must be displayed or indicated.

2. It should be possible to view the values of any correction factors that are automatically applied by built-in or attached microprocessor.

3. When the chamber sensitivity has to be entered in the instrument memory, it should be possible to view the value applied at any time.

4. It is desirable that any automatic temperature and pressure corrections can be disabled.

5. If corrections are made for ambient conditions, the sensing elements must always be capable of being separately calibrated and the measured values of the ambient conditions should always be displayed.

6. If temperature sensors are employed, they must be located close to the ionisation chamber volume.

7. If the polarising voltage applied to the chamber can be adjusted by the user, its value should be displayed.

8. It is desirable that the secondary standard is capable of operation on a "stand-alone" basis without reliance on an external computer.

9. Where data, eg chamber calibration factors, are entered into instrument memory for use on more than one occasion they should be protected from unauthorised change by, for example, the use of passwords.

APPENDIX C Recommended Radiation Qualities

C1 IEC RECOMMENDED DIAGNOSTIC QUALITIES

C1.1 STANDARD RADIATION QUALITIES RQR

Radiation qualities in radiation beams emerging from the X-ray tube assembly.

The standard radiation qualities RQR are described in terms of:
- the nominal first half value layer as given in the second column of the table;
- an adapted total filtration of the X-ray tube assembly;
- an adapted X-ray tube voltage derived from the values given in the last column of Table C2;
- an emitting target of tungsten.

Table C1 Characterisation of standard radiation qualities RQR 2 to RQR 10

Standard RADIATION QUALITY Characterisation	Nominal first HALF VALUE LAYER in thickness of aluminium (mm)
RQR 2	1.0
RQR 3	1.5
RQR 4	2.0
RQR 5	2.5
RQR 6	2.9
RQR 7	3.3
RQR 8	3.7
RQR 9	4.5
RQR 10	5.7

Table C2 Parameters for achieving standard radiation qualities RQR 2 to RQR 10

Standard RADIATION QUALITY Characterisation	Approximate X-RAY TUBE VOLTAGE (kV)
RQR 2	40
RQR 3	50
RQR 4	60
RQR 5	70
RQR 6	80
RQR 7	90
RQR 8	100
RQR 9	120
RQR 10	150

C1.2 STANDARD RADIATION QUALITIES RQA

Radiation qualities based on aluminium as added filter

The standard radiation qualities RQA are described in terms of:
- the nominal first half value layer as given in the second column of Table C3;
- by a total filtration consisting of:
  - a quality equivalent filtration of the X-ray tube assembly of 2.5 mm aluminium, as established at an X-ray tube voltage of 75 kV; and
  - an added filter as given in the second column of Table C4;
- an adapted X-ray tube voltage derived from the values given in the last column of Table C4;
- an emitting target of tungsten.

Table C3 Characterisation of standard radiation qualities RQA2 to RQA 10

Standard RADIATION QUALITY Characterisation	Nominal first HALF VALUE LAYER in thickness of aluminium (mm)
RQA 2	2.4
RQA 3	4.0
RQA 4	5.7
RQA 5	7.1
RQA 6	8.4
RQA 7	9.1
RQA 8	9.9
RQA 9	11.5
RQA 10	12.8

Table C4 Parameters for achieving standard radiation qualities RQA2 to RQA10

Standard RADIATION QUALITY Characterisation	ADDED FILTER for RQA thickness in aluminium (mm)	Approximate X-RAY TUBE VOLTAGE (kV)
RQA 2	4	40
RQA 3	10	50
RQA 4	16	60
RQA 5	21	70
RQA 6	26	80
RQA 7	30	90
RQA 8	34	100
RQA 9	40	120
RQA 10	45	150

C2 IEC RECOMMENDED MAMMOGRAPHIC QUALITY

C2.1 STANDARD RADIATION CONDITION RQN-M

Radiation condition for studies in mammography based on a special tissue-equivalent added filter (narrow beam condition)

The standard conditions RQN-M is described in terms of:
- a total filtration effected by:
  - 0.03 mm molybdenum in the X-ray tube assembly;
  - an added filter (for patient simulation);
- a constant potential X-ray tube voltage of 28 kV ± 0.5 kV;
- an emitting target of molybdenum.

For simulating the patient in achieving the standard radiation condition RQN-M an added filter shall be available, which simulates breast tissue of a mean composition of 50% adipose and 50% glandular tissue.

C3 IPSM RECOMMENDED DIAGNOSTIC QUALITIES

C3.1 RADIATION BEAMS SIMULATING THOSE INCIDENT ON THE PATIENT

Table C5 Half value layers for radiation beams simulating those incident on the patient and recommended factors for obtaining these to a first approximation for an X-ray tube with a tungsten target and a total filtration of 2.5 mm aluminium.

First half value layer (mm Al)	Recommended factors	
	X-ray tube voltage (kV)	Added filtration (mm Al)
1.5	50	-
2.0	60	-
2.5	70	-
3.3	90	-
4.5	120	-

RADIATION BEAMS SIMULATING THOSE TRANSMITTED THROUGH THE PATIENT

Table C6 Half value layers for radiation beams simulating those transmitted through the patient and recommended factors for obtaining these to a first approximation for an X-ray tube with a tungsten target and filtration added to the baseline filtration of 2.5 mm aluminium.

First half value layer (mm Al)	Recommended factors	
	X-ray tube voltage (kV)	Added filtration (mm Al)
4.0	50	10
5.7	60	16
7.1	70	21
9.1	90	30
11.5	120	40

C4 IPSM RECOMMENDED MAMMOGRAPHIC QUALITIES

RADIATION QUALITIES SIMULATING THOSE INCIDENT ON A BREAST

Table C7 Radiation qualities to be used to simulate radiation incident on a breast for an X-ray tube with a molybdenum target and 0.03 mm molybdenum filtration.

X-ray tube voltage (kV)	Approximate first half value layer (mm Al)
25	0.28
30	0.34
35	0.37

C4.2 RADIATION QUALITIES SIMULATING THOSE TRANSMITTED THROUGH A BREAST

Table C8 Radiation qualities to be used to simulate radiation transmitted through a breast for an X-ray tube with a molybdenum target, 0.03 mm molybdenum and 2 mm aluminium filtration.

X-ray tube voltage (kV)	Approximate first half value layer (mmAl)
25	0.58
30	0.67
35	0.75