



## SPECIFICATIONS

### X-ray products for a secondary standard dosimetry laboratory

#### 1. Scope

These specifications describe the requirements for products (beam collimation system; set of filters; half value layer measurement assembly; and the ancillary equipment (hereinafter referred to as the “Products”) which will be used with existing X-ray calibration system (hereinafter referred to as the “X-ray system”) of the Secondary Standards Dosimetry Laboratory of Bosnia and Herzegovina (hereinafter referred to as the “SSDL”) in the framework of the IAEA Technical Cooperation project BOH9009, “Sustaining an Integrated Management System and Capabilities in the Regulatory Body and Strengthening Capabilities of the Dosimetry Laboratory”. Pictures and the layout of the premises are given in the Appendix 1.

#### 2. Applicable documents

The following documents shall be applicable for these Specifications to the extent specified hereinafter:

2.1. INTERNATIONAL ATOMIC ENERGY AGENCY, “Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards” General Safety Requirements Part 3 No. GSR Part 3, IAEA, Vienna 2014

[http://www-pub.iaea.org/MTCD/publications/PDF/Pub1578\\_web-57265295.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/Pub1578_web-57265295.pdf)

2.2. INTERNATIONAL ATOMIC ENERGY AGENCY, “Calibration of Radiation Protection Monitoring Instruments”, Safety Reports Series No. 16., IAEA Vienna (2000)

[http://www-pub.iaea.org/MTCD/publications/PDF/P074\\_scr.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/P074_scr.pdf)

2.3. INTERNATIONAL ORGANIZATION FOR STANDARDIZATION, X and gamma reference radiation for calibrating dosimeters and dose rate meters and for determining their response as a function of photon energy, ISO, Geneva, ISO 4037 1-4, 1996 – 2004

2.4. INTERNATIONAL ATOMIC ENERGY AGENCY, "Dosimetry in diagnostic radiology: An international code of practice", Technical Reports Series No. 457, IAEA, Vienna (2007)

[http://www-pub.iaea.org/MTCD/publications/PDF/TRS457\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/TRS457_web.pdf)

2.5. INTERNATIONAL ATOMIC ENERGY AGENCY, "Implementation of the International Code of Practice on Dosimetry in Diagnostic Radiology (TRS 457): Review of Test Results", IAEA Human Health Reports No.4, IAEA, Vienna (2011),

[http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1498\\_web.pdf](http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1498_web.pdf)



2.6. INTERNATIONAL ELECTROTECHNICAL COMMISSION, “Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics”, IEC 61267, Geneva, Switzerland 2005

2.7. INTERNATIONAL ATOMIC ENERGY AGENCY, "Calibration of Reference Dosimeters for External Beam Radiotherapy (TRS 469)", Technical Report Series No. 469, IAEA, Vienna (2009), [http://www-pub.iaea.org/MTCD/publications/PDF/trs469\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/trs469_web.pdf)

2.8. The Consultative Committee for Standards of Ionizing Radiations (CCRI), X-ray beam qualities, Bureau International des Poids et Mesures (BIPM), <http://www.bipm.org/en/scientific/ionizing/dosimetry/x-ray/>

2.9. INTERNATIONAL ATOMIC ENERGY AGENCY Radiation Protection in the Design of Radiotherapy Facilities: SAFETY REPORTS SERIES No. 47, ISBN 92–0–100505–9, Vienna, 2006, [http://www-pub.iaea.org/MTCD/publications/PDF/Pub1223\\_web.pdf](http://www-pub.iaea.org/MTCD/publications/PDF/Pub1223_web.pdf)

In the event of conflict between the documents listed above and the content of these Specifications, the content of these Specifications shall take precedence to the extent of the conflict.

### 3. Definitions, Acronyms and Abbreviations

The following definitions, acronyms, and abbreviations shall apply throughout these Specifications unless defined otherwise hereinafter:

BIPM :	Bureau International des Poids et Mesures
CBA:	Calibration Beam Axis
CCRI:	Consultative Committee for Standards of Ionizing Radiations
FSD:	Field Size Diameter (defined at 50% isodose)
HVL:	Half Value Layer
SDD:	Source to Detector Distance

### 4. Requirements

The Products shall fulfil requirements given in these specifications.

#### 4.1. Functional Requirements

The Products shall be used to establish X-ray radiation qualities required for calibration of dosimetry equipment used in radiation protection, radiation therapy and diagnostic radiology.

#### 4.2. Performance Requirements

The Products shall be compatible with the existing X-ray system:

- TEMA ENERGIE s.r.l. X-Ray calibration Unit XCS-320-ST (in the bunker)
- Canberra Packard X-Strahl XRC controller (in the control room)
- Monitor chamber type TW34014 (in the bunker)



- Calibration bench (in the bunker)
- Filter wheel and assembly

**4.3. All performance specifications and tests shall comply with the relevant standards of the IAEA, IEC and ISO, specified in Section 2 Technical Requirements**

The Products shall include the following components:

- **Beam collimation system**
- **Set of filters**
- **HVL (Half Value Layer) measurement assembly**
- **Ancillary equipment**

**4.3.1. Beam collimation system (secondary)**

The beam collimation system shall fulfil the following specifications:

- 4.3.1.1. The secondary beam collimation system shall be compatible with the primary collimation of the existing X-ray system, monitor chamber holder and filter wheel system;
- 4.3.1.2. The secondary collimation system shall be used to define a reference field size at the reference distance used according to the different irradiation conditions. The secondary collimator shall be placed between the filter assembly and place of the monitor chamber;
- 4.3.1.3. A set of collimators shall be provided with various diameters accessible for exchange to obtain field sizes matching various irradiation conditions. At least, the following irradiation conditions shall be possible to adjust: FSD=30 cm at SDD = 200 cm, FSD=10 cm and FSD=5 cm (for HVL measurements) at the SDD = 100 cm;
- 4.3.1.4. The design shall allow easy exchange of the secondary collimators with no need to dismount a monitor chamber;
- 4.3.1.5. Another collimator shall be provided and to be placed after the monitor chamber. This conical aperture shall have a diameter bigger than radiation field size. The purpose of this aperture is to reduce backscatter radiation; and
- 4.3.1.6. The distance between the focal spot of the X-ray tube and the last aperture on the CBA shall not exceed 40 cm.

**4.3.2. Set of filters**

The set of filters shall fulfil the following specifications:

- 4.3.2.1. The filters are used to modify the photon spectrum of radiation beams produced by the X-ray tube to meet the characteristics of radiation qualities required for calibration of dosimetry equipment (refer to Appendix 2). Requested radiation qualities shall be:
  - 4.3.2.1.1. Radiotherapy: BIPM-CCRI qualities with low and medium energies (30 kV- 180 kV) per Table 4 in Appendix 2 [2.8];



- 4.3.2.1.2. Diagnostic radiology: IEC 61267 RQR 2 - 10 qualities per Table 2 in Appendix 2 [2.4 and 2.6];
- 4.3.2.1.3. Diagnostic radiology: IEC 61267 RQT 8 - 10 qualities per Table 3 in Appendix 2 [2.4 and 2.6]; and
- 4.3.2.1.4. Mammography: 0.5 mm aluminium filter.
- 4.3.2.2. A set of metal filters (Al, Cu) shall be provided to produce desired radiation qualities characterized by 1st HVL, as described in Appendix 2. The thickness of added filtrations, given in Appendix 2, are representing the nominal values and shall be adjusted individually with the given X-ray tube to obtain desired HVL values within required tolerances required in the references;
- 4.3.2.3. The metal filters (Al, Cu) used for the establishment of required radiation qualities shall have at least a certified purity of 99.9%; and
- 4.3.2.4. The appropriate metal filter sets of radiation qualities shall be compatible with the existing filter wheels. The filters shall have a circular shape with diameter of  $84.5 \pm 0.1$  mm. The SSDL has filter wheels for the new qualities and new filter wheels are not requested.

#### **4.3.3. HVL measurement assembly**

The HVL measurement system shall fulfil the following specifications:

- 4.3.3.1. The HVL measurement system includes a holder for removable attenuators (aluminium and copper sheets made of various thicknesses);
- 4.3.3.2. The centre of the attenuators shall be located at the CBA. The height of the CBA from the floor is 150 cm;
- 4.3.3.3. The distance from the focus of the X-ray tube to the position of removable attenuators shall be minimum 50 cm;
- 4.3.3.4. A set of metal filters shall be provided for HVL measurements of all radiation qualities given in Appendix 2 including ISO-4037 narrow-spectrum series;
- 4.3.3.5. The filter set shall cover the thickness range from 0.10 mmAl to 15 mmAl and from 0.05 mmCu to 7 mmCu;
- 4.3.3.6. The actual thickness of attenuators shall be known with an uncertainty not exceeding 10  $\mu$ m;
- 4.3.3.7. The metal filters (Al, Cu) used for the HVL measurements of required radiation qualities shall have at least a certified purity of 99.9%; and
- 4.3.3.8. Each metal filter shall be accompanied with certificate stating its purity and thickness, including measurement uncertainty.

#### **4.3.4. Ancillary equipment**

The following ancillary equipment shall be included and it shall fulfil the following specifications:

- 4.3.4.1. A laser alignment system, to define the CBA mounted in the X-ray irradiation room. Its beam diameter shall be less than 1 mm at the distance of 2 m. Another cross laser mounted on the bench to mark the perpendicular direction at the CBA



height. Both lasers shall have power supply and a robust holder for fixation and final adjustment. Lasers shall have red colour; and

- 4.3.4.2. A detector holder assembly, to hold the instrument to be calibrated in predetermined position. Holder assembly for ionization chambers (3 pcs) and survey meters (2 pcs) are required. The chamber holder shall allow fixing the stem of various ionization chambers. The detector holder shall be mounted on a linear track with at least 10 cm travel length in X and Y direction with positioning accuracy of 0.05 mm.

## 5. Marking

The Products shall have the safety marking as required by international standards given in Section 2 “Applicable documents”.

## 6. Packing

The Products shall be packed in accordance with international standards that are applicable for the shipment of this type of equipment.

## 7. Testing and Acceptance

- 7.1. The Products shall be tested in the factory before the shipment (FAT – Factory Acceptance Testing) to assure that the Products are in working conditions and fulfil all technical requirements.
- 7.2. The X-ray system including the Products shall be tested by the Contractor (in the presence of the SSDL personnel) in accordance with the applicable standards in Section 2 to demonstrate that:
- 7.2.1. the performance meets the manufacturer’s performance specifications and the minimum requirements specified herein as determined by the IAEA;
- 7.2.2. the functionalities of the whole system are maintained; and
- 7.2.3. The results of the testing of the X-ray system shall be documented by the Contractor in Acceptance Protocol that shall be signed by the representative of the SSDL.

## 8. Installation

- 8.1. The Contractor shall install the Products at the SSDL, Institute of Metrology of Bosnia and Herzegovina, Jovana Dučića 23A, 78000 Banja Luka, Bosnia and Herzegovina.

## 9. Deliverable Data Items

Following accompanying documents shall be included in English:

- 9.1. Performance specifications; and
- 9.2. Operating instructions.

### Appendices:

Appendix 1: Picture of the existing X-ray system

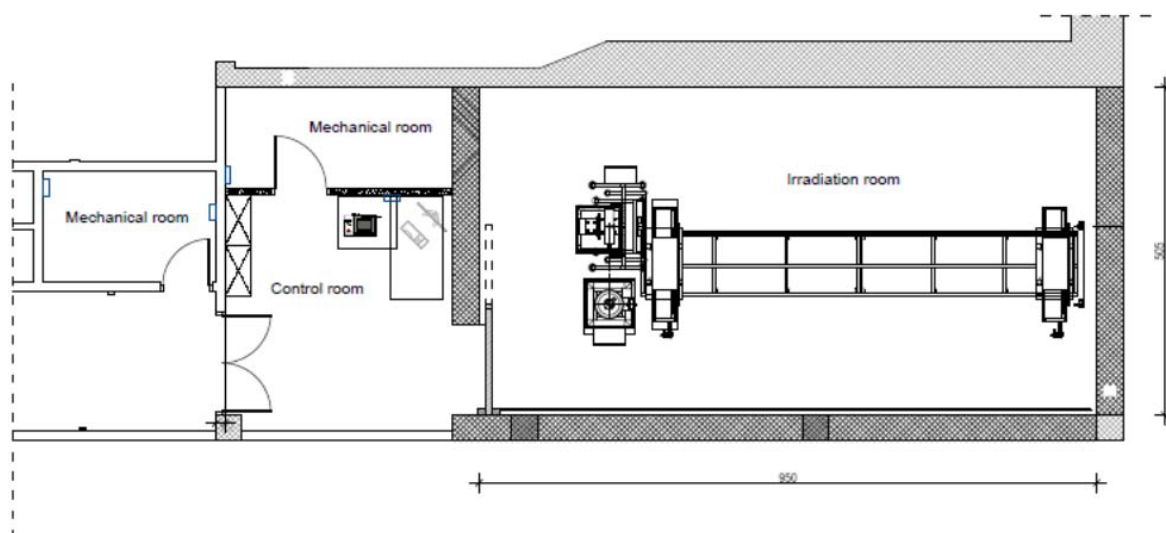
Appendix 2: Radiation qualities for calibrations





## APPENDIX 1

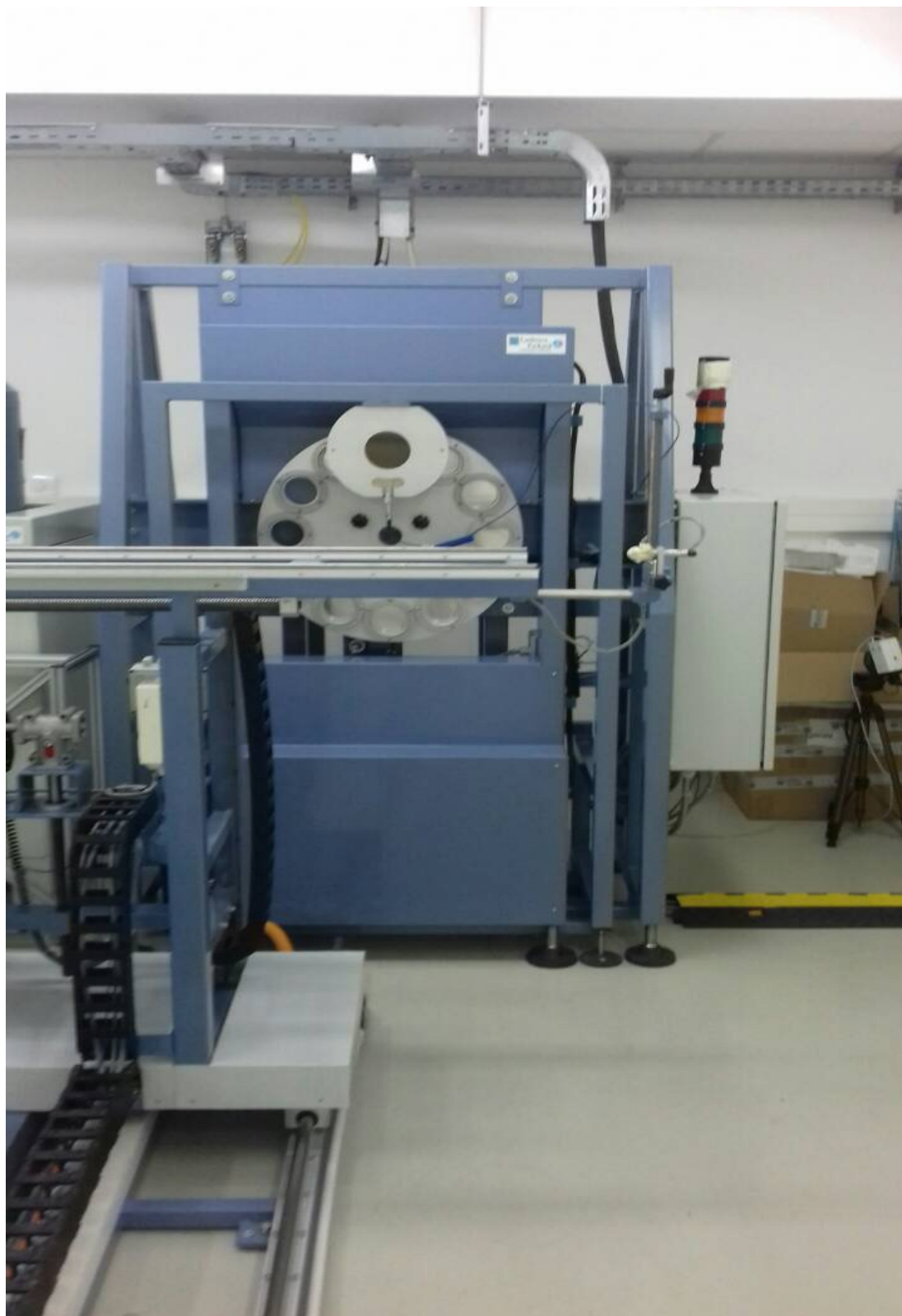
### Layout of the bunker and photos of the existing X-ray system



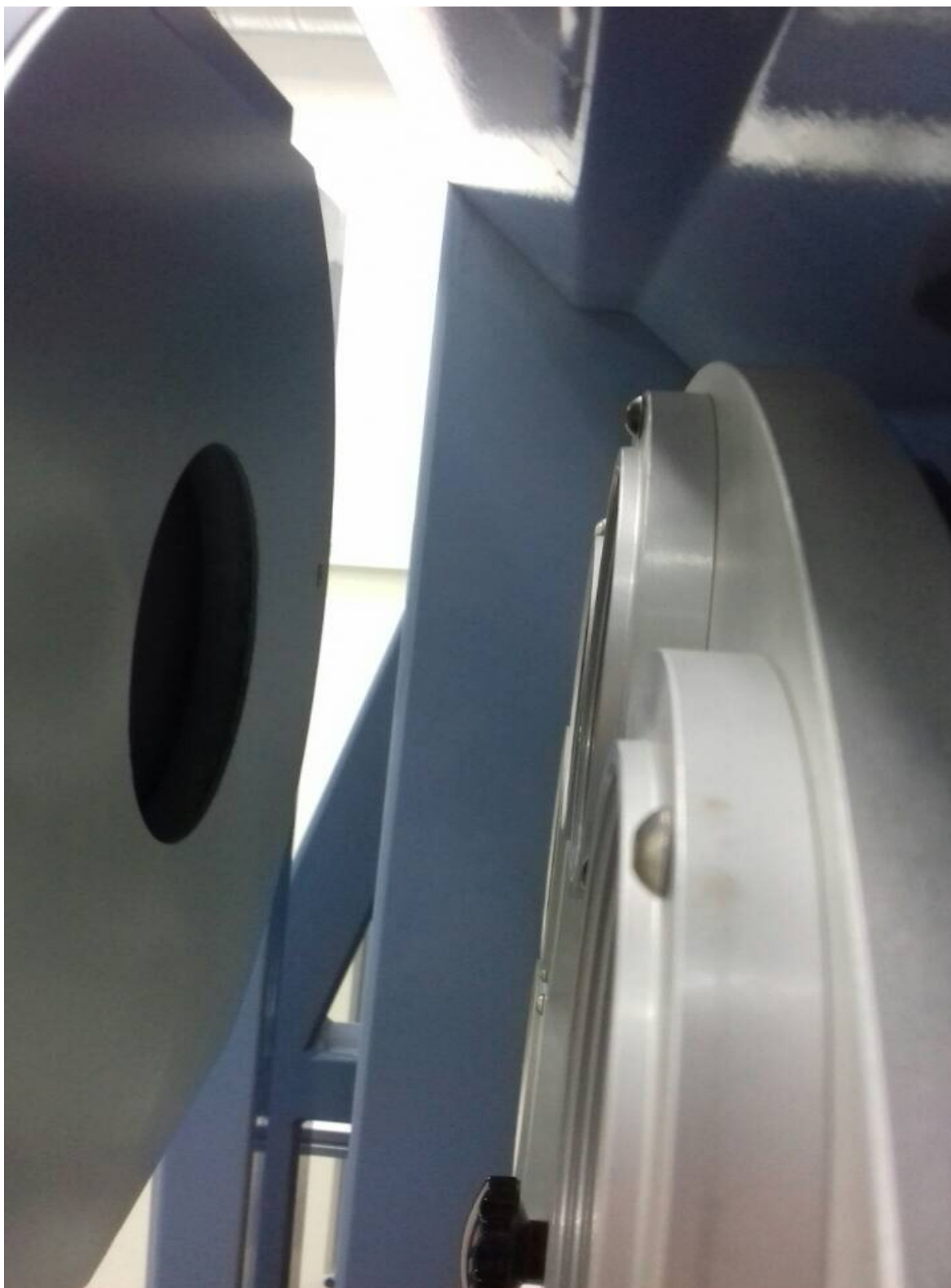














## APPENDIX 2

### BEAM QUALITIES FOR PROTECTION LEVEL CALIBRATIONS

**Table 1.** Characteristics of X-ray narrow-spectrum series ISO-4037 [2.3]. The minimum range of established beam qualities for the SSDL is in the range from **N40** to **N300**

Mean energy $\bar{E}$ keV	Resolution $R_E$ %	Tube potential <sup>1)</sup> kV	Additional filtration <sup>2)</sup> mm				1st HVL <sup>4)</sup> mm	2nd HVL <sup>4)</sup> mm
			Pb	Sn	Cu	Al <sup>3)</sup>		
33	30	40			0.21		0.084 Cu	0.091 Cu
48	36	60			0.6		0.24 Cu	0.26 Cu
65	32	80			2.0		0.58 Cu	0.62 Cu
83	28	100			5.0		1.11 Cu	1.17 Cu
100	27	120		1.0	5.0		1.71 Cu	1.77 Cu
118	37	150		2.5			2.36 Cu	2.47 Cu
164	30	200	1.0	3.0	2.0		3.99 Cu	4.05 Cu
208	28	250	3.0	2.0			5.19 Cu	5.23 Cu
250	27	300	5.0	3.0			6.12 Cu	6.15 Cu

1) The tube potential is measured under load.

2) Except for the five lowest energies, where recommended inherent filtration is 1 mm Be, the total filtration consists of the additional filtration plus the inherent filtration, adjusted to 4 mm of aluminium.

3) The recommended inherent filtration is 1 mm Be, but other values may be used provided that the mean energy is within  $\pm 5\%$  and the resolution is within  $\pm 15\%$  of the values given in the table.

4) The HVLs are measured at 1 m from the focal spot.

### RADIATION QUALITIES FOR DIAGNOSTIC LEVEL CALIBRATIONS

**Table 2.** Characterization of radiation quality series **RQR, IEC 61267 [2.6]**

Radiation quality	X-ray tube voltage (kV)	**Added filtration (mm Al)	1st HVL (mm Al)	Homogeneity coefficient (h)
RQR 2	40	2.45	1.42	0.81
RQR 3	50	2.45	1.78	0.76
RQR 4	60	2.69	2.19	0.74
<b>RQR 5*</b>	<b>70</b>	2.88	<b>2.58</b>	<b>0.71</b>
RQR 6	80	3.15	3.01	0.69
RQR 7	90	3.39	3.48	0.68
RQR 8	100	3.52	3.97	0.68
RQR 9	120	3.90	5.00	0.68
RQR 10	150	4.72	6.57	0.72

\*This value is selected as the reference radiation quality for non-attenuated beams for general radiography applications.

\*\* The fixed filtration consists of 1.0 mm Be + monitor chamber. The values of added filtration are informative only and shall be adjusted to achieve desired HVL values within  $\pm 5\%$ .



## APPENDIX 2

### RADIATION QUALITIES FOR DIAGNOSTIC LEVEL CALIBRATIONS

**Table3.** Characterization of radiation quality series **RQT, IEC 61267 [2.6]**

Radiation quality	X-ray tube voltage (kV)	Added filtration (mm Cu)	Nominal 1st HVL (mm Al)
RQT 8	100	RQR8 + 0.2	6.9
<b>RQT 9*</b>	<b>120</b>	<b>RQR9 + 0.25</b>	<b>8.4</b>
RQT 10	150	RQR10 + 0.3	10.1

\*This value is selected as the reference radiation quality for computed tomography.

\*\* The fixed filtration consists of 1.0 mm Be + monitor chamber. The values of added filtration are informative only and shall be adjusted to achieve desired HVL values within  $\pm 5\%$ .

### RADIATION QUALITIES FOR THERAPY LEVEL CALIBRATIONS

**Table 4.** BIPM-CCRI Radiation qualities for calibrations of therapy level calibrations [2.8]

a. Low energy X-ray beams

Tube voltage [kV]	Added filtration* Al [mm]	HVL Al [mm]
30	0.20	0.18
25	0.36	0.25
50	1.03	1.00
50	4.02	2.30

\*) The inherent filtration is 0.8 mm Be. The values of added filtration are informative only and shall be adjusted to achieve desired HVL values within  $\pm 5\%$ .

b. Medium energy X-ray beams

Tube voltage [kV]	Added filtration *		HVL	
	Al [mm]	Cu [mm]	Al [mm]	Cu [mm]
100	3.65	-	4.00	
135	0.96	0.25		0.50
180	0.96	0.52		1.00

\*) The inherent filtration is 3 mm Be. The values of added filtration are informative only and shall be adjusted to achieve desired HVL values within  $\pm 2\%$ .