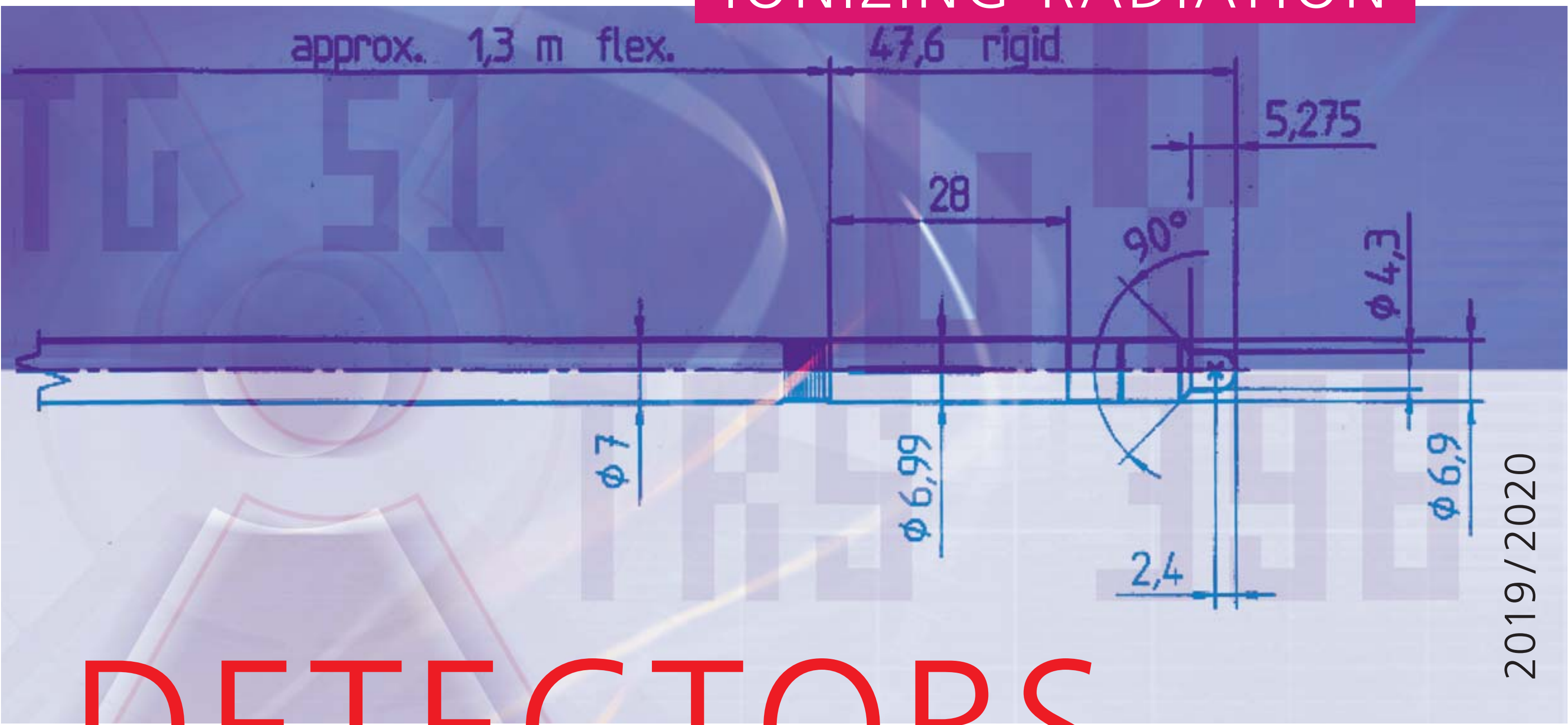
IONIZING RADIATION



2019/2020

DETECTORS

Including Codes of Practice

PTW THE DOSIMETRY COMPANY

Looking back on a long history…

PTW-Freiburg is an internationally operating company, manufacturing and marketing specialized dosimetry and quality control equipment for the medical radiology and health physics market. Founded in 1922, the company is located in Freiburg on the western side of the famous Black Forest mountains in southwestern Germany.

Our Operations

PTW-Freiburg designs, develops, manufactures and distributes high quality dosimetry and QC equipment mainly for use in the medical field, especially in radiation therapy, diagnostic radiology and nuclear medicine. The development and production of mechanical, electronic and software components are all done in house. Our products, especially the PTW ionization chambers, are well known throughout the world and are recognized for their workmanship and high level of quality. PTW-Freiburg is the market leader in its major product lines. The PTW distribution is organized internationally. A number of daughter companies and exclusive PTW representations are established in many countries around the world. We cooperate closely with official public agencies worldwide, and we participate actively in national and international work groups for the standardization of devices and procedures for dose measurement and quality control in radiation medicine.

Our History

In 1922, twenty-seven years after Röntgen discovered the X-rays, Professor Hammer from the Physics Institute of Freiburg University founded PTW to produce and market his development of an X-ray dosemeter based on the electrostatic relais, a revolutionary new electromechanical component for measuring very small electrical charges. In 1927, Dr. Herbert Pychlau took over the company and developed it during four decades into an internationally recognized manufacturer of quality dosemeters for medical radiology. PTW has developed and manufactured many generations of up-to-date products over the years, based on the newest technology. The company has grown continuously. Today, PTW employs a staff of more than 350 all over the world.

The evolvement of radiation detectors

1922 Compact chambers with fixed preamplifier *Hammer Dosimeter*
1927 Barrel type chambers as secondary transfer standards *Küstner Dosimeter*
1928 Shadow-free chambers *Schattenfreie Kammer*
1930 Pressurized radiation protection chambers *Streustrahlenkammer*
1932 Continuous monitoring therapy chambers *Tubusrelais*
1933 Water protected chambers for water phantom use *Wasserphantom*
1933 Capacitor chambers for „wireless“ measurement *Ionognom*
1936 Waterproof sealed chambers for brachytherapy *Mikrokammern*
1950 Flat chambers for diagnostic radiology and mammography *Flachkammern*
1959 Transparent chambers for dose area product measurement *DIAMENTOR®*
1971 Pressurized well type chambers for nuclear medicine *CURIEMENTOR®*
1977 Plane-parallel low energy chambers *Soft X-ray Chambers*
1980 Dedicated electron chamber *Markus Chamber*
1985 Single and multiple detectors for brachytherapy *AM6 Detectors*
1989 Pencil chamber for computed tomography *CT Chamber*
1993 Diamond detector for water phantom use *Diamond Detector*
1995 Liquid filled ionization chamber linear array *LA 48 Array*
1995 Diode detectors for diagnostic radiology *DIADOS Detectors*
1996 Well type chambers for brachytherapy source measurement *HDR Chambers*
1997 Ultracompact ionization chambers *PinPoint Chambers*
1999 Dosimetry diodes for water phantom use *Dosimetry Diodes*
2002 4π flat chamber for seed measurement *SourceCheck*
2003 2D ionization chamber array *2D-ARRAY seven29*
2005 Ultracompact chamber with 3D characteristics *PinPoint 3D Chamber*
2005 Dedicated proton chamber *Bragg Peak Chamber*
2008 High resolution chamber matrix *STARCHECK*
2009 Fullsize high resolution chamber matrix *STARCHECK^{maxi}*
2012 Liquid filled 2D ionization chamber array *OCTAVIUS Detector 1000^{SRS}*
2013 First synthetic diamond detector (SCDD) *microDiamond*

General Remarks

1. All air filled ionization chambers described in this catalog are shipped with a PTW calibration certificate for one measuring quantity (please specify), valid for the stated reference radiation quality.
2. An instruction manual in English is included with every detector.
3. The cable length of the detectors is 1 m, if not stated otherwise.
4. All detectors in this catalog can be operated with a PTW extension cable up to 100 m in length.
5. For very accurate measurements a pre-irradiation dose of (1 ... 3) Gy is recommended for all therapy ionization chambers, even if the data sheet does not specify a mandatory pre-irradiation dose.
6. In case a detector is not used together with a PTW electrometer, the user must ensure that the polarizing voltage is applied by a current-limiting device with a maximum current of 0.5 mA.
7. Most detectors in this catalog are available with 3 different connecting systems (BNT, TNC and M type).
8. All technical data published in this catalog are typical data for the various detector types. Certain data of individual detectors may vary slightly within the ranges of tolerance.

Trademarks®

Contents

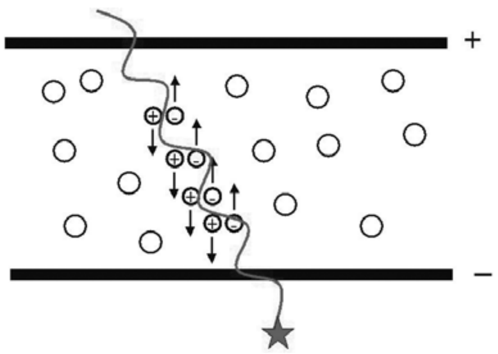
The Physics

General Aspects

Radiation detectors convert radiation energy into electrical energy. The electrical signal of a detector when irradiated is measured by an electrometer connected to the detector. By applying a certain detector specific calibration factor (e.g. Gy/C), the detector signal is related to a radiation dose value. Further correction factors depending on the detector characteristics and the beam quality may be used. A variety of detector types with different design for intensity measurements of ionizing radiation is available. The radiation detection for dosimetric purposes in the medical field of diagnostic radiology, radiotherapy and nuclear medicine is mainly based on three principles of measurement, realized by three different detector types: the ionization chamber, the silicon diode detector and the synthetic diamond diode detector.

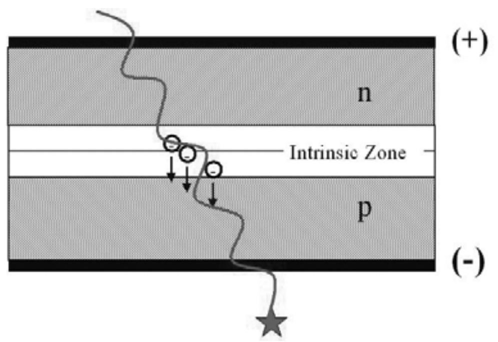
Ionization Chamber

An ionization chamber basically consists of a gas volume between two electrodes connected to a high voltage supply of typically 100 V to 1000 V. In this gas volume ionizing radiation creates ion pairs. These, being positive and negative charge carriers, are attracted by the electrodes thus creating a current which can be measured by an electrometer. Gas (air) volumes vary from 0.005 cm^3 to 50,000 cm^3, corresponding currents can be between 10^{-14} A and 10^{-7} A. Using non-polar fluids, liquid-filled ionization chambers can be realized.



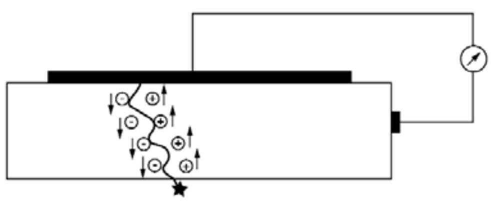
Silicon Diode Detector

In silicon semiconductors a layer of n-type silicon is brought into contact with a layer of p-type silicon, allowing electrons to drift from the n to the p region of the detector thus creating an insulating intrinsic zone. Incident radiation frees electrons in the intrinsic zone (sensitive layer of the detector) which move to the positively charged p region, generating a current. This solar cell principle does not need an external bias voltage.



Synthetic Diamond Diode Detector

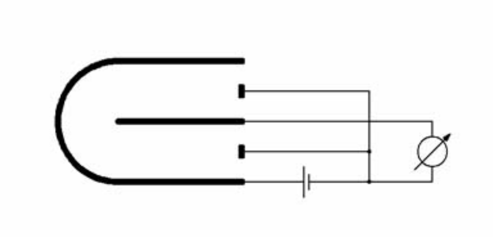
A Schottky diode develops below the top metal contact. The incident radiation generates positive and negative charge carriers. These are separated by the field of the diode, thereby producing a signal current that can be measured with an electrometer. Like the silicon semiconductors, no external bias voltage is required.



The Detector Design

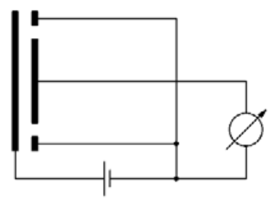
Thimble Ionization Chamber

A thimble chamber (also known as compact chamber) consists of a central electrode and a cylindrical chamber wall with a spherical or conical end mounted on a cylindrical stem. A guard on central electrode potential leading up to the sensitive volume limits dark currents and stem effects.



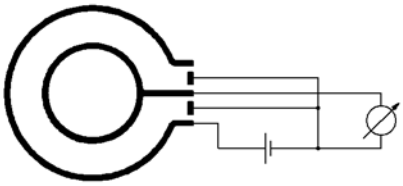
Plane-Parallel Ionization Chamber

A plane-parallel chamber (also known as flat chamber) consists of a high voltage electrode plate and a measuring electrode plate confining the sensitive volume. A guard on central electrode potential around the measuring electrode plate limits dark current and perturbation effect.



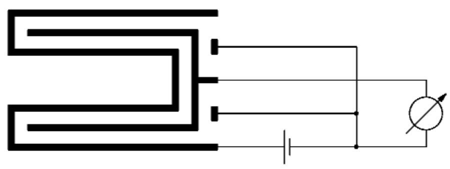
Spherical Ionization Chamber

A spherical chamber consists of two concentric balls representing the central measuring electrode and the chamber wall and confining the sensitive volume. A guard on central electrode potential around the measuring electrode stem limits the dark current.



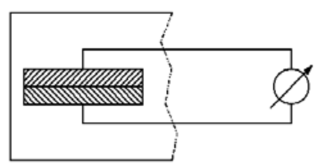
Well-Type Ionization Chamber

A well-type chamber consists of an outer housing with an inset cylindrical cavity – representing the chamber wall – to receive the measuring object. The measuring electrode also surrounds this cavity. A guard on central electrode potential around the measuring electrode stem limits the dark current.



Silicon or Diamond Diode

A silicon semiconductor or synthetic diamond detector consists of a layered silicon disk with contact wires to the measuring instrument. This is embedded horizontally or vertically in protective and / or build-up material depending on the intended application to form a useful probe.
This detector does neither need an external bias voltage nor a guard.



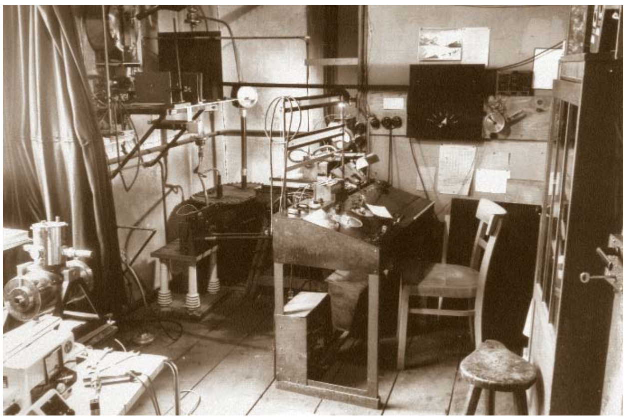
PTW Calibration Laboratory

As both the oldest and the largest manufacturer of ionization chambers and medical dosimetry equipment, PTW-Freiburg has always maintained a calibration laboratory for dosimetric measuring quantities. While being an integral part of the company and a key component of the PTW-Freiburg comprehensive quality assurance system, the calibration laboratory is also proud of its very own traditions and achievements. The PTW Calibration Laboratory as an independent functional unit today is recognized internationally as one of the leading Secondary Standard Dosimetry Laboratories of the world.

Front view of the PTW-Freiburg factory, building with calibration laboratory to the left. Chamber assembly building in the background

Origin and tradition

PTW-Freiburg was founded on May 9, 1922 for the purpose of manufacturing radiation therapy dosemeters based on the electrostatic relay invented by one of the founders, Prof. Hammer. Early photographs of the calibration laboratory show Hammer and Küstner dosimeters and their ionization chambers facing X-ray tubes supplied by open high-voltage leads. Calibration traceability to the National Laboratory (first PTR, now PTB) always was of prime importance. Original and



Detail of the calibration laboratory approx. 1957

improved versions of the Küstner Transfer Standard instrument in the PTW museum bear witness of that tradition. Internal traceability is proudly extended to the point of preserving the original measurement notes to every calibration performed since 1937. This traditional approach to quality today gives the laboratory the advantage of access to what is probably the largest database on calibrations of clinical dosimetry in the world.

Calibration facilities and instrumentation

Our facility is one of the largest, most modern commercial ionizing radiation calibration lab and repair facility in the world. In 2008 the space for the calibration lab is enlarged up to 900 sq. meters. Today the PTW calibration laboratory operates 13 separate calibration benches for radiological and radiotherapy measurements ranging from small mammography and soft X-ray facilities up to ^{137}Cs and the 74 TBq (2000 Ci) ^{60}Co radiotherapy standard. Work at all these single calibration places is coordinated using a custom-made laboratory software for process control, data acquisition from the calibration monitors (UNIDOS instru-

The building with the calibration laboratory (with solar panels) seen from above (Photo: Bavaria Luftbild Verlags GmbH)

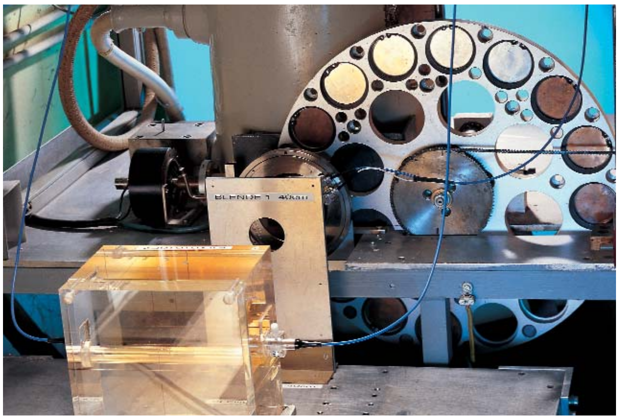
ments) and calibration calculation for the department office writing the calibration certificates. As far as possible (for connector compatibility) the reference class UNIDOS electrometers are also used for the measurement of the customer chambers. The calibration in electrical measuring quantities of all electrometers used is also traceable to the PTB primary standard.
Besides the dose and dose rate ranges the laboratory maintains facilities for the calibration of non-invasive kV-meters and nuclear medicine isotope calibrators.

Quality and regulatory compliance

Both as part of PTW-Freiburg and as Secondary Standard Dosimetry Laboratory the PTW Calibration Laboratory is qualified by adherence to the most stringent QA standards. Current certifications comprise ISO 9001:2008, ISO 13485:2016, ISO 17025:2005 and Annex II and Annex V of the Directive 93/42/EEC (Medical Device Directive).
Customers have the choice of Factory Calibration Certificate or Secondary Standard Calibration Certificate (DAkkS) for dose / dose rate calibrations.

Scope of work

Repair and electrical calibration of measuring instruments are mainly done for PTW dosimeters. This includes complete electrical recalibration of the modern electrometers through all their measuring ranges as well as early fault elimination by burn-in and comprehensive electrical safety tests.
Whenever possible radiological calibrations include the adjustment of the instrument to directly display dose at the reference quality. Radiological calibrations are performed in the measuring quantities and radiation quality ranges as shown on page 8.
For these calibrations every instrument from every manufacturer is accepted (as long as it works and physically fits within the beam). Special radiological calibrations are available upon request. In consequence the PTW laboratory is one of the busiest radiological calibration laboratories worldwide with over 12000 instruments calibrated every year.



300 kV X-ray installation with filter wheel

Comparison measurements

Comparison measurements both in the form of direct comparisons in the calibration chain and ring comparisons between laboratories of equal rank are essential in documenting and maintaining traceability for any calibration laboratory. At the PTW Calibration Laboratory comparisons both with primary laboratories and with other secondary standard dosimetry laboratories are done on a regular basis. Traceability to PTB is maintained by calibration of six sets of dosimetry equipment every two years with comparative measurements and reports every three months. Comparison with IAEA is done by exchange of mailed TLD every year and occasional comparative measurements with ionization chambers. Deviations are always minimal.

Setting up a chamber

Participation in European Ring Comparisons (mostly also supplied with PTW equipment) continuously shows very successful results.
TLD comparison measurements between IAEA and PTW both using the IAEA system and the PTW TLD audit probes have shown only minimal differences.

Secondary Standard Laboratory/ Cooperation with IAEA and PTB

Having successfully participated in the regular comparisons for some years, since the year 2000 the PTW calibration laboratory is formally recognized as a Secondary Standard Dosimetry Laboratory in the IAEA/WHO SSDL network[1].
This so far is the latest expression of the extremely good and fruitful cooperation PTW has enjoyed with the IAEA Dosimetry Laboratory. (Since 1996 PTW has qualified and thrice requalified as preferred supplier of clinical dosimetry equipment to IAEA.) Another positive aspect of this cooperation is in the mutual discussion of procedures and equipment which has lead to the design or continued development of several dosimetry components as for example the PTW Farmer chambers.
A similar close cooperation is traditionally maintained with the German National Laboratory, PTB. Joint development has lead to such successful results as the Böhm extrapolation chamber and the Roos electron chamber. In the German DKD service of secondary standard laboratories PTW was the first and only laboratory for dosimetric quantities[2]. PTW is also one of the oldest members of this service (since 1980).

[1] IAEA /WHO SSDL Newsletter No. 43 July 2000 page 43 (http://www.iaea.or.at/programmes/nahunet/e3/dmrp_e3_pub.html)
[2] Physikalisch-Technische Bundesanstalt, DKD Deutscher Kalibrierdienst, Verzeichnis der Kalibrierlaboratorien, Ausgabe 3/2001: DKD-K-01501 (http://www.dkd.ptb.de)

Calibration Service - Radiation Qualities

Radiation Therapy Dosemeters

- X-rays 10, 15, 30, 50, 70, 100 kV
  (TW qualities according to DIN 6809-4)
- X-rays 70, 100, 140, 200, 280 kV
  (TH qualities according to DIN 6809-5)
- ^{137}Cs 662 keV
- ^{60}Co 1.3 MeV

Diagnostic Radiology Dosemeters

- X-rays 50, 70, 90, 120, 150 kV Conventional
  (RQR and RQA qualities according to IEC 61267)
- X-rays 70, 90, 120, 150 kV CT
  (RQR and RQA qualities according to IEC 61267)
- X-rays 100, 120, 150 kV CT
  (RQT qualities according to IEC 61267)
- X-rays 50, 70, 90 kV Dental
- X-rays 25, 28, 30, 35 kV Mammography
  Qualities according to IEC 61267 Mo/Mo, Mo/Rh, Rh/Rh, W/Ag, W/Al, W/Rh (each with 2 mm Al optional)

Radiation Protection Dosemeters

- X-rays 20, 30, 40 kV
  (Narrow Spectrum Series (N) qualities according to ISO 4037-1:1996)
- X-rays 60, 80, 100, 150, 200, 250 kV
  (Narrow Spectrum Series (N) qualities according to ISO 4037-1:1996)
- ^{137}Cs 662 keV
- ^{60}Co 1.3 MeV

Miscellaneous Calibrations

- Source strength ($cGym^2h^{-1}$) of brachytherapy sources measured by well-type chambers
- Diagnostic X-ray generator high voltage of all types of X-ray equipment measured non-invasively by kV-meters: Different ranges from 20 to 150 kV
- Nuclide activity in nuclear medicine measured by isotope calibrators (only CURIEMENTOR instruments)
- Electrical measuring quantities charge (C) and current (A) measured by highly sensitive electrometers

General Information

According to the PTW definition, each such set of beam qualities represents one calibration point for a certain application and can be ordered with a single order number. For more detailed information please refer to "Calibrations at PTW – A Short Guide" which you will find in the section Services-Calibrations on our website www.ptw.de.

Therapy Detectors

Therapy Detectors

Farmer® Chamber
Type 30010

Classical therapy chamber for absolute dosimetry in high-energy photon, electron and proton beams

Features

- Fully guarded chamber
- Sensitive volume 0.6 cm³, vented to air
- Acrylic wall, graphited
- Aluminum central electrode
- Radioactive check device (option)

The 30010 Farmer chamber is a wide spread ionization chamber for absolute dose measurements in radiation therapy. Correction factors needed to determine absorbed dose to water or air kerma are published in the pertinent dosimetry protocols. The acrylic chamber wall ensures the ruggedness of the chamber. The chamber is designed for the use in solid state phantoms and therefore not waterproof.

Specification

Type of product	vented cylindrical ionization chamber acc. IEC 60731
Application	absolute dosimetry in radiotherapy beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.6 cm³
Design	not waterproof, vented, fully guarded
Reference point	on chamber axis, 13 mm from chamber tip
Direction of incidence	radial
Nominal response	20 nC/Gy
Long-term stability	≤ 0.5 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect at ^{60}Co	< 0.5 %
Photon energy response	≤ ± 2 % (70 kV ... 280 kV) ≤ ± 4 % (200 kV ... ^{60}Co)
Directional response in solid state phantom	≤ ± 0.5 % for rotation around the chamber axis and for tilting of the axis up to ± 5°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.335 mm PMMA, 1.19 g/cm³ 0.09 mm graphite, 1.85 g/cm³
Total wall area density	56.5 mg/cm²
Dimension of sensitive volume	radius 3.05 mm length 23.0 mm
Central electrode	Al 99.98, diameter 1.15 mm
Build-up cap	PMMA, thickness 4.55 mm

Ion collection efficiency at nominal voltage:

Ion collection time	140 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 5 Gy/s 10 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.46 mGy 0.91 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	30 kV ... 50 MV photons (10 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(5 x 5) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN30010-1 Farmer type chamber 0.6 cm³, PMMA/Al, connecting system BNT

TW30010-1 Farmer type chamber 0.6 cm³, PMMA/Al, connecting system TNC

TM30010-1 Farmer type chamber 0.6 cm³, PMMA/Al, connecting system M

Options

T48012 Radioactive check device ^{90}Sr

T48002.3.003 Chamber holding device for check device

Farmer® Chamber

Type 30012

Farmer chamber with graphite wall for absolute dosimetry in high-energy photon, electron and proton beams

Features

- Fully guarded chamber
- Sensitive volume 0.6 cm³, vented to air
- Graphite wall
- Aluminum central electrode
- Radioactive check device (option)

The 30012 Farmer chamber is intended for absolute dose measurements in radiation therapy. Correction factors needed to determine absorbed dose to water or air kerma are published in the pertinent dosimetry protocols. The graphite wall makes the chamber almost water-equivalent, the aluminum central electrode improves the energy response at energies below ^{60}Co. The chamber is intended for the use in solid state phantoms and therefore not waterproof.

Specification

Type of product	vented cylindrical ionization chamber acc. IEC 60731
Application	absolute therapy dosimetry in solid state phantoms and air
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.6 cm³
Design	not waterproof, vented, fully guarded
Reference point	on chamber axis, 13 mm from chamber tip
Direction of incidence	radial
Nominal response	20 nC/Gy
Long-term stability	≤ 0.5 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect at ^{60}Co	< 0.5 %
Photon energy response	≤ ± 2 % (70 kV ... 280 kV) ≤ ± 4 % (200 kV ... ^{60}Co)
Directional response in solid state phantom	≤ ± 0.5 % for rotation around the chamber axis and for tilting of the axis up to ± 5°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.425 mm graphite, 1.85 g/cm³
Total wall area density	79 mg/cm²
Dimension of sensitive volume	radius 3.05 mm length 23.0 mm
Central electrode	Al 99.98, diameter 1.15 mm
Build-up cap	PMMA, thickness 4.55 mm

Ion collection efficiency at nominal voltage:

Ion collection time	140 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 5 Gy/s 10 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.46 mGy 0.91 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	60 kV ... 50 MV photons (10 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(5 x 5) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN30012-1 Farmer type chamber 0.6 cm³, C/Al, connecting system BNT

TW30012-1 Farmer type chamber 0.6 cm³, C/Al, connecting system TNC

Options

T48012 Radioactive check device ^{90}Sr

T48002.3.003 Chamber holding device for check device

Farmer® Chamber
Type 30013

Waterproof therapy chamber for absolute dosimetry in high-energy photon, electron and proton beams

Features

- Waterproof, fully guarded chamber
- Sensitive volume 0.6 cm^3, vented to air
- Acrylic wall, graphited
- Aluminum central electrode
- Radioactive check device (option)

The 30013 Farmer chamber is the standard ionization chamber for absolute dose measurements in radiation therapy. Correction factors needed to determine absorbed dose to water or air kerma are published in the pertinent dosimetry protocols. Its waterproof design allows the chamber to be used in water or in solid state phantoms. The acrylic chamber wall ensures the ruggedness of the chamber.

Specification

Type of product	vented cylindrical ionization chamber acc. IEC 60731
Application	absolute therapy dosimetry in water, solid state phantoms and air
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.6 cm^3
Design	waterproof, vented, fully guarded
Reference point	on chamber axis, 13 mm from chamber tip
Direction of incidence	radial
Nominal response	20 nC/Gy
Long-term stability	≤ 0.5 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect at ^{60}Co	< 0.5 %
Photon energy response	≤ ± 2 % (70 kV ... 280 kV) ≤ ± 4 % (200 kV ... ^{60}Co)
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis and for tilting of the axis up to ± 5°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.335 mm PMMA, 1.19 g/cm^3 0.09 mm graphite, 1.85 g/cm^3
Total wall area density	56.5 mg/cm^2
Dimension of sensitive volume	radius 3.05 mm length 23.0 mm
Central electrode	Al 99.98, diameter 1.15 mm
Build-up cap	PMMA, thickness 4.55 mm

Ion collection efficiency at nominal voltage:

Ion collection time	140 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 5 Gy/s 10 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.46 mGy 0.91 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	30 kV ... 50 MV photons (10 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(5 x 5) cm^2 ... (40 x 40) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN30013 Farmer type chamber 0.6 cm^3, waterproof, connecting system BNT

TW30013 Farmer type chamber 0.6 cm^3, waterproof, connecting system TNC

TM30013 Farmer type chamber 0.6 cm^3, waterproof, connecting system M

Options

T48012 Radioactive check device ^{90}Sr

T48002.3.003 Chamber holding device for check device

0.07 cm³ Semiflex 3D Chamber

Type 31021

Standard therapy chamber with excellent 3D characteristics for scanning systems and for absolute dosimetry

Features

- Waterproof, semiflexible design for easy mounting in scanning water phantoms
- Excellent 3D characteristics
- Sensitive volume of 0.07 cm³
- Outperforms all requirements of IEC 60731 and AAPM TG-51
- Designed for axial and radial irradiation

The 31021 Semiflex 3D chamber is ideal for dose measurements in small fields as encountered e.g. in IORT, IMRT and stereotactic beams as well as for dose measurements in standard fields up to 40 x 40 cm². Relative dose distribution can be measured with high spatial resolution in any direction. The waterproof, fully guarded chamber can be used in air, solid state phantoms and in water.

Specification

Type of product	vented cylindrical ionization chamber
Application	absolute dosimetry in radiotherapy beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.07 cm³
Design	waterproof, vented, fully guarded
Reference point	on chamber axis, 3.45 mm from chamber tip
Direction of incidence	axial, radial
Nominal response	2 nC/Gy
Long-term stability	≤ 0.3 % over 2 years
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect	photons ≤ ± 0.8 % electrons ≤ ± 1 %
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis ≤ ± 1 % for tilting of the axis up to ± 90°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 100 fC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.57 mm PMMA, 1.19 g/cm³ 0.09 mm graphite, 1.85 g/cm³
Total wall area density	84 mg/cm²
Dimension of sensitive volume	radius 2.4 mm length 4.8 mm
Central electrode	Al 99.98, diameter 0.8 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	118 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 6.7 Gy/s 13.4 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.68 mGy 1.42 mGy

Useful ranges:

Chamber voltage	± (50 ... 400) V
Radiation quality	^{60}Co ... 50 MV photons (9 ... 45) MeV electrons
Field size	(2.5 x 2.5) cm² ... (40 x 40) cm² (3.0 x 3.0) cm² ... (40 x 40) cm² ≥ 18 MV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 - 1060) hPa

Ordering Information

TN31021 Semiflex 3D chamber 0.07 cm³, connecting system BNT

TW31021 Semiflex 3D chamber 0.07 cm³, connecting system TNC

TM31021 Semiflex 3D chamber 0.07 cm³, connecting system M

Options

T48012 Radioactive check device ^{90}Sr
T48002.1.004 Chamber holding device for check device

0.125 cm^3 Semiflex Chamber

Type 31010

Standard therapy chamber for scanning systems and for absolute dosimetry

Features

- Waterproof, semiflexible design for easy mounting in scanning water phantoms
- Minimized directional response
- Sensitive volume 0.125 cm^3, vented to air
- Radioactive check device (option)

The 31010 semiflexible chamber is the ideal compromise between small size for reasonable spatial resolution and large sensitive volume for precise dose measurements. This makes the 31010 chamber to one of the most commonly used chambers in scanning water phantom systems. The chamber volume of 0.125 cm^3 gives enough signal to use the chamber also for high precision absolute dose measurements. The sensitive volume is approximately spherical resulting in a flat angular response and a uniform spatial resolution along all three axes of a water phantom.

Specification

Type of product	vented cylindrical ionization chamber
Application	absolute dosimetry in radiotherapy beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.125 cm^3
Design	waterproof, vented, fully guarded
Reference point	on chamber axis, 4.5 mm from chamber tip
Direction of incidence	radial
Nominal response	3.3 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect at ^{60}Co	< 2 %
Photon energy response	≤ ± 2 % (140 kV ... 280 kV) ≤ ± 4 % (200 kV ... ^{60}Co) ≤ ± 5 % (50 kV ... 150 kV)
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis and for tilting of the axis up to ± 10°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.55 mm PMMA, 1.19 g/cm^3 0.15 mm graphite, 0.82 g/cm^3
Total wall area density	78 mg/cm^2
Dimension of sensitive volume	radius 2.75 mm length 6.5 mm
Central electrode	Al 99.98, diameter 1.1 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	121 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 6 Gy/s 12 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.5 mGy 1.0 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	140 kV ... 50 MV photons (10 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(3 x 3) cm^2 ... (40 x 40) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 - 1060) hPa

Ordering Information

TN31010 Semiflex chamber 0.125 cm^3, connecting system BNT

TW31010 Semiflex chamber 0.125 cm^3, connecting system TNC

TM31010 Semiflex chamber 0.125 cm^3, connecting system M

Options

T48012 Radioactive check device ^{90}Sr
T48002.1.004 Chamber holding device for check device

0.3 cm³ Semiflex Chamber

Type 31013

Therapy chamber for scanning systems and for absolute dosimetry

Features

- Waterproof, semiflexible design for easy mounting in scanning water phantoms
- Increased sensitive volume for low level measurements
- Sensitive volume 0.3 cm³, vented to air
- Radioactive check device (option)

The 31013 semiflexible chamber is ideal for precise dose measurements and for the measurement of dose distributions in scanning water phantom systems. The chamber is used as an alternative for the 31010 chamber in cases where increased signal levels are required and spatial resolution along the axis of the chamber can be compromised.

Specification

Type of product	vented cylindrical ionization chamber
Application	absolute dosimetry in radiotherapy beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.3 cm³
Design	waterproof, vented, fully guarded
Reference point	on chamber axis, 9.5 mm from chamber tip
Direction of incidence	radial
Nominal response	10 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect at ^{60}Co	< 1 %
Photon energy response	≤ ± 2 % (140 kV ... 280 kV) ≤ ± 4 % (100 kV ... ^{60}Co)
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis and for tilting of the axis up to ± 10°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.55 mm PMMA, 1.19 g/cm³ 0.15 mm graphite, 0.82 g/cm³
Total wall area density	78 mg/cm²
Dimension of sensitive volume	radius 2.75 mm length 16.25 mm
Central electrode	Al 99.98, diameter 0.9 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	121 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 14 Gy/s 28 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.8 mGy 1.5 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	100 kV ... 50 MV photons (10 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(4 x 4) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN31013 Semiflex chamber 0.3 cm³, connecting system BNT

TW31013 Semiflex chamber 0.3 cm³, connecting system TNC

TM31013 Semiflex chamber 0.3 cm³, connecting system M

Options

T48012 Radioactive check device ^{90}Sr

T48002.1.004 Chamber holding device for check device

0.3 cm³ Rigid Stem Chamber

Type 30016

Therapy chamber for absolute dosimetry in high-energy photon and electron beams

Features

- Fully guarded chamber
- Sensitive volume 0.3 cm³, vented to air
- Acrylic wall, graphited
- Aluminum central electrode
- Radioactive check device (option)

The 30016 chamber is used for absolute dose measurements in radiation therapy in cases where the high volume of the 30015 chamber is not needed and a higher spatial resolution is needed. Correction factors needed to determine absorbed dose to water or air kerma are published in the pertinent dosimetry protocols. The acrylic chamber wall ensures the ruggedness of the chamber. The chamber is designed for the use in solid state phantoms and is therefore not waterproof.

Specification

Type of product	vented cylindrical ionization chamber
Application	absolute dosimetry in radiotherapy beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.3 cm³
Design	not waterproof, vented, fully guarded
Reference point	on chamber axis, 9.5 mm from chamber tip
Direction of incidence	radial
Nominal response	10.5 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	400 V nominal ± 600 V maximal
Polarity effect	≤ 1 %
Photon energy response	≤ ± 2 % (70 kV ... 250 kV) ≤ ± 4 % (200 kV ... ^{60}Co)
Directional response in solid state phantom	≤ ± 0.5 % for rotation around the chamber axis, ≤ ± 1 % for tilting of the axis up to ± 20°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.35 mm PMMA, 1.19 g/cm³ 0.135 mm graphite, 1.85 g/cm³
Total wall area density	67 mg/cm²
Dimension of sensitive volume	radius 2.5 mm length 18 mm
Central electrode	Al 99.98, diameter 0.85 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	84 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 11.5 Gy/s 23.1 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.69 mGy 1.38 mGy

Useful ranges:

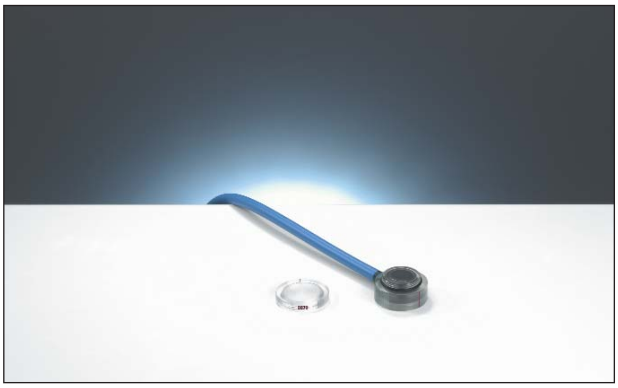
Chamber voltage	± (100 ... 600) V
Radiation quality	70 kV ... 25 MV photons (6 ... 25) MeV electrons
Field size	(5 x 5) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(20 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN30016 Rigid stem chamber 0.3 cm³, connecting system BNT
TW30016 Rigid stem chamber 0.3 cm³, connecting system TNC
TM30016 Rigid stem chamber 0.3 cm³, connecting system M

Options

T48012 Radioactive check device ^{90}Sr
T48002.3.004 Chamber holding device for check device



Advanced Markus® Chamber

Type 34045

Perturbation-free version of the famous classic Markus chamber for absolute dosimetry in high-energy electron beams

Features

- Perturbation-free electron chamber
- Thin entrance window and waterproof protection cap
- Small-sized for high spatial resolution
- Sensitive volume 0.02 cm^3, vented to air
- Radioactive check device (option)

The 34045 Advanced Markus chamber is the successor of the well-known classic Markus electron chamber, equipped with a wide guard ring for perturbation-free measurements. The thin entrance window allows measurements in solid state phantoms up to the surface. The protection cap makes the chamber waterproof for measurements in water phantoms.

Specification

Type of product	vented plane parallel ionization chamber
Application	absolute dosimetry in high-energy electron beams
Measuring quantity	absorbed dose to water
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.02 cm^3
Design	waterproof with protection cap, vented
Reference point	in chamber center on entrance foil, or 1.3 mm below surface of protection cap
Direction of incidence	perpendicular to chamber plane
Nominal response	0.67 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	300 V nominal ± 400 V maximal
Polarity effect	≤ 1 % for electrons ≥ 9 MeV
Directional response in water	≤ ± 0.1 % for chamber tilting ≤ ± 10°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance foil	0.03 mm PE (polyethylene CH_2), 2.76 mg/cm^2
Protection cap	0.87 mm PMMA, 1.19 g/cm^3, 0.4 mm air
Total window area density	106 mg/cm^2, 1.3 mm (protection cap included)
Water-equivalent window thickness	1.06 mm (protection cap included)
Sensitive volume	radius 2.5 mm depth 1 mm
Guard ring width	2 mm

Ion collection efficiency at nominal voltage:

Ion collection time	22 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 187 Gy/s 375 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 2.78 mGy 5.56 mGy

Useful ranges:

Chamber voltage	± (50 ... 300) V
Radiation quality	(2 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(3 x 3) cm^2 ... (40 x 40) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34045 Advanced Markus electron chamber, 0.02 cm^3, connecting system BNT

TW34045 Advanced Markus electron chamber, 0.02 cm^3, connecting system TNC

TM34045 Advanced Markus electron chamber, 0.02 cm^3, connecting system M

Options

T48010 Radioactive check device ^{90}Sr

T23343/11 Chamber holding device for check device

Markus® Chamber
Type 23343

Classic plane parallel chamber for absolute dosimetry in high-energy electron beams

Features

- Thin entrance window and waterproof protection cap
- Small-sized for high spatial resolution
- Sensitive volume 0.055 cm³, vented to air
- Radioactive check device (option)

The 23343 Markus chamber is manufactured in the original famous Markus design. Absorbed dose to water can be measured by applying correction factors for perturbation effects as published in pertinent dosimetry protocols. The thin entrance window allows measurements in solid state phantoms up to the surface. The protection cap makes the chamber waterproof for measurements in water phantoms.

Specification

Type of product	vented plane parallel ionization chamber
Application	absolute dosimetry in high-energy electron beams
Measuring quantity	absorbed dose to water
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.055 cm³
Design	waterproof with protection cap, vented
Reference point	in chamber center on entrance foil, or 1.3 mm below surface of protection cap
Direction of incidence	perpendicular to chamber plane
Nominal response	2 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	300 V nominal ± 400 V maximal
Polarity effect	≤ 1 % for electrons ≥ 9 MeV
Directional response in water	≤ ± 0.1 % for chamber tilting ≤ ± 10°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 3.5 pC/(Gy·cm)

Materials and measures:

Entrance foil	0.03 mm PE (polyethylene CH_2), 2.76 mg/cm²
Protection cap	0.87 mm PMMA, 1.19 g/cm³, 0.4 mm air
Total window area density	106 mg/cm², 1.3 mm (protection cap included)
Water-equivalent window thickness	1.06 mm (protection cap included)
Sensitive volume	radius 2.65 mm depth 2 mm
Guard ring width	< 0.2 mm

Ion collection efficiency at nominal voltage:

Ion collection time	90 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 12 Gy/s 24 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.7 mGy 1.4 mGy

Useful ranges:

Chamber voltage	± (100 ... 300) V
Radiation quality	(2 ... 45) MeV electrons (50 ... 270) MeV protons
Field size	(3 x 3) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN23343 Markus electron chamber 0.055 cm³, connecting system BNT
TW23343 Markus electron chamber 0.055 cm³, connecting system TNC
TM23343 Markus electron chamber 0.055 cm³, connecting system M

Options

T48010 Radioactive check device ^{90}Sr
T23343/11 Chamber holding device for check device

Roos® Chamber
Type 34001

Waterproof plane parallel chamber for absolute dosimetry in high-energy electron and proton beams

Features

- Perturbation-free, minimized polarity effect
- Waterproof, wide guard ring design
- Sensitive volume 0.35 cm^3, vented to air
- Radioactive check device (option)

The 34001 Roos chamber is the golden standard for absolute dose measurements in high-energy electron beams. Modern dosimetry protocols refer to the chamber's design and provide dosimetric correction factors. Its waterproof design allows the chamber to be used in water or in solid state phantoms. The Roos chamber is also well suited for the measurement of high-energy photon depth dose curves. The chamber can be used for dose measurements of proton beams.

Specification

Type of product	vented plane parallel ionization chamber acc. IEC 60731
Application	absolute dosimetry in high-energy electron and proton beams
Measuring quantity	absorbed dose to water
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.35 cm^3
Design	waterproof, vented
Reference point	in chamber center, 1.12 mm below surface
Direction of incidence	perpendicular to chamber plane, see label 'Focus'
Nominal response	12 nC/Gy
Long-term stability	≤ 0.5 % per year
Chamber voltage	200 V nominal ± 400 V maximal
Polarity effect	< 0.5 %
Directional response in water	≤ ± 0.1 % for chamber tilting ≤ ± 10°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance window	1.01 mm PMMA, 1.19 g/cm^3 0.02 mm graphite, 0.82 g/cm^3 0.1 mm varnish, 1.19 g/cm^3
Total window area density	132 mg/cm^2
Water-equivalent window thickness	1.3 mm
Sensitive volume	radius 7.8 mm depth 2 mm
Guard ring width	4 mm

Ion collection efficiency at nominal voltage:

Ion collection time	125 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 5.2 Gy/s 10.4 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.46 mGy 0.93 mGy

Useful ranges:

Chamber voltage	± (50 ... 300) V
Radiation quality	(2 ... 45) MeV electrons ^{60}Co ... 25 MV photons (50 ... 270) MeV protons
Field size	(4 x 4) cm^2 ... (40 x 40) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34001 Roos electron chamber 0.35 cm^3, connecting system BNT

TW34001 Roos electron chamber 0.35 cm^3, connecting system TNC

TM34001 Roos electron chamber 0.35 cm^3, connecting system M

Options

T48010 Radioactive check device ^{90}Sr
T48004 Chamber holding device for check device

Bragg Peak® Chamber

Type 34070

Waterproof plane-parallel chamber for dosimetry in proton beams

Features

- Waterproof, wide guard ring design
- Sensitive volume 10.5 cm^3, vented to air

The 34070 Bragg peak chamber is designed to measure the exact location of the Bragg peak in therapy proton beams. The large diameter of the chamber allows the measurement of the complete proton beam diameter (non-scanned) including the scattered protons. The chamber is waterproof and consequently can either be used in air behind a water column or in a water phantom.
In water, the Bragg Peak chamber can be used for measurements of horizontal beams. Due to the thickness of the entrance and exit windows, the chamber can additionally be used in vertical beams where measurements are performed in different water depths.

Specification

Type of product	vented plane parallel ionization chamber
Application	relative dosimetry in high-energy proton beams
Nominal sensitive volume	10.5 cm^3
Design	waterproof, vented, guarded, perturbation free
Reference point	in chamber center, 3.47 mm from chamber surface
Direction of incidence	perpendicular to chamber plane, see label 'Focus'
Nominal response	325 nC/Gy (at ^{60}Co free in air)
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect	≤ 1 %
Leakage current	≤ ± 100 fA
Cable leakage	≤ 1 pC/(Gy·cm)
Cable length	2.5 m

Materials and measures:

Entrance window	3.35 mm PMMA 0.02 mm graphite 0.1 mm varnish
Total window area density	411 mg/cm^2
Water-equivalent window thickness	4 mm
Sensitive volume	radius 40.8 mm, depth 2 mm
Guard ring width	1.1 mm

Ion collection efficiency at nominal voltage:

Ion collection time	67 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 21 Gy/s 42 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.9 mGy 1.8 mGy

Useful ranges:

Chamber voltage	± (300 ... 500) V
Radiation quality	(70 ... 250) MeV protons
Field size	diameter (3 ... 10) mm
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34070-2,5 Bragg peak chamber 10.5 cm^3, connecting system BNT

TW34070-2,5 Bragg peak chamber 10.5 cm^3, connecting system TNC

TM34070-2,5 Bragg peak chamber 10.5 cm^3, connecting system M

Bragg Peak® Chamber

Type 34073

Waterproof plane-parallel chamber for dosimetry in proton beams

Features

- Small dimensions, thin entrance window
- Sensitive volume 2.5 cm^3, vented to air

The design of the 34073 Bragg Peak chamber is derived from the design of the well-known Roos electron chamber type 34001. The chamber allows the measurement of the complete pencil beam diameter (non-scanned) including the scattered protons for determining the exact location of the Bragg peak in therapy proton beams. The chamber has relatively small dimensions, thin windows and a sensitive volume of 2.5 cm^3. The chamber is waterproof and consequently can either be used in air behind a water column or in a water phantom.
In water, the Bragg Peak chamber can be used for measurements of horizontal beams.

Specification

Type of product	vented plane parallel ionization chamber
Application	relative dosimetry in high-energy proton beams
Nominal sensitive volume	2.5 cm^3
Design	waterproof, vented, guarded, perturbation free
Reference point	in chamber center, 1.13 mm from chamber surface
Direction of incidence	perpendicular to chamber plane, see label 'Focus'
Nominal response	78 nC/Gy (at ^{60}Co free in air)
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect	≤ 1 %
Leakage current	≤ ± 100 fA
Cable leakage	≤ 1 pC/(Gy·cm)
Cable length	1.08 m

Materials and measures:

Entrance window	1.01 mm PMMA 0.02 mm graphite 0.1 mm varnish
Total window area density	133 mg/cm^2
Water-equivalent window thickness	1.3 mm
Sensitive volume	radius 19.8 mm depth 2 mm
Guard ring width	4 mm

Ion collection efficiency at nominal voltage:

Ion collection time	67 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 21 Gy/s 42 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.9 mGy 1.8 mGy

Useful ranges:

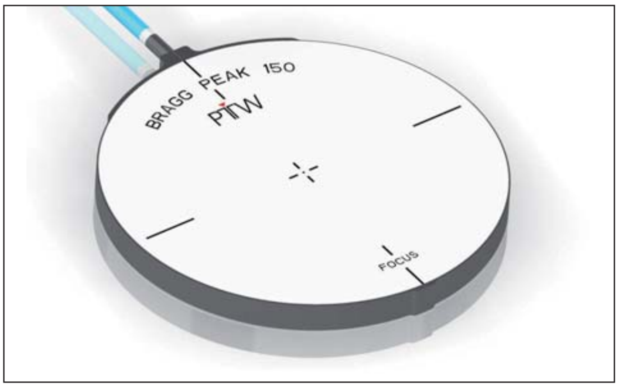
Chamber voltage	± (300 ... 500) V
Radiation quality	(70 ... 250) MeV protons
Field size	diameter (3 ... 10) mm
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34073-1,08 Bragg peak chamber 2.5 cm^3, connecting system BNT

TW34073-1,08 Bragg peak chamber 2.5 cm^3, connecting system TNC

TM34073-1,08 Bragg peak chamber 2.5 cm^3, connecting system M



Bragg Peak® 150

Type 34089

Very large area plane-parallel chamber for dosimetry in proton beams

Features

- Waterproof, wide guard ring design
- Sensitive volume 34 cm³, vented to air
- Very large diameter

The 34089 Bragg peak chamber is designed to measure the exact location of the Bragg peak in therapy proton beams. The very large diameter of the chamber allows the measurement of the proton pencil beam diameter including the beam halo. The chamber is waterproof and consequently can either be used in air behind a water column or in a water phantom.

In water, the Bragg Peak chamber can be used for measurements of horizontal beams. Due to the thickness of the entrance and exit windows, the chamber can additionally be used in vertical beams where measurements are performed in different water depths.

Specification

Type of product	vented plane parallel ionization chamber
Application	relative dosimetry in high-energy proton beams
Nominal sensitive volume	34 cm³
Design	waterproof, vented, guarded
Reference point	in chamber center, inner side of the entrance window
Direction of incidence	perpendicular to chamber plane, see label 'Focus'
Pre-irradiation dose	1 Gy
Nominal response	1.24 µC/Gy (at ^{60}Co free in air)
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect	± 1 %
Leakage current	≤ ± 250 fA
Cable leakage	≤ 1 pC/(Gy·cm)
Cable length	2.5 m

Materials and measures:

Entrance window	0.29 mm PC 0.1 mm GFRP 2.47 mm CFRP 0.03 mm graphite
Total window area density	465 mg/cm²
Water-equivalent window thickness (photons)	4.65 mm
Sensitive volume	radius 73.5 mm, depth 2 mm
Guard ring width	1.2 mm

Ion collection efficiency at nominal voltage:

Ion collection time	67 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 21 Gy/s 42 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.9 mGy 1.8 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(70 ... 250) MeV protons
Field size	diameter (3 ... 10) mm
Temperature	(15 ... 35) °C (59 ... 95) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(540 ... 1060) hPa

Ordering Information

TN34089 Bragg Peak 150, connecting system BNT

TW34089 Bragg Peak 150, connecting system TNC

TW34089 Bragg Peak 150, connecting system M

PinPoint® Chamber
Type 31023

Ultra small-sized therapy chamber for dosimetry in high-energy photon beams

Features
- Small-sized sensitive volumes of only 0.015 cm^3 and 2 mm in diameter, vented to air
- Very high spatial resolution when used for scans perpendicular to the chamber axis
- Small polarity effect
- Minimal cable irradiation effect

The 31023 PinPoint chamber is ideal for dose measurements in small fields as encountered e.g. in IMRT and stereotactic beams as well as for FFF. Relative dose distributions can be measured with very high spatial resolution when the chamber is moved perpendicular to the chamber axis. The waterproof, fully guarded chamber can be used in air, solid state phantoms and in water.

Specification

Type of product	vented cylindrical ionization chamber
Application	dosimetry in high-energy photon beams with high spatial resolution
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.015 cm^3
Design	waterproof, vented, fully guarded
Reference point	on chamber axis, 3.4 mm from chamber tip
Direction of incidence	radial, axial
Pre-irradiation dose	1 Gy
Nominal response	400 pC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	200 V nominal ± 500 V maximal
Polarity effect	≤ ± 0,8 %
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis, ≤ ± 1 % for tilting of the axis up to ± 10 %
Leakage current	≤ ± 4 fA
Cable leakage	≤ 100 fC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.57 mm PMMA, 1.19 g/cm^3 0.09 mm graphite, 1.85 g/cm^3
Total wall area density	85 mg/cm^2
Dimensions of sensitive volume	radius 1 mm length 5 mm
Central electrode	Al 99.98, diameter 0.6 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	19 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 248 Gy/s 495 kGy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 3.8 mGy 10.1 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	^{60}Co ... 25 MV photons
Field size	(2 x 2) cm^2 ... (40 x 40) cm^2
Small fields[1]	down to 0.9 cm
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information
TN31023 PinPoint chamber 0.015 cm^3, connecting system BNT
TW31023 PinPoint chamber 0.015 cm^3, connecting system TNC
TM31023 PinPoint chamber 0.015 cm^3, connecting system M

Options
T48012 Radioactive check device ^{90}Sr
T48002.1.010 Chamber holding device for check device

[1] This detector is well suited for measurements in small and very small fields. Please note that for high accuracy measurements any detector may need correction factors in small fields. The small field size limit is provided as equivalent square field size following the methodology of IAEA TRS483:2017. In accordance with TRS483, the smallest field size considered is 0.4 cm.

PinPoint® Chamber
Type 31015

Small-sized therapy chamber for dosimetry in high-energy photon beams

Features

- Small-sized sensitive volume of only 0.03 cm³ and 2.9 mm in diameter, vented to air
- Very high spatial resolution when used for scans perpendicular to the chamber axis
- Aluminum central electrode
- Radioactive check device (option)

The 31015 PinPoint chamber is ideal for dose measurements in small fields as encountered e.g. in IORT, IMRT and stereotactic beams. Relative dose distributions can be measured with very high spatial resolution when the chamber is moved perpendicular to the chamber axis. The waterproof, fully guarded chamber can be used in air, solid state phantoms and in water.

Specification

Type of product	vented cylindrical ionization chamber
Application	dosimetry in high-energy photon beams with high spatial resolution
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.03 cm³
Design	waterproof, vented, fully guarded
Reference point	on chamber axis, 3.4 mm from chamber tip
Direction of incidence	radial
Pre-irradiation dose	2 Gy
Nominal response	800 pC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect	≤ ± 2 %
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis, ≤ ± 1 % for tilting of the axis up to ± 20° (radial incidence) ± 15° (axial incidence)
Leakage current	≤ ± 4 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.57 mm PMMA, 1.19 g/cm³ 0.09 mm graphite, 1.85 g/cm³
Total wall area density	85 mg/cm²
Dimensions of sensitive volume	radius 1.45 mm length 5 mm
Central electrode	Al 99.98, diameter 0.3 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	50 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 29 Gy/s 55 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 1.2 mGy 2.3 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	^{60}Co ... 50 MV photons
Field size	(2 x 2) cm² ... (30 x 30) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN31015 PinPoint chamber 0.03 cm³, connecting system BNT

TW31015 PinPoint chamber 0.03 cm³, connecting system TNC

TM31015 PinPoint chamber 0.03 cm³, connecting system M

Options

T48012 Radioactive check device ^{90}Sr
T48002.1.007 Chamber holding device for check device

PinPoint® 3D Chamber

Type 31022

Ultra small-sized therapy chamber with 3D characteristics for dosimetry in high-energy photon beams

Features

- Small polarity effect
- Minimal cable irradiation effect
- Short ion collection time
- Large field size range

The 31022 PinPoint 3D chamber is ideal for measurements in small fields but can also be used for measurements in large fields. Designed for radial beam orientation, the small-sized chamber shows excellent 3D characteristics. Relative dose distributions can be measured with high spatial resolution in any direction. It is waterproof and fully guarded, thus it can be used in air, solid state phantoms and in water.

Specification

Type of product	vented cylindrical ionization chamber
Application	dosimetry in photon beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.016 cm^3
Design	waterproof, vented, guarded
Reference point	on chamber axis, 2.4 mm from chamber tip
Direction of incidence	radial
Pre-irradiation dose	1 Gy
Nominal response	400 pC/Gy
Long-term stability	≤ 0.5 % per year
Chamber voltage	300 V nominal ± 500 V maximal
Polarity effect	≤ ± 0.8 %
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis, ≤ ± 1 % for tilting of the axis up to ± 10°
Leakage current	≤ ± 4 fA
Cable leakage	≤ 100 fC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	0.57 mm PMMA, 1.19 g/cm^3 0.09 mm graphite, 1.85 g/cm^3
Total wall area density	84 mg/cm^2
Dimensions of sensitive volume	radius 1.45 mm length 2.9 mm
Central electrode	Al 99.98, diameter 0.6 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	45 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 46 Gy/s 91 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.8 mGy 2.2 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	^{60}Co ... 25 MV photons
Field size	(2 x 2) cm^2 … (40 x 40) cm^2
Small fields[1]	down to 0.8 cm
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN31022 PinPoint 3D chamber 0.016 cm^3, connecting system BNT

TW31022 PinPoint 3D chamber 0.016 cm^3, connecting system TNC

TM31022 PinPoint 3D chamber 0.016 cm^3, connecting system M

Options

T48012 Radioactive check device ^{90}Sr

T48002.1.010 Chamber holding device for check device

[1] This detector is well suited for measurements in small and very small fields. Please note that for high accuracy measurements any detector may need correction factors in small fields. The small field size limit is provided as equivalent square field size following the methodology of IAEA TRS483:2017. In accordance with TRS483, the smallest field size considered is 0.4 cm.

microSilicon
Type 60023

Waterproof silicon diode detector for dosimetry in high-energy electron and photon beams

Features

- Useful for measurements in all electron fields and for photon fields ≤ (10 x 10) cm^2
- Excellent spatial resolution
- Thin entrance window for measurements in the vicinity of surfaces and interfaces
- Very small detector to detector variation
- Excellent dose stability

The microSilicon is ideal for dose measurements in electron and small photon fields. The excellent spatial resolution makes it possible to measure very precisely beam profiles even in the penumbra region of small fields. The microSilicon is recommended for dose measurements in all electron fields and for photon fields up to (10 x 10) cm^2. The waterproof detector can be used in air and in water.
The microSilicon shows a very small detector to detector variation which provides a sound basis for reliable small field correction factors.

Specification

Type of product	p-type silicon diode
Application	relative dosimetry in radiotherapy beams
Measuring quantity	absorbed dose to water
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.03 mm^3
Design	waterproof, disk-shaped sensitive volume perpendicular to detector axis
Reference point[1]	on chamber axis, 0.9 mm from chamber tip
Direction of incidence	axial
Nominal response	19 nC/Gy
Dose stability Electrons Photons	 ≤ 0.5 %/kGy at 10 MV ≤ 1 %/kGy at 21 MV ≤ 0.1 %/kGy at 6 MeV ≤ 0.5 %/kGy at 18 MeV
Temperature response	≤ (0.1 ± 0.05) %/K
Energy response	at higher depths than d_{max}, the percentage depth dose curves match curves measured with ionization chambers within ± 0.5 %
Bias voltage	0 V
Signal polarity	negative
Directional response in water	≤ ± 1 % for rotation around the chamber axis, ≤ ± 1 % for tilting of the axis up to ± 20°
Leakage current	≤ ± 100 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance window	0.3 mm RW3 0.01 mm Al 0.48 mm epoxy
Total window area density	92 mg/cm^2
Water-equivalent window thickness	0.9 mm
Sensitive volume	radius 0.75 mm thickness 18 µm
Outer dimensions	diameter 7 mm, length 45.5 mm

Useful ranges:

Radiation quality	(6 ... 25) MeV electrons ^{60}Co ... 25 MV photons
Field size	(1 x 1) cm^2 ... (40 x 40) cm^2 for electrons (1 x 1) cm^2 ... (10 x 10) cm^2 for photons
Small fields[2]	down to 0.4 cm
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(540 ... 1060) hPa

Ordering Information

TN60023 microSilicon, connecting system BNT
TW60023 microSilicon, connecting system TNC
TM60023 microSilicon, connecting system M

[1] Photons: Reference point corresponds to the effective point of measurement.
Electrons: Effective point of measurement is 0.3 mm from tip.

[2] This detector is well suited for measurements in small and very small fields. Please note that for high accuracy measurements any detector may need correction factors in small fields. The small field size limit is provided as equivalent square field size following the methodology of IAEA TRS483:2017. In accordance with TRS483, the smallest field size considered is 0.4 cm.

Dosimetry Diode P

Type 60016

Waterproof silicon detector for dosimetry in high-energy photon beams up to field size 40 cm x 40 cm

Features

- Useful for measurements in small and large photon fields
- Excellent spatial resolution
- Minimized energy response for field size independent measurements up to 40 cm x 40 cm

The 60016 Dosimetry Diode P is ideal for dose measurements in small photon fields as encountered in IORT, IMRT and stereotactic beams. The excellent spatial resolution makes it possible to measure very precisely beam profiles even in the penumbra region of small fields. The superior energy response enables the user to perform accurate percentage depth dose measurements which are field size independent up to field sizes of (40 x 40) cm². The waterproof detector can be used in air, solid state phantoms and in water.

Specification

Type of product	p-type silicon diode
Application	dosimetry in radiotherapy beams
Measuring quantity	absorbed dose to water
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.03 mm³
Design	waterproof, disk-shaped sensitive volume perpendicular to detector axis
Reference point	on detector axis, 2.42 mm from detector tip
Direction of incidence	axial
Nominal response	9 nC/Gy
Dose stability	≤ 0.5 %/kGy at 6 MV ≤ 1 %/kGy at 15 MV ≤ 0.5 %/kGy at 5 MeV ≤ 4 %/kGy at 21 MeV
Temperature response	≤ 0.4 %/K
Bias voltage	0 V
Signal polarity	negative
Directional response in water	≤ ± 0.5 % for rotation around the chamber axis, ≤ ± 1 % for tilting ≤ ± 40°
Leakage current	≤ ± 50 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance window	1 mm RW3, 1.045 g/cm³ 1 mm epoxy
Total window area density	250 mg/cm²
Water-equivalent window thickness	2.42 mm
Sensitive volume	1 mm² circular 30 µm thick
Outer dimensions	diameter 7 mm, length 47 mm

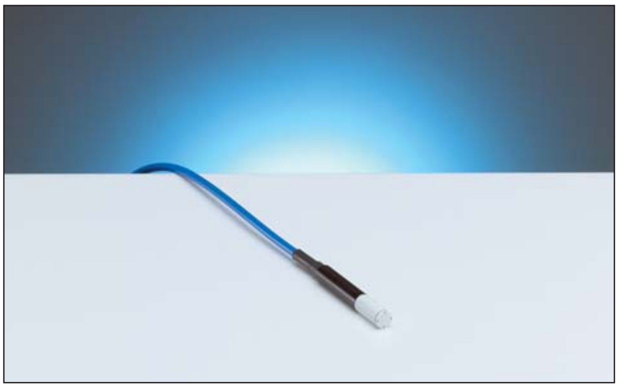
Useful ranges:

Radiation quality	^{60}Co ... 25 MV photons
Field size	(2 x 2) cm² ... (40 x 40) cm²
Small fields[1]	down to 1.2 cm
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³

Ordering Information

TN60016 Dosimetry Diode P, connecting system BNT
TW60016 Dosimetry Diode P, connecting system TNC
TM60016 Dosimetry Diode P, connecting system M

[1] This detector is well suited for measurements in small and very small fields. Please note that for high accuracy measurements any detector may need correction factors in small fields. The small field size limit is provided as equivalent square field size following the methodology of IAEA TRS483:2017. In accordance with TRS483, the smallest field size considered is 0.4 cm.



microDiamond

Type 60019

Diamond Detector for dosimetry in high-energy photon, electron, proton and carbon ion beams, especially useful for small field dosimetry

Features

- Small sensitive volume of 0.004 mm^3
- Excellent radiation hardness and temperature independence
- Near tissue-equivalence
- Operates without high voltage
- All connecting systems available (BNT, TNC, M)

The microDiamond detector is a synthetic single crystal diamond detector (SCDD), based on a unique fabrication process [1, 2]. Significant advantages of the synthetic production are standardised assembly and consequently a high reproducibility of the dosimetric properties and good availability of the detector.

Specification

Type of product	synthetic single crystal diamond detector
Application	dosimetry in radiotherapy beams
Measuring quantitiy	absorbed dose to water
Reference radiation quality	^{60}Co
Nominal sensitive volume	0.004 mm^3
Design	waterproof, disk-shaped, sensitive volume perpendi-cular to detector axis
Reference point	on detector axis, 1 mm from detector tip, marked by ring
Direction of incidence	axial
Pre-irradiation dose	5 Gy
Nominal response	1 nC/Gy
Long-term stability	≤ 0.5 % per year
Dose stability	< 0.25 % / kGy at 18 MV
Temperature response	≤ 0.08 % / K
Bias voltage	0 V
Signal polarity	positive
Directional response in water	≤ 1 % for tilting ≤ ± 40°
Leakage current[1]	≤ 20 fA
Cable leakage	≤ 200 fC / (Gy·cm)

Materials and measures:

Entrance window	0.3 mm RW3 0.6 mm Epoxy 0.01 mm Al 99.5
Total window area density	101 mg/cm^2
Water-equivalent window thickness	1.0 mm
Sensitive volume	radius 1.1 mm, circular, thickness 1 µm
Outer dimensions	diameter 7 mm, length 45.5 mm

Useful ranges:

Radiation quality	100 keV ... 25 MV photons (6 ... 25) MeV electrons (70 … 230) MeV protons[2] (115 … 380) MeV/u carbon ions[2]
Field size	(1 x 1) cm^2 ... (40 x 40) cm^2
Small fields[3]	down to 0.4 cm
Temperature	(10 ... 35) °C, (50 ... 95) °F
Humidity range	(10 ... 80) %, max 20 g/m^3

Ordering Information

TN60019 microDiamond Detector, connecting system BNT
TW60019 microDiamond Detector, connecting system TNC
TM60019 microDiamond Detector, connecting system M

The microDiamond detector is realized in collaboration with Marco Marinelli and Gianluca Verona-Rinati and their team, Industrial Engineering Department of Rome Tor Vergata University, Italy.

[1] I. Ciancaglioni, M. Marinelli, E. Milani, G. Prestopino, C. Verona, G. Verona-Rinati, R. Consorti, A. Petrucci and F. De Notaristefani, Dosimetric characterization of a synthetic single crystal diamond detector in clinical radiation therapy small photon beams, Med. Phys. **39** (2012), 4493

[2] C. Di Venanzio, M. Marinelli, E. Milani, G. Prestopino, C. Verona, G. Verona-Rinati, M. D. Falco, P. Bagalà, R. Santoni and M. Pimpinella, Characterization of a synthetic single crystal diamond Schottky diode for radiotherapy electron beam dosimetry, Med. Phys. **40** (2013), 021712

1 At the high end of the temperature range, higher leakage currents may occur.

2 In rare cases, an individual microDiamond can exhibit an LET dependence in proton or hadron radiation. If you suspect that this might be the case for your microDiamond, please contact PTW technical service.

3 This detector is well suited for measurements in small and very small fields. Please note that for high accuracy measurements any detector may need correction factors in small fields. The small field size limit is provided as equivalent square field size following the methodology of IAEA TRS483:2017. In accordance with TRS483, the smallest field size considered is 0.4 cm.

T-REF Chamber
Type 34091

Reference detector for small fields

Features

- Very low total area density of 206 mg/cm^2
- No measurable perturbation of the beam
- High and very stable signal
- No contact to linac head
- Fast and easy to mount

The T-REF chamber 34091 provides a solution to the problem where to put a reference detector in small fields. The T-REF chamber is a large-area plane-parallel transmission reference chamber and proved to be easy to use. From the minimum distance to the water surface on, there are no measurable perturbations of the beam. The very good signal-to-noise-ratio makes it an excellent option for the use as a reference detector.

Specification

Type of product	vented plane-parallel ionization chamber
Application	relative dosimetry in high-energy photon beams
Nominal sensitive volume	10.5 cm^3
Design	waterproof, vented, guarded, perturbation-free
Reference point	inside of entrance window, center
Direction of incidence	perpendicular to the entrance window, see label “Focus”
Nominal response	325 nC/Gy (at ^{60}Co free in air)
Chamber voltage	400 V nominal ± 500 V maximal
Polarity effect	≤ ± 1 %
Leakage current	≤ ± 100 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Total area density	206 mg/cm^2
Water-equivalent window thickness	2.06 mm for photons
Dimension of sensitive volume	radius 40.8 mm depth 2 mm

Ion collection efficiency at nominal voltage:

Ion collection time	67 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 21 Gy/s 42 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.9 mGy 1.8 mGy

Useful ranges:

Chamber voltage	± (300 ... 500) V
Radiation quality	^{60}Co ... 25 MV photons
Max. field size in 20 cm distance to water surface	(5 x 5) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34091 T-REF chamber, connecting system BNT including holder
TW34091 T-REF chamber, connecting system TNC including holder
TM34091 T-REF chamber, connecting system M including holder

0.005 cm^3 Soft X-Ray Chamber

Type 34013

Thin window plane parallel chamber for dose measurements in superficial radiation therapy

Features

- Ultra thin entrance window
- For low-energy photons from 15 kV to 70 kV
- Extremely small size
- Sensitive volume 0.005 cm^3, vented to air

The 34013 soft X-ray chamber is used for absolute dose measurements in low-energy photon beams as used in superficial radiation therapy. The chamber's small size enables the user to perform measurements with excellent spatial resolution. Correction factors needed for the determination of absorbed dose to water are available. The chamber is designed for the use in solid state phantoms.

Specification

Type of product	vented plane parallel ionization chamber
Application	absolute dosimetry in low-energy photon beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	30 kV, HVL 0.37 mm Al (T30)
Nominal sensitive volume	0.006 cm^3
Design	not waterproof, vented
Reference point	in chamber center of entrance foil underside
Direction of incidence	perpendicular to chamber plane
Nominal response	200 pC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	400 V nominal ± 400 V maximal
Directional response	≤ 5 % for chamber tilting up to ± 10°
Leakage current	≤ ± 10 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance foil	0.03 mm PE
Total window area density	2.76 mg/cm^2
Sensitive volume	radius 1.45 mm depth 0.9 mm
Electrode	radius 1.4 mm

Ion collection efficiency at nominal voltage:

Ion collection time	14 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.5 kGy/s 1.0 kGy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 4.5 mGy 9.1 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(15 ... 70) kV X-rays
Field size	(0.5 x 0.5) cm^2 ... (40 x 40) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(20 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34013 Soft X-ray chamber 0.005 cm^3, connecting system BNT

TW34013 Soft X-ray chamber 0.005 cm^3, connecting system TNC

TM34013 Soft X-ray chamber 0.005 cm^3, connecting system M

0.02 cm^3 Soft X-Ray Chamber

Type 23342

Thin window plane parallel chamber for dose measurements in superficial radiation therapy

Features

- Ultra thin entrance window
- For low-energy photons from 15 kV to 70 kV
- Sensitive volume 0.02 cm^3, vented to air
- Radioactive check device (option)

The 23342 soft X-ray chamber is the golden standard for absolute dose measurements in low-energy photon beams as used in superficial radiation therapy. Correction factors needed for the determination of absorbed dose to water are available. The chamber is designed for the use in solid state phantoms.

Specification

Type of product	vented plane parallel ionization chamber acc. IEC 60731
Application	absolute dosimetry in low-energy photon beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	30 kV, HVL 0.37 mm Al (T30)
Nominal sensitive volume	0.02 cm^3
Design	not waterproof, vented
Reference point	in chamber center of entrance foil underside
Direction of incidence	perpendicular to chamber plane
Nominal response	1 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	300 V nominal ± 500 V maximal
Directional response	≤ ± 1 % for chamber tilting up to ± 20°
Leakage current	≤ ± 10 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance foil	0.03 mm PE
Total window area density	2.76 mg/cm^2
Sensitive volume	radius 2.55 mm depth 1 mm
Electrode	radius 1.5 mm

Ion collection efficiency at nominal voltage:

Ion collection time	22 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 188 Gy/s 375 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 2.8 mGy 5.6 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(15 ... 70) kV X-rays
Field size	(1 x 1) cm^2 ... (40 x 40) cm^2
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(20 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN23342 Soft X-ray chamber 0.02 cm^3, connecting system BNT

TW23342 Soft X-ray chamber 0.02 cm^3, connecting system TNC

TM23342 Soft X-ray chamber 0.02 cm^3, connecting system M

Options

T48010 Radioactive check device ^{90}Sr
T23238 Chamber holding device for check device

0.2 cm³ Soft X-Ray Chamber

Type 23344

Thin window plane parallel chamber for dose measurements in superficial radiation therapy

Features

- Ultra thin entrance window
- For low-energy photons from 15 kV to 70 kV
- Sensitive volume 0.2 cm³, vented to air
- Radioactive check device (option)

The 23344 soft X-ray chamber is used for absolute dose measurements in low-energy photon beams as used in superficial radiation therapy. The sensitive volume is larger than that of the 23342 chamber, giving a higher signal at the cost of a lower spatial resolution. Correction factors needed for the determination of absorbed dose to water are available. The chamber is designed for the use in solid state phantoms.

Specification

Type of product	vented plane parallel ionization chamber acc. IEC 60731
Application	absolute dosimetry in low-energy photon beams
Measuring quantities	absorbed dose to water, air kerma, exposure
Reference radiation quality	30 kV, HVL 0.37 mm Al (T30)
Nominal sensitive volume	0.3 cm³
Design	not waterproof, vented
Reference point	in chamber center of entrance foil underside
Direction of incidence	perpendicular to chamber plane
Nominal response	10 nC/Gy
Long-term stability	≤ 1 % per year
Chamber voltage	400 V nominal ± 500 V maximal
Directional response	≤ ± 1 % for chamber tilting up to ± 20°
Leakage current	≤ ± 10 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance foil	0.03 mm PE
Total window area density	2.76 mg/cm²
Sensitive volume	radius 7.95 mm depth 1.5 mm
Electrode	radius 6.5 mm

Ion collection efficiency at nominal voltage:

Ion collection time	38 µs
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 66 Gy/s 132 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 1.6 mGy 3.3 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(15 ... 70) kV X-rays
Field size	(2 x 2) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(20 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN23344 Soft X-ray chamber 0.2 cm³, connecting system BNT

TW23344 Soft X-ray chamber 0.2 cm³, connecting system TNC

TM23344 Soft X-ray chamber 0.2 cm³, connecting system M

Options

T48010 Radioactive check device ^{90}Sr
T23236 Chamber holding device for check device

SOURCECHECK $^{4\pi}$

Type 33005

Ionization chamber for measuring the source strength of radioactive seeds and intravascular brachytherapy sources

Features

- Measures low energy seeds and high energy afterloading sources
- Measures all sources in a full 4π geometry
- Adapters for all commercial afterloading devices and seeds
- User friendly accessories for fast and safe handling
- Compatible to high class PTW dosemeters
- Calibration for Ir-192, Co-60 and I-125 available

The SOURCECHECK $^{4\pi}$ well-type ionization chamber is suitable for source strength measurements of all kind of brachytherapy sources. International standards require the measurement of radioactive brachytherapy sources. For HDR afterloading sources an acceptance test after the replacement of the source and additional constancy checks are required. For permanent implanted seeds the typical quality assurance is measuring a defined amount seeds out of a delivered batch.
Various adapters for all kind of afterloading applicators and for different seeds and seed strands are available. The radioactive check source T48010 can be used for constancy checks. The chamber can be calibrated for Ir-192, Co-60 and I-125.

Specification

Type of product	well-type ionization chamber
Application	source strength measurement of brachytherapy sources
Measuring quantities	apparent activity, air kerma strength, exposure strength
Calibration	Ir-192, Co-60, I-125, others upon request
Nominal response	125 fA/MBq (Ir-192) 65 fA/MBq (I-125)
Nominal volume	116 cm^3
Design	vented, guarded
Chamber voltage	400 V nominal
Reference point	95 mm below chamber top
Long-term stability	≤ ± 1 % per year
Leakage current	≤ ± 50 fA

Measures:

Inner well diameter	32 mm
Outer dimensions	height 180 mm base diameter 127 mm outer well diameter 93 mm
Weight	1.4 kg

Useful ranges:

Temperature	(10 ... 40) °C for sources > 100 keV photons (15 ... 35) °C for sources < 100 keV photons or < 1 MeV electrons
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN33005 SOURCECHECK $^{4\pi}$, connecting system BNT
TW33005 SOURCECHECK $^{4\pi}$, connecting system TNC
TM33005 SOURCECHECK $^{4\pi}$, connecting system M

Options

T33004.1.012 HDR Universal Adapter 1.0 – 1.8 mm
T33004.1.013 HDR Universal Adapter 1.8 – 3.2 mm
T33004.1.014 HDR Universal Adapter 3.2 – 4.6 mm
T33004.1.015 HDR Universal Adapter 4.5 – 5.9 mm
T33004.1.016 HDR Universal Adapter 5.8 – 7.2 mm
T33002.1.009 Adapter for Nucletron AL
T33005.1.100 SOURCECHECK single seed adapter
T33005.1.150 SOURCECHECK seed adapter Nucletron
T33005.1.130 SOURCECHECK strand adapter
T33005.1.120 SOURCECHECK Rapid Strand adapter
T33005.1.020 SOURCECHECK radioactive check source adapter

T48010 Check device 90-Sr, point source
E21272 SOURCECHECK calibration Ir-192
E21271 SOURCECHECK calibration I-125

System Incorporated Detectors for Radiotherapy

Besides the radiation detectors presented in this chapter, there are available a number of further detectors which are incorporated components of therapy dosemeters.

Patient in-vivo Detectors

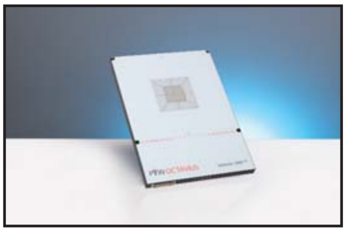
Semiconductor probes for in-vivo dosimetry measure the patient skin, entrance or exit dose during external radiation treatments. Different detector types for photon energies or electron measurements are available. Additionally a risk organ diode with increased sensitivity and homogeneous directional response is available.

Afterloading Probes

For intracavitary dosimetry during gynecological afterloading brachytherapy, the five-fold semiconductor probe is positioned in the patient's rectum and a single detector probe is placed in the bladder to monitor the radiation load to the most radiation sensitive organs automatically. The five-fold probe has five individual detectors spaced 15 mm apart from each other to increase the chance to measure the maximum dose.

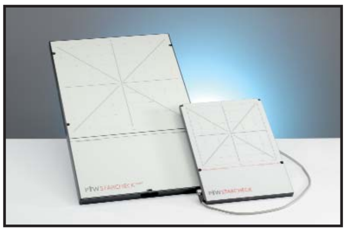
OCTAVIUS Detector 729 and 1500 Chamber Arrays

The OCTAVIUS Detector 729 and the OCTAVIUS Detector 1500 are ion chamber matrices for IMRT verification and quality control in radiation therapy. There are 729/1500 vented plane-parallel ion chambers located in a matrix of 27 x 27. Utilizing ion chambers avoids radiation defects, the major drawback of solid-state detectors.



OCTAVIUS Detector 1000^{SRS} Chamber Array

The OCTAVIUS Detector 1000^{SRS} is the first liquid-filled 2D ionization chamber array. The very small detector size of only 2.3 mm x 2.3 mm x 0.5 mm makes this array ideal suited for dosimetry of small fields.
Target application is patient plan verification in stereotactic radio surgery and quality assurance of small fields.



STARCHECK Planar Chamber Arrays

STARCHECK and STARCHECK^{maxi} are precise and reliable tools for fast measurements in radiation therapy beams. Typical applications are quality control and LINAC beam adjustment. The 527/707 ionization chambers feature an excellent relative response stability, avoiding the need of frequent recalibration and a excellent spatial resolution of only 3 mm.

Radioactive ^{90}Sr Check Devices

Radioactive check devices are used for air density corrections of vented ionization chambers and for constancy checks of the complete dosemeters including chamber. Appropriate holding devices are available.

Check Devices for Ion Chambers

The check device type T48012 is specially designed for thimble chambers, the check device type T48010 for flat chambers. Both include an encapsulated ^{90}Sr source with a low activity. The sources are equivalent to ISO class C64444.

Details upon request

Diagnostic Detectors

Diagnostic Detectors

CT Chamber
Type 30009

Vented cylindrical pencil chamber for dose length product measurements in computed tomography

Features

- Pencil type chamber for measurements within a CT head or body phantom or free in air
- Provides a sensitive measuring length of 10 cm
- Shows a homogeneous response over the whole chamber length

The CT chamber is a vented cylinder chamber designed for dose length product and dose length product rate measurements in computed tomography. The chamber allows the determination of the $CTDI_{100}$[1], $CTDI_W$[2] and $CTDI_{Vol}$[3] according to IEC 61223-2-6 and IEC 61223-3-5.

Specification

Type of product	vented pencil type chamber
Application	dosimetry in computed tomography
Measuring quantities	air kerma length product, exposure length product
Reference radiation quality	120 kV, HVL 8.4 mm Al (RQT9)
Nominal sensitive volume	3.14 cm³
Design	not waterproof, vented, pencil type
Reference point	chamber center
Direction of incidence	radial
Nominal response	14 nC/(Gy·cm)
Chamber voltage	- 100 V nominal ± 500 V maximal high voltage to be connected only with active current-limiting device (I_{max} < 0.5 mA)
Energy response	≤ ± 5 % for (70 ... 150) kV
Leakage current	≤ ± 10 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall material	1 mm PMMA, graphite coated
Wall area density	119 mg/cm²
Dimension of sensitive volume	radius 3.5 mm length 100 mm
Electrode	Al tube, graphited outer diameter 3 mm

Ion collection efficiency at nominal voltage:

Ion collection time	274 µs
Max. dose rate for ≥ 95.0 % saturation	12.4 Gy/s
Max. dose per pulse for ≥ 95.0 % saturation	2.26 mGy

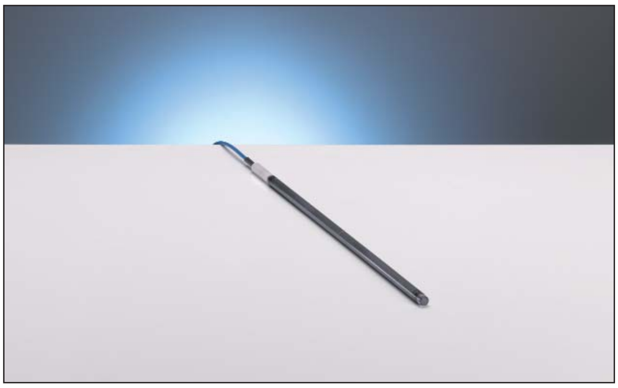
Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(50 ... 150) kV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN30009 CT chamber 3.14 cm³, connecting system BNT
TW30009 CT chamber 3.14 cm³, connecting system TNC
TM30009 CT chamber 3.14 cm³, connecting system M
TL30009 CT chamber 3.14 cm³, connecting system L

[1] $CTDI_{100}$ = Computed Tomography Dose Index 100
[2] $CTDI_W$ = Weighted $CTDI_{100}$
[3] $CTDI_{Vol}$ = Volume $CTDI_W$



CT Chamber
Type 30017

Vented cylindrical pencil chamber for dose length product measurements in computed tomography

Features

- Pencil type chamber for measurements free in air
- Provides a sensitive measuring length of 30 cm
- Shows a homogeneous response over the whole chamber length

The CT chamber is a vented cylinder chamber designed for dose length product and dose length product rate measurements in computed tomography according to the amendment to IEC 60601-2-44.

Specification

Type of product	vented pencil type chamber
Application	dosimetry in computed tomography
Measuring quantities	air kerma length product, exposure length product
Reference radiation quality	120 kV, HVL 8.4 mm Al (RQT9)
Nominal sensitive volume	9.3 cm^3
Design	not waterproof, vented, pencil type
Reference point	chamber center
Direction of incidence	radial
Nominal response	13 nC/(Gy·cm)
Chamber voltage	- 100 V nominal ± 500 V maximal high voltage to be connected only with active current-limiting device (I_{max} < 0.5 mA)
Energy response	≤ ± 5 % for (50 ... 150) kV
Leakage current	≤ ± 10 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall material	1 mm PMMA, graphite coated
Wall area density	119 mg/cm^2
Dimension of sensitive volume	radius 3.5 mm length 300 mm
Electrode	Al tube, graphited outer diameter 3 mm

Ion collection efficiency at nominal voltage:

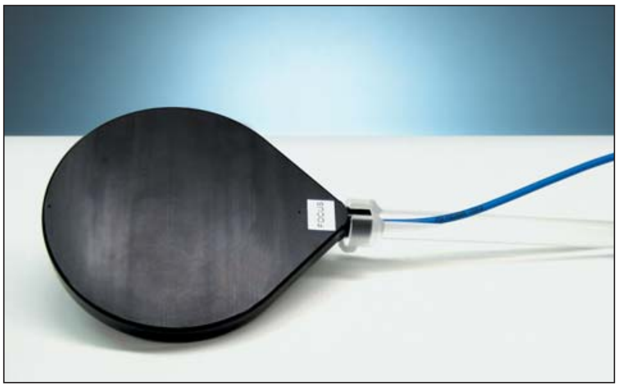
Ion collection time	274 µs
Max. dose rate for ≥ 95.0 % saturation	12.4 Gy/s
Max. dose per pulse for ≥ 95.0 % saturation	2.26 mGy

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(50 ... 150) kV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering Information

TN30017 CT chamber 9.3 cm^3, connecting system BNT
TW30017 CT chamber 9.3 cm^3, connecting system TNC
TM30017 CT chamber 9.3 cm^3, connecting system M
TL30017 CT chamber 9.3 cm^3, connecting system L



75 cm³ SFD Diagnostic Chamber

Type 34060

Shadow-free plane parallel chamber for absolute dosimetry in diagnostic radiology

Features

- Shadow-free design for use with automatic exposure control / brightness control
- Sensitive volume 75 cm³, vented to air
- Suitable for measurements in front of and behind a phantom

The 34060 SFD diagnostic chamber is a general purpose, high precision chamber for measurements in diagnostic radiology. The chamber complies with the standard IEC 61674. Its shadow-free design makes it possible to use the chamber even while the automatic exposure control or brightness control is activated. Together with an adequate diagnostic dosemeter the chamber features a wide dynamic range for measurements either in front of or behind a patient-equivalent phantom. The length of the mounted connection cable is 2.5 m.

Specification

Type of product	vented plane parallel ionization chamber acc. IEC 61674
Application	absolute dosimetry in diagnostic radiology
Measuring quantities	air kerma, exposure
Reference radiation quality	70 kV, HVL 2.58 mm Al (RQR5)
Nominal sensitive volume	75 cm³
Design	not waterproof, vented
Reference point	in chamber center
Direction of incidence	perpendicular to chamber plane, see label 'Focus'
Nominal response	2.8 µC/Gy
Long-term stability	≤ 0.5 % per year
Chamber voltage	200 V nominal ± 400 V maximal
Energy response	≤ ± 2 % (50 ... 150) kV
Polarity effect	≤ 1 %
Directional response	≤ 3 % for chamber tilting up to ≤ ± 15°
Leakage current	≤ ± 5 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance window	0.6 mm polycarbonate, 1.55 g/cm³ 0.002 mm graphite 0.32 g/cm³
Total window area density	93 mg/cm²
Water-equivalent window thickness	0.9 mm
Sensitive volume	radius 45.7 mm depth 2 x 5.71 mm

Ion collection efficiency at nominal voltage:

Ion collection time	1 ms
Max. dose rate for ≥ 99 % saturation ≥ 95 % saturation	 0.16 Gy/s 0.78 Gy/s

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(25 ... 150) kV X-rays
Field size	(11 x 11) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34060 SFD diagnostic chamber 75 cm³, connecting system BNT

TW34060 SFD diagnostic chamber 75 cm³, connecting system TNC

TM34060 SFD diagnostic chamber 75 cm³, connecting system M

TL34060 SFD diagnostic chamber 75 cm³, connecting system L

6 cm³ SFD Mammo Chamber

Type 34069

Shadow-free plane parallel chamber for absolute dosimetry in diagnostic radiology and mammography

Features

- Shadow-free design for use with automatic exposure control
- Sensitive volume 6 cm³, vented to air
- Suitable for measurements in front of and behind a phantom

The 34069 SFD mammo chamber is a high precision chamber for measurements in diagnostic radiology at high dose rates and in mammography. The chamber complies with the standard IEC 61674. Its shadow-free design makes it possible to use the chamber even while the automatic exposure control is activated. Together with an adequate diagnostic dosemeter the chamber features a wide dynamic range for measurements either in front of or behind a patient-equivalent phantom. The length of the mounted connection cable is 2.5 m.

Specification

Type of product	vented plane parallel ionization chamber acc. IEC 61674
Application	absolute dosimetry in diagnostic radiology
Measuring quantities	air kerma, exposure
Reference radiation quality	30 kV, HVL 0.337 mm Al (RQR-M3) 70 kV, HVL 2.58 mm Al (RQR5)
Nominal sensitive volume	6 cm³
Design	not waterproof, vented
Reference point	in chamber center
Direction of incidence	perpendicular to chamber plane, see label 'Focus'
Nominal response	230 nC/Gy
Long-term stability	≤ 2 % per year
Chamber voltage	200 V nominal ± 400 V maximal
Energy response	≤ ± 2 % (25 ... 35) kV
Polarity effect	≤ 1 % (≤ 2 %)
Directional response	≤ 3 % for chamber tilting up to ≤ ± 15°
Leakage current	≤ 5 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance window	0.32 mm PMMA, 1.19 g/cm³ 0.002 mm graphite 0.32 g/cm³
Total window area density	38 mg/cm²
Water-equivalent window thickness	0.4 mm
Sensitive volume	radius 15.2 mm depth 2 x 4.21 mm

Ion collection efficiency at nominal voltage:

Ion collection time	550 µs
Max. dose rate for ≥ 99 % saturation ≥ 95 % saturation	 0.53 Gy/s 2.65 Gy/s

Useful ranges:

Chamber voltage	± (100 ... 400) V
Radiation quality	(25 ... 150) kV X-rays
Field size	(5 x 5) cm² ... (40 x 40) cm²
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

TN34069 SFD mammo chamber 6 cm³, connecting system BNT

TW34069 SFD mammo chamber 6 cm³, connecting system TNC

TM34069 SFD mammo chamber 6 cm³, connecting system M

TL34069 SFD mammo chamber 6 cm³, connecting system L

R/F/D and MAM Detectors

Types 60004, 60005

Semiconductor detectors for diagnostic X-rays

Features

- Fully comply with IEC 61674
- Small size and lightweight precision probes
- For acceptance testing, service and QC in X-ray diagnostics

The R/F/D and MAM detectors are sturdy semiconductor detectors designed to withstand tough handling. Air density corrections with a radioactive check device or measurement of air pressure and temperature are unnecessary. Both detectors do not need a high voltage supply. Fully compliant to IEC 61674 they are suitable for measurements during acceptance tests, service and quality control procedures.
Two detector types are available, covering either the radiography/fluoroscopy and dental range (40 … 150) kV or the mammography range (25 … 45) kV.

The following quantities can be measured in conjunction with e.g. the NOMEX Dosemeter:

- air kerma and dose (with an additional absorber) in the conventional range
- air kerma and dose (with an additional absorber) in the dental range
- air kerma and dose (with additional 2 mm Al) in mammography
- dose per pulse and number of pulses in fluoroscopy and irradiation time.

Specification

Type of product	semiconductor detector
Application	absolute dosimetry in diagnostic radiology
Measuring quantities	air kerma, exposure
Reference radiation qualities	30 kV, HVL 0.337 mm Al (RQR-M3) 70 kV, HVL 2.58 mm Al (RQR5)
Reference point	5.7 mm below the top side
Direction of incidence	perpendicular to detector plane
Nominal response	type 60005: 15 µC/Gy type 60004: 50 µC/Gy
Long-term stability	≤ ± 1 % per year
Energy response	≤ ± 5 %
Leakage current	≤ ± 100 fA
Cable leakage	≤ 1 pC/Gy*cm

Measures:

Dimension of volume	type 60005: 2x diameter 5.04 mm type 60004: diameter 11.28 mm
Outer dimensions	40 mm x 30 mm x 12 mm

Useful ranges:

Radiation qualities	(25 ... 45) kV X-rays (RQR-M, MRV, WAV, WRV, WSV, RRV) (40 ... 150) kV X-rays (RQR2 ... RQR10, RQA2 ... RQA10)
Temperature	(10 ... 40) °C (50 … 104) °F
Humidity	(10 ... 80) %, max. 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

Connecting system TNC or L:

60004 R/F/D Detector
60005 MAM Detector

System Incorporated Detectors for Diagnostic Radiology

Besides the radiation detectors presented in this chapter, there are available a number of further detectors which are incorporated components of diagnostic dosemeters.

DIAMENTOR® Patient Dosimetry Chambers

DIAMENTOR chambers for dose area product measurements are available in different sizes and types to cover a wide range of diagnostic X-ray installations. The chambers can easily be mounted to the X-ray collimator or are firmly installed parts of the X-ray installation. The transparent models do not interfere with the collimators light field diaphragm.

NOMEX® Multimeter

The NOMEX Multimeter is a miniaturized non-invasive measuring system for absolute dosimetry and quality control in X-ray diagnostic radiology. It can be used for radiography, fluoroscopy, dental, CT and mammography (Mo/Mo, Mo/Rh, W/Al, W/Rh, W/Ag, Rh/Rh) application.

XLS X-Ray Leakage Chamber

This rectangular plane parallel XLS ionization chamber is used as part of the XLS X-ray leakage system for radiation leakage measurements of diagnostic X-ray installations. Up to 18 of these chambers can be arranged for radiation leakage detection around X-ray tubes.

Notes

Radiation Monitoring Detectors

Radiation Monitoring Detectors

3 Liter Radiation Monitoring Chamber

Types 34031

Cylindrical polyethylene ionization chamber for stationary radiation monitoring of gamma radiation

Features

- Vented sensitive volume of 3 liters
- Suitable as radiation monitoring chamber
- Gamma energy range 80 keV to 1.3 MeV

The 3 liter chamber is used as a stationary surveillance device for environmental radiation monitoring. The chamber is designed to measure protection level dose rates. The chamber is fully guarded up to the sensitive volume. Since the sensitive volume is open to the surroundings, air density correction is required for precise measurement. The cylindrical chamber is made of graphite coated polyethylene with 4 mm wall thickness. The ion-collecting electrode is made of graphite coated polyethylene too. The external chamber diameter is 150 mm and the length is approx. 200 mm. For the transfer of the measuring signal and the polarizing voltage, the chamber is supplied with two coaxial connectors. The maximal chamber polarizing voltage is 1000 V. The chamber is supplied with an integrated adapter for positioning a radioactive check source of type T48010, which makes it possible to check the proper performance of the entire measuring system.

Specification

Type of product	vented cylindrical ionization chamber
Application	radiation monitoring
Measuring quantity	photon equivalent dose
Nominal sensitive volume	3 l
Design	not waterproof, vented
Reference point	chamber center
Direction of incidence	radial
Nominal response	100 µC/Sv
Chamber voltage	1000 V nominal
Energy response	≤ ± 10 % (E_{photon} ≥ 80 keV)
Directional response in air	≤ ± 10 % for tilting perpendicular to the axis up to ± 20°
Leakage current	≤ ± 50 fA

Materials and measures:

Wall of sensitive volume	4 mm PE graphite coated, 0.95 g/cm³
Total wall area density	0.38 g/cm²
Dimension of sensitive volume	radius 71.25 mm length 200 mm
Central electrode	graphite coated PE, diameter 28 mm
Outer dimensions	diameter 150 mm length 200 mm

Ion collection efficiency at nominal range:

Ion collection time	25 ms
Max. dose rate for ≥ 99 % saturation ≥ 90 % saturation	 0.95 Sv/h 9.5 Sv/h

Useful ranges:

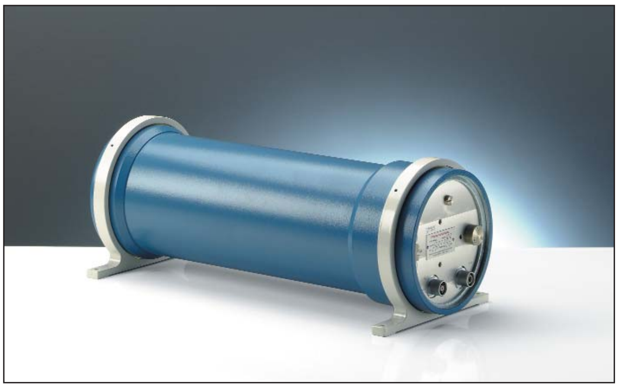
Radiation quality	80 keV ... 1.3 MeV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

T34031 Radiation monitoring chamber 3 l, Fischer coax connectors

Option

T7262/U10-1.5 Connection cable with M connector, length 1.5 m



50 Liter Radiation Monitoring Chamber

Type 7262

Cylindrical pressurized steel ionization chamber for stationary gamma radiation monitoring

Features

- Sealed sensitive volume of 50 liters
- Suitable as stationary radiation monitoring chamber
- Gamma energy range 80 keV to 1.3 MeV

The ionization chamber T7262 has a constructive volume of 5 liters filled with Argon gas at the pressure of 10 bar, resulting in an effective sensitive volume of 50 liters. This superior design makes the chamber very sensitive and enables performing low level gamma radiation measurements down to the natural radiation background. The chamber is used as highly sensitive stationary surveillance device for environmental radiation monitoring. The chamber is fully guarded up to the sensitive volume. Since the sensitive volume is sealed, no air density correction is required. The cylindrical 50 liter chamber is made of steel with 3.25 mm wall thickness and a 3 mm aluminum cover. The ion-collecting electrode is made of brass. The external chamber diameter is 195 mm and the length is 538 mm. The chamber is supplied with two coaxial Fischer connectors for the transfer of the measuring signal and the polarizing voltage. Via an optional adapter cable of 1.5 m length, the chamber can be connected to a dosemeter with M connector, which has input circuits on ground potential. The maximal chamber polarizing voltage is 1000 V.

Specification

Type of product	pressurized cylindrical ionization chamber
Application	radiation monitoring
Measuring quantity	photon equivalent dose
Nominal sensitive volume	50 l
Design	sealed and pressurized, filled with Ar (10 bar)
Reference point	chamber center
Direction of incidence	radial
Nominal response	2 mC/Sv.
Chamber voltage	1000 V nominal
Energy response	≤ ± 10 % (E_{photon} ≥ 80 keV)
Directional response in air	≤ ± 10 % for tilting perpendicular to the axis up to ± 20°
Leakage current	≤ ± 50 fA

Materials and measures:

Wall of sensitive volume	3 mm Al, 2.7 g/cm³ 3.25 mm steel, 7.85 g/cm³
Total wall area density	3.361 g/cm²
Dimension of sensitive volume	radius 66.75 mm length 360 mm
Central electrode	brass, diameter 17.5 mm
Outer dimensions	diameter 195 mm length 538 mm

Ion collection efficiency at nominal range:

Ion collection time	30 ms
Max. dose rate for ≥ 99 % saturation ≥ 90 % saturation	 1 mSv/h 10 mSv/h

Useful ranges:

Radiation quality	80 keV ... 1.3 MeV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering Information

T7262 Radiation monitoring chamber 50 l, Fischer coax connectors

Option

T7262/U10-1.5 Connection cable with M connector, length 1.5 m

1 Liter Spherical Ionization Chamber
Type 32002

Spherical ionization chamber for radiation protection

Features

- Vented sensitive volume of 1 liter
- Suitable for survey meter calibration and low level measurements
- Superior energy response, reproducibility, directional dependence and long-term stability
- Radioactive check device (option)

The spherical chamber is designed for the measurement of ionizing radiation in radiation protection. Superior features make the chamber suitable as standard chamber for calibration purposes. It fulfills the requirement for excellent reproducibility and long-term stability of the sensitive volume. The spherical construction ensures a nearly uniform response to radiation from every direction. The energy response is very flat. This is achieved by the thin layer of aluminum on the inner wall surface, which provides for an increased photoelectric yield to compensate for the absorption of soft X-rays. The outer chamber diameter is 140 mm.

Specification

Type of product	vented spherical ionization chamber
Application	radiation protection measurements
Measuring quantity	air kerma, photon equivalent dose
Nominal sensitive volume	1 l
Design	not waterproof, vented
Reference point	chamber center
Nominal response	40 µC/Gy
Chamber voltage	400 V nominal ± 500 V maximal
Energy response	≤ ± 4 % (32002)
Leakage current	≤ ± 10 fA

Materials and measures:

Wall of sensitive volume	3 mm POM (polyoxymethylene), 0.02 mm graphite, 0.22 mm varnish
Total wall area density	453 mg/cm²
Central electrode	graphite coated polystyrene, diameter 50 mm
Outer dimension	diameter 140 mm

Ion collection efficiency at nominal range:

Ion collection time	37 ms
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 210 mGy/h 420 mGy/h
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 1.6 µGy 3.1 µGy

Useful ranges:

Chamber voltage	± (300 ... 500) V
Radiation quality	25 keV ... 50 MeV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering information

TN32002 Spherical chamber 1 l, connecting system BNT
TW32002 Spherical chamber 1 l, connecting system TNC
TM32002 Spherical chamber 1 l, connecting system M

Options

T48010 Radioactive check device ^{90}Sr
T48001 Chamber holding device for check device

10 Liter Spherical Ionization Chamber

Type 32003

Spherical ionization chamber for radiation protection

Features

- Vented sensitive volume of 10 liters
- Suitable for survey meter calibration and low level measurements
- Superior energy response, reproducibility, directional dependence and long-term stability
- Radioactive check device (option)

The spherical chamber is designed for the measurement of ionizing radiation in radiation protection. Superior features make the chamber suitable as standard chamber for calibration purposes. It fulfills the requirement for excellent reproducibility and long-term stability of the sensitive volume. The spherical construction ensures a nearly uniform response to radiation from every direction. The energy response is very flat. This is achieved by the thin layer of aluminum on the inner wall surface, which provides for an increased photoelectric yield to compensate for the absorption of soft X-rays. The outer chamber diameter is 276 mm.

Specification

Type of product	vented spherical ionization chamber
Application	radiation protection measurements
Measuring quantity	air kerma, photon equivalent dose
Nominal sensitive volume	10 l
Design	not waterproof, vented
Reference point	chamber center
Nominal response	330 µC/Gy
Chamber voltage	400 V nominal ± 500 V maximal
Energy response	≤ ± 3 %
Leakage current	≤ ± 10 fA

Materials and measures:

Wall of sensitive volume	2.75 mm POM (polyoxymethylene) 0.02 mm graphite, 0.22 mm varnish
Total wall area density	417 mg/cm²
Central electrode	graphite coated polystyrene, diameter 100 mm
Outer dimensions	diameter 276 mm

Ion collection efficiency at nominal range:

Ion collection time	150 ms
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 13 mGy/h 26 mGy/h
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 0.3 µGy 0.8 µGy

Useful ranges:

Chamber voltage	± (300 ... 500) V
Radiation quality	25 keV ... 50 MeV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering information

TN32003 Spherical chamber 10 l, connecting system BNT
TW32003 Spherical chamber 10 l, connecting system TNC
TM32003 Spherical chamber 10 l, connecting system M

Options

T48010 Radioactive check device ^{90}Sr
T48001 Chamber holding device for check device

PS-50 and PS-10 Spherical Chambers

Types 32007S, 32008S

Primary standard spherical ionization chambers for radiation protection measurements

Features

- Vented sensitive volumes of 50 cm^3 and 10 cm^3
- Suitable as primary standard for radiation protection measurements
- Exact volume individually determined
- Designed in collaboration with the National Institute of Standards and Technology (NIST)

The spherical graphite chambers PS-50 and PS-10 are vented ionization chambers for the use as primary standard for radiation protection measurements and for absolute dosimetry. The spherical graphite chambers have been designed in collaboration with the Radiation Interactions and Dosimetry Group at the National Institute of Standards and Technology (NIST). The exact volume of each chamber is individually determined. The homogeneity of the walls and electrodes is 0.06 mm. The chambers are constructed with a long rigid stem of approx. 29 cm length for easy mounting in the radiation beam. Air density correction is required for each measurement.

Specification

Type of product	vented spherical ionization chambers
Application	primary standard for radiation protection measurements
Measuring quantity	air kerma, photon equivalent dose
Nominal sensitive volume	50 cm^3 (32007S) 10 cm^3 (32008S)
Design	not waterproof, vented
Reference point	chamber center
Nominal response	1.73 µC/Gy (32007S) 0.349 µC/Gy (32008S)
Chamber voltage	1000 V nominal (32007S) 500 V nominal (32008S) ± 1000 V maximal
Directional response in air	≤ ± 0.5 % for rotation around the chamber axis and ≤ ± 1 % for tilting the chamber axis up to ± 60° (32007S) ≤ ± 1 % for tilting the chamber axis up to ± 50° (32008S)
Leakage current	≤ ± 5 fA

Materials and measures:

Wall of sensitive volume	3.5 mm graphite
Total wall area density	647 mg/cm^2
Central electrode	graphite, diameter 3 mm
Outer dimensions	diameter 53 mm (32007S) diameter 34 mm (32008S)

Ion collection efficiency at nominal range:

Ion collection time	8.7 ms (32007S) 1.9 ms (32008S)
Max. dose rate for ≥ 99,5 % saturation ≥ 90 % saturation	 (32007S), (32008S) 1.23 mGy/s, 26 mGy/s 2.46 mGy/s, 52 mGy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 (32007S), (32008S) 7.1 µG, 33 µGy 14.2 µGy, 65 µGy

Useful ranges:

Chamber voltage	± (400 … 1000) V
Radiation quality	^{60}Co, ^{137}Cs
Field size (square field)	≥ (6 x 6) cm^2 (32007S) ≥ (4 x 4) cm^2 (32008S)
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering information

TN32007S Spherical chamber PS-50, connecting system BNT

TN32008S Spherical chamber PS-10, connecting system BNT

Spherical Ionization Chamber TK-30

Type 32005

Spherical ionization chamber with a long rigid stem for radiation protection measurement

Features

- Vented sensitive volume of 28 cm^3
- Suitable as high precision reference chamber for radiation protection dosimetry
- Very flat energy response within a wide range

The spherical chamber TK-30 is designed as a reference chamber for absolute dosimetry to be used by secondary standard dosimetry laboratories (SSDL) and users with high quality requirements. It has very small variations of response with radiation quality from low X-ray energies up to high-energy photon radiation. The guard ring is designed up to the sensitive volume. The chamber is constructed with a long rigid stem of approx. 20 cm length for easy mounting in the radiation beam. Air density correction is required for each measurement.

Specification

Type of product	vented spherical ionization chamber
Application	radiation protection measurements
Measuring quantity	photon equivalent dose, exposure
Nominal sensitive volume	27.9 cm^3
Design	not waterproof, vented
Reference point	chamber center
Direction of incidence	radial
Nominal response	900 nC/Gy
Chamber voltage	400 V nominal ± 1000 V maximal
Energy response	≤ ± 5 % (48 keV ... ^{60}Co)
Directional response in air	≤ ± 0.5 % for rotation around the chamber axis and ≤ ± 3 % for tilting of the axis up to ± 45°
Leakage current	≤ ± 5 fA

Materials and measures:

Wall of sensitive volume	3 mm POM (polyoxymethylene) 0.02 mm graphite, 0.22 mm varnish
Total wall area density	453 mg/cm^2
Dimension of sensitive volume	radius 22 mm
Central electrode	graphite coated PMMA, diameter 4.2 mm

Ion collection efficiency at nominal range:

Ion collection time	4.5 ms
Max. dose rate for ≥ 99 % saturation ≥ 90 % saturation	 29.4 Gy/h 294 Gy/h
Max. dose per pulse for ≥ 99 % saturation	 26 μGy

Useful ranges:

Chamber voltage	± (200 ... 400) V
Radiation quality	25 keV ... 50 MeV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering information

TN32005 Spherical chamber TK-30, connecting system BNT

TW32005 Spherical chamber TK-30, connecting system TNC

TM32005 Spherical chamber TK-30, connecting system M

30 cm³ Cylinder Stem Ionization Chamber

Type 23361

Cylindrical PMMA ionization chamber with a long rigid stem for radiation protection measurement

Features

- Vented sensitive volume of 30 cm³
- Suitable as high precision reference chamber for radiation protection dosimetry
- Very flat energy response within a wide range
- Radioactive check device (option)

The cylinder stem chamber is designed as a reference chamber for absolute dosimetry to be used by secondary standard dosimetry laboratories (SSDL) and users with high quality requirements. It has very small variations of response with radiation quality from low X-ray energies up to high-energy photon radiation. The guard ring is designed up to the sensitive volume. The chamber is constructed with a long rigid stem of approx. 20 cm length for easy mounting in the radiation beam. An acrylic build-up cap with 3 mm wall thickness for in-air measurement in ^{60}Co beams is included with each chamber, as well as a calibration certificate. Air density correction is required for each measurement. A radioactive check device and an appropriate holding device are available.

Specification

Type of product	vented cylindrical ionization chamber
Application	radiation protection measurements
Measuring quantity	air kerma, photon equivalent dose, exposure
Nominal sensitive volume	30 cm³
Design	not waterproof, vented
Reference point	on chamber axis, 27 mm from chamber tip
Direction of incidence	radial
Nominal response	1 µC/Gy
Chamber voltage	400 V nominal ± 500 V maximal
Energy response	≤ ± 4 % (40 keV ... ^{60}Co)
Directional response in air	≤ ± 0.5 % for for rotation around the chamber axis *for tilting see diagram page 64*
Leakage current	≤ ± 10 fA
Stem leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Wall of sensitive volume	1 mm PMMA, graphited
Total wall area density	119 mg/cm²
Dimension of sensitive volume	radius 15.5 mm length 51 mm
Central electrode	graphite coated Al, diameter 14 mm
Outer dimensions	diameter 33 mm length 335 mm
Build-up cap	PMMA, thickness 3 mm

Ion collection efficiency at nominal range:

Ion collection time	1.3 ms
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 60 mGy/s 120 mGy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 50 µGy 100 µGy

Useful ranges:

Radiation quality	30 keV ... 50 MeV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering information

TN23361 Cylinder stem chamber 30 cm³, connecting system BNT

TW23361 Cylinder stem chamber 30 cm³, connecting system TNC

TM23361 Cylinder stem chamber 30 cm³, connecting system M

Options

T48010 Radioactive check device ^{90}Sr

T23237 Chamber holding device for check device

$H_p(10)$ Secondary Standard Chamber

Type 34035

Parallel plate ionization chamber for direct measurement of $H_p(10)$ personal dose equivalent on a slab phantom

Features

- Vented sensitive volume of 10 cm^3
- Measures the $H_p(10)$ personal dose equivalent directly
- Suitable as a reference chamber for $H_p(10)$ calibration

The parallel plate ionization chamber model 34035[1] is integrated into a slab phantom to measure the $H_p(10)$ radiation protection measuring quantity directly. The high performance chamber is designed to be used as a secondary standard chamber for calibration purposes. The beam calibration with the $H_p(10)$ chamber makes it unnecessary to precisely determine the spectrum of the X-ray beam. The chamber comes uncalibrated; a primary standard calibration by PTB, the German National Laboratory, is available. The chamber set includes a phantom slab of 31 mm thickness with chamber assembly and an additional PMMA phantom slab of 120 mm thickness. Both sets available include an adapter cable to connect the chamber either to a dosemeter with M connector or with BNC connector and banana pin. The $H_p(10)$ chamber should be used in connection with a high quality dosemeter such as UNIDOS, UNIDOS E or UNIDOS*webline* to ensure best performance.

Specification

Type of product	vented parallel plate chamber
Application	radiation protection measurements
Measuring quantity	$H_p(10)$ personal dose equivalent
Nominal sensitive volume	10 cm^3
Design	not waterproof, vented
Reference conditions	20°C, 1013 hPa 65 % rel. humidity
Reference point	chamber center, 13.5 mm below chamber surface or 15.5 mm below surface of integrated step cylinder
Nominal response	285 nC/Sv
Chamber voltage	400 V nominal
Leakage current	≤ ± 10 fA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Phantom material	PMMA
Outer dimensions	300 mm x 300 mm
chamber assembly	height 31 mm
additional slab phantom	height 120 mm

Useful ranges:

Chamber voltage	± (300 ... 500) V
Radiation quality	(15 ... 1400) keV
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering information

L981937 $H_p(10)$ Secondary standard chamber type 34035, connecting system M

L981938 $H_p(10)$ Secondary standard chamber type 34035, connecting system BNC and banana pin

Option

PTB Primary standard calibration upon request

[1] Ankerhold, Ambrosi, Eberle – A chamber for determining the conventionally true value of $H_p(10)$ and H*(10) needed by calibration laboratories – Rad. Prot. Dos. Vol. 96, Nos 1-3, pp. 133 - 137 (2001), Nucl. Techn. Publishing

Monitor Ionization Chambers

Types 34014, 786

Large size plane parallel transmission chambers for use as dose monitors combined with calibration facilities

Features

- Vented sensitive volumes of 94 cm^3 and 86 cm^3
- Include twin-sensitive volumes
- Shadow-free transmission chambers for dose monitoring with calibration facilities

The circular plane parallel transmission chambers are used for dose monitoring in combination with calibration benches. The sensitive volumes are designed as twin-chambers with 2.5 mm measuring depth each and a diameter of 155 mm (model 786) or 148 mm (model 34014). The chamber walls and the electrodes are made of polyimide (PI) of 0.025 mm thickness each with graphite layer. The chambers are fully guarded. The external diameter of the chamber housing is 230 mm. Two holes with 6 mm threads serve for mechanical chamber fixation.

Two chamber versions are available: model 786 is used together with dosemeters having the input circuits on ground potential, and model 34014 is used together with dosemeters having the input circuits on high voltage.

Specification

Type of product	vented plane parallel twin-chambers
Application	dose monitoring in calibration facilities
Measuring quantity	exposure
Nominal sensitive volumes	86 cm^3 (34014) 94 cm^3 (786)
Design	not waterproof, vented
Nominal response	depends on field size
Chamber voltage	400 V nominal
Leakage current	≤ 1 pA

Materials and measures:

Entrance window	3 x 0.025 mm polyimide, graphite coated
Total window area density	3 x 3.55 mg/cm^2
Electrode	polyimide foil, graphite coated
Outer dimensions	diameter 230 mm

Ion collection efficiency at nominal voltage:

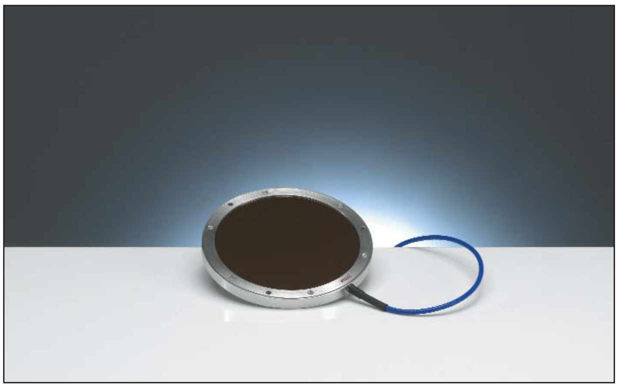
Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 8.5 Gy/s 17 Gy/s (34014) 18 Gy/s (786)
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 590 µGy 1.19 mGy

Useful ranges:

Radiation quality	(7.5 ... 420) kV X-rays
Field size	≤ 148 mm diameter (34014) ≤ 155 mm diameter (786)
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering information

TN34014 Monitor chamber, connecting system BNT
TW34014 Monitor chamber, connecting system TNC
TM786 Monitor chamber, connecting system M
TB786 Monitor chamber, connecting system BNC and banana pin
Monitor chambers with smaller diameter of sensitive volume upon request



X-ray Therapy Monitor Chamber

Type 7862

Large size plane parallel transmission chamber for use as dose monitor combined with X-ray therapy units

Features

- Vented sensitive volume of 17.6 cm³
- Shadow-free transmission chamber for dose monitoring with radiation therapy X-ray equipment

The circular plane parallel transmission chamber model 7862 is used for dose monitoring in combination with radiotherapy X-ray units. The sensitive volume is designed as a very thin cylinder of 2.4 mm thickness and 96.5 mm diameter. The chamber wall and the electrode are made of polyimide (PI) of 0.05 mm thickness each with graphite layer, mechanically protected by another PI foil of 0.05 mm in front of each wall. The nominal photon energy range is 7.5 kV up to 420 kV and the leakage current is less than 1 pA. The chamber is fully guarded. The external diameter of the chamber housing is 119.5 mm. Three holes with 3.5 mm threads serve for mechanical chamber fixation. The transmission chamber model 7862 is used in connection with dosemeters having the input circuits on ground potential.

Specification

Type of product	vented plane parallel triple-chamber
Application	dose monitoring in X-ray therapy units
Measuring quantity	exposure
Nominal sensitive volume	17.6 cm³
Design	not waterproof, vented
Nominal response	depends on field size
Chamber voltage	400 V nominal
Leakage current	≤ 1 pA

Materials and measures:

Entrance window	4 x 0.05 mm polyimide, graphite coated
Total window area density	4 x 7.1 mg/cm²
Electrode	polyimide foil, graphite coated
Outer dimensions	diameter 119.5 mm

Ion collection efficiency at nominal voltage:

Max. dose rate for ≥ 99.5 % saturation ≥ 99.0 % saturation	 10 Gy/s 20 Gy/s
Max. dose per pulse for ≥ 99.5 % saturation ≥ 99.0 % saturation	 640 µGy 1.29 mGy

Useful ranges:

Radiation quality	(7.5 ... 420) kV X-rays
Field size	≤ 95 mm diameter
Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m³
Air pressure	(700 ... 1060) hPa

Ordering information

TM7862 Monitor chamber for X-ray therapy units, connecting system M

Böhm Extrapolation Chamber

Type 23392

Low energy extrapolation chamber with adjustable volume depth for measurements of absorbed dose in soft tissue

Features

- Measures absolute dose of beta radiation and X-rays in soft tissue equivalent material very precisely
- Includes a micrometer screw for the depth adjustment of the sensitive volume down to zero
- Suitable for beta calibration at PSDLs and SSDLs

The Böhm extrapolation chamber is a high quality device for absorbed dose measurements of beta and low energy X radiation in certain depths below the surface of the entrance window. Primary standard dosimetry laboratories (PSDL) and secondary standard dosimetry laboratories (SSDL) use it for low energy radiation calibration. The dose is determined from the ionization density in a small air gap, the extrapolation chamber volume, embedded in tissue equivalent material (PMMA). The chamber is supplied with a very thin entrance window of 0.75 mg/cm^2 and a collecting electrode of 30 mm in diameter. By means of the built-in micrometer screw, the collecting electrode surrounded by a guard ring of 15 mm can be moved to adjust the depth of the sensitive volume between 10.5 mm and 0.5 mm. The zero point of the chamber depth setting can be obtained by measuring the chamber capaciting charge C versus the chamber depth x and extrapolating C^{-1} towards x = 0. The chamber is equipped with two BNC sockets for signal and polarizing voltage. A connection cable from both BNC sockets to an electrometer with M type connector is available. An electrometer with the input circuits on ground potential is required. The extrapolation chamber comes in a protective storage case.

Specification

Type of product	extrapolation chamber according to Böhm
Application	absolute dosimetry of beta radiation and X-rays
Measuring quantity	absorbed dose in soft tissue
Nominal sensitive volume	(0.353 ... 7.422) cm^3
Design	not waterproof, vented, fully guarded
Reference point	in chamber center of entrance foil underside
Nominal response	dependent on electrode distance
Chamber voltage	dependent on electrode distance 500 V maximal
Leakage current	≤ 1 pA
Cable leakage	≤ 1 pC/(Gy·cm)

Materials and measures:

Entrance window	PET, graphite coated
Total window area density	0.75 mg/cm^2
Measuring electrode	diameter 30 mm
Rear electrode	PMMA, graphite coated diameter 60.5 mm
Distance between electrodes	(0.5 ... 10.5) mm

Ion collection efficiency at nominal voltage:

Ion collection time and max. dose rate	dependent on electrode distance

Useful ranges:

Temperature	(10 ... 40) °C (50 ... 104) °F
Humidity	(10 ... 80) %, max 20 g/m^3
Air pressure	(700 ... 1060) hPa

Ordering information

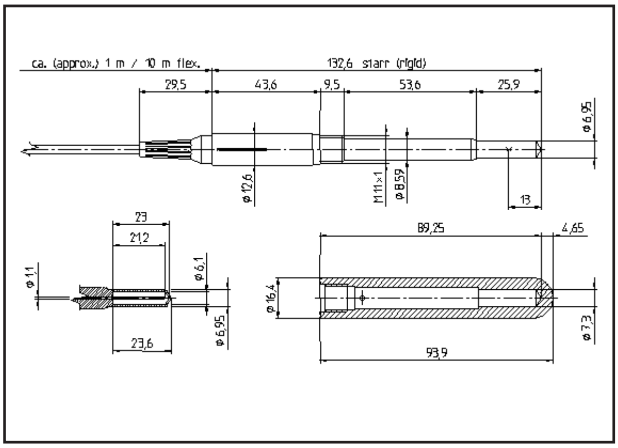
T23392 Böhm extrapolation chamber

T23392/U5 Connection cable for Böhm extrapolation chamber, connecting system M

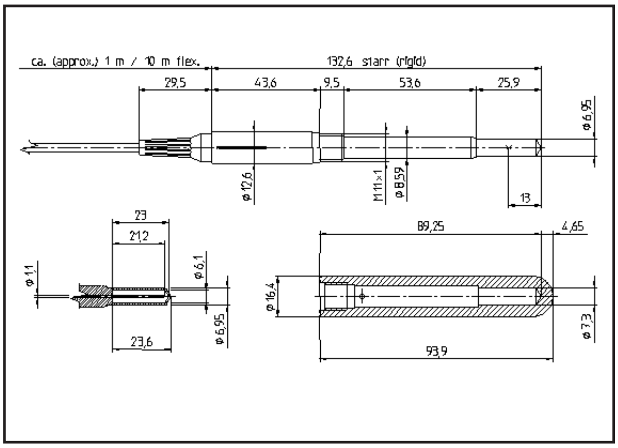
Quick View

Product Family Quick View

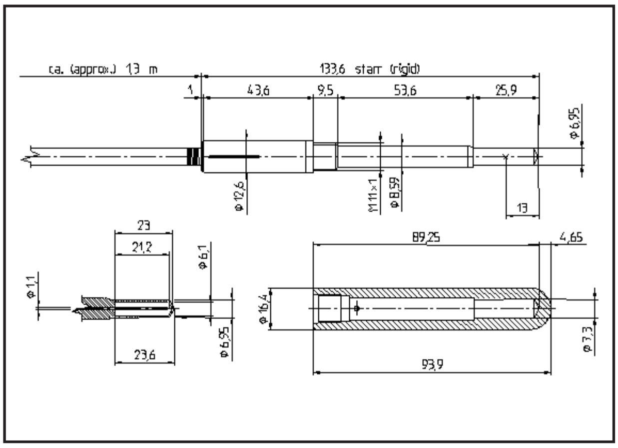
Drawings



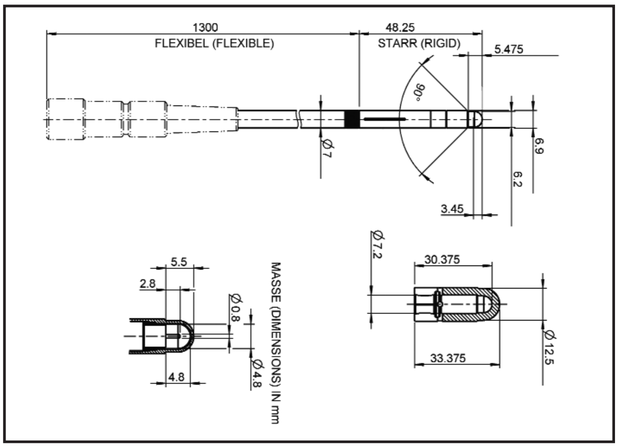
Farmer Chamber 30010



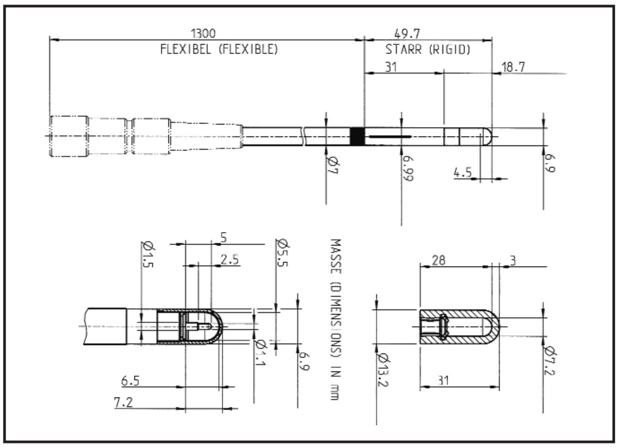
Farmer Chamber 30012



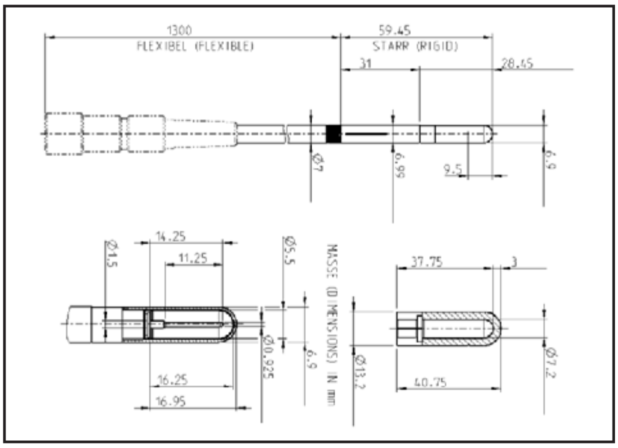
Farmer Chamber 30013



0.07 cm³ Semiflex 3D Chamber 31021

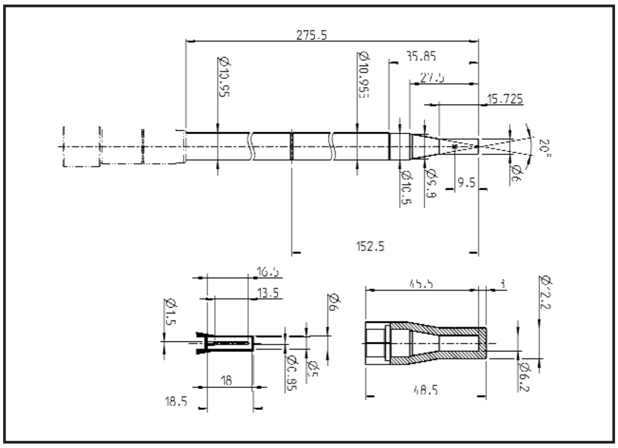


0.125 cm³ Semiflex Chamber 31010

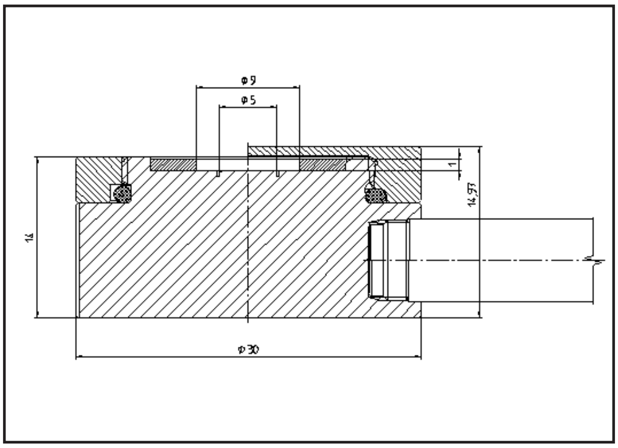


0.3 cm³ Semiflex Chamber 31013

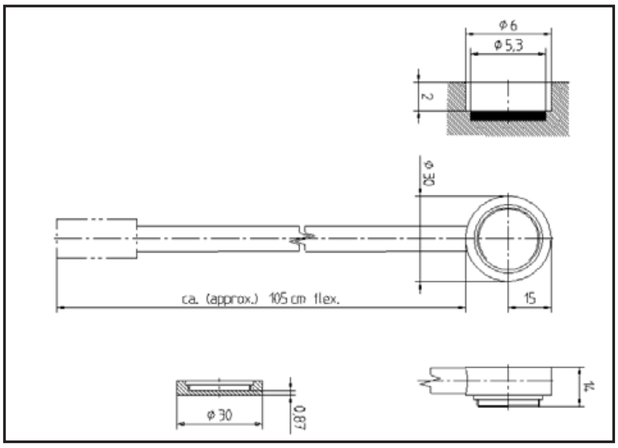
PTW



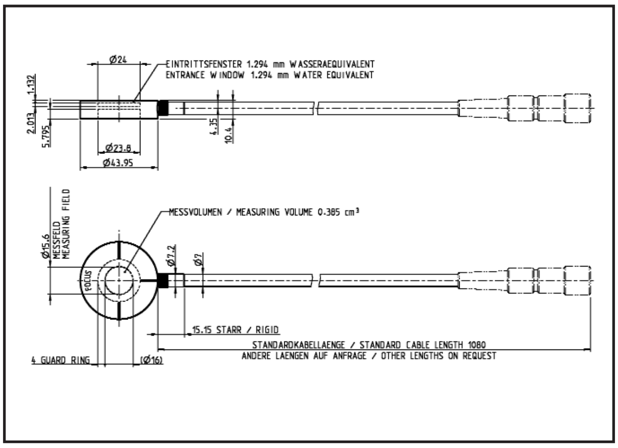
0.3 cm³ Rigid Stem Chamber 30016



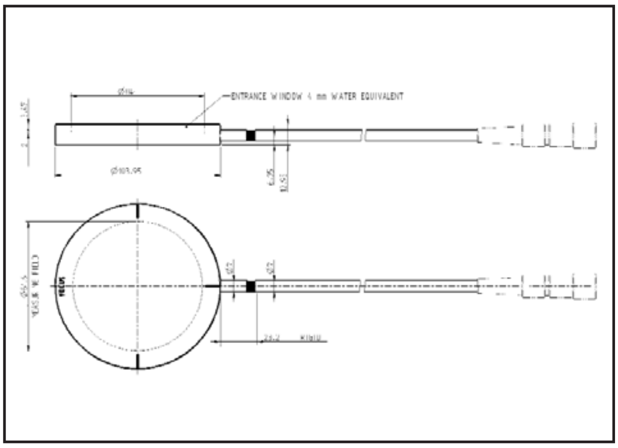
Advanced Markus Chamber 34045



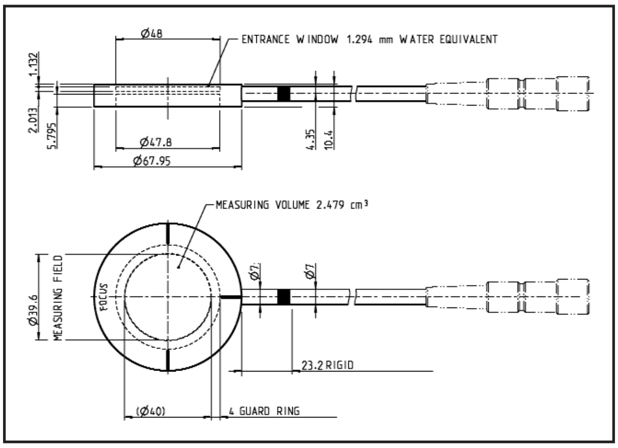
Markus Chamber 23343



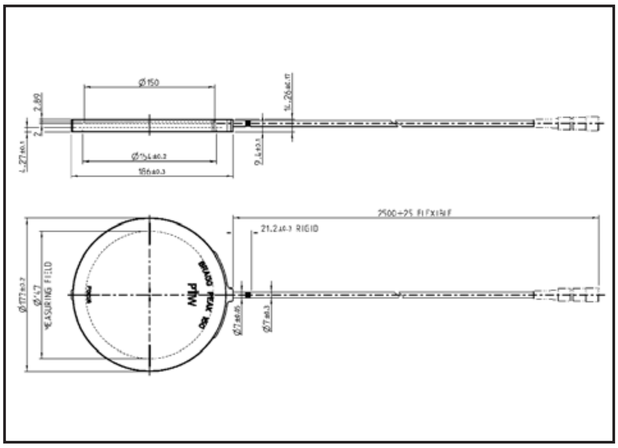
Roos Chamber 34001



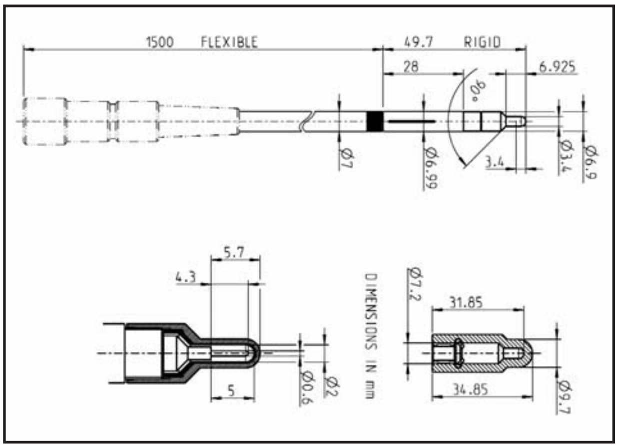
10.5 cm³ Bragg Peak Chamber 34070



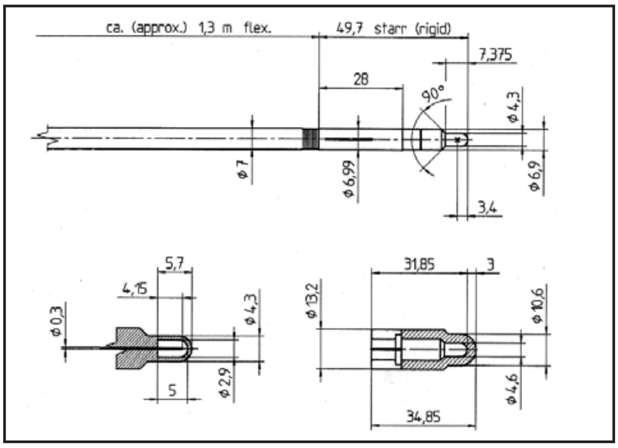
2.5 cm³ Bragg Peak Chamber 34073



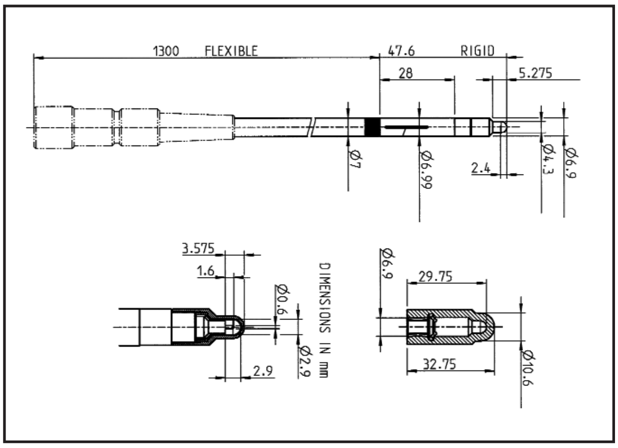
34 cm³ Bragg Peak 150 Chamber 34089



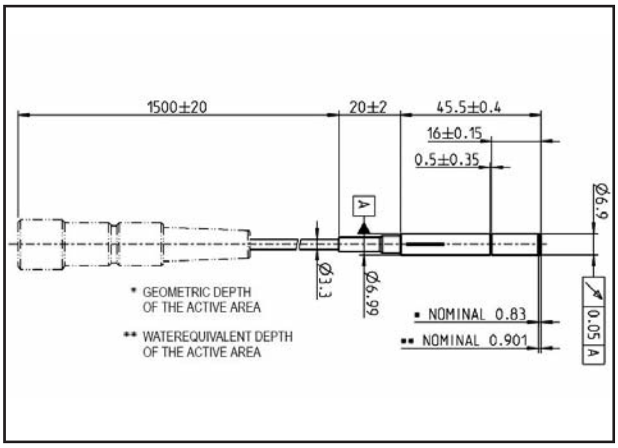
PinPoint Chamber 31023



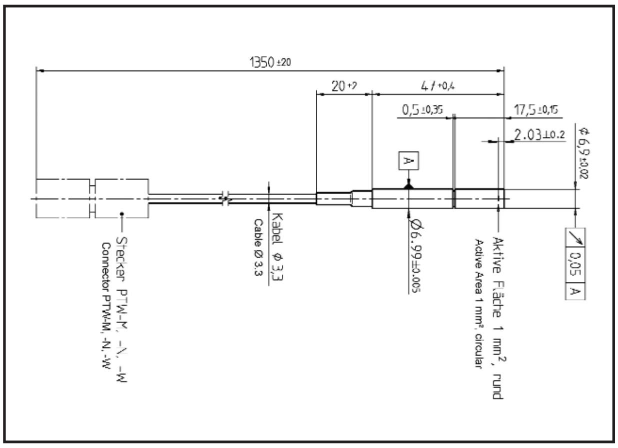
PinPoint Chamber 31015



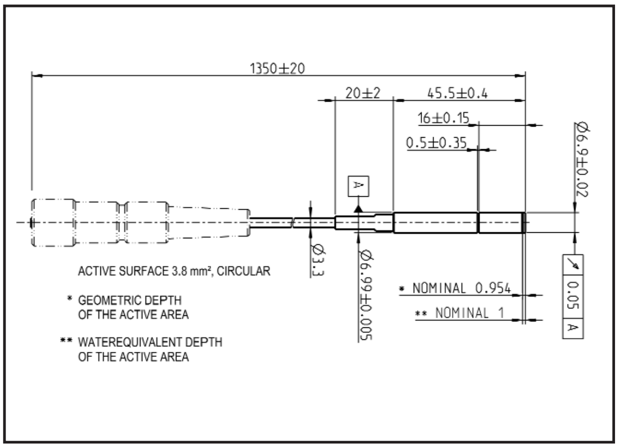
PinPoint 3D Chamber 31022



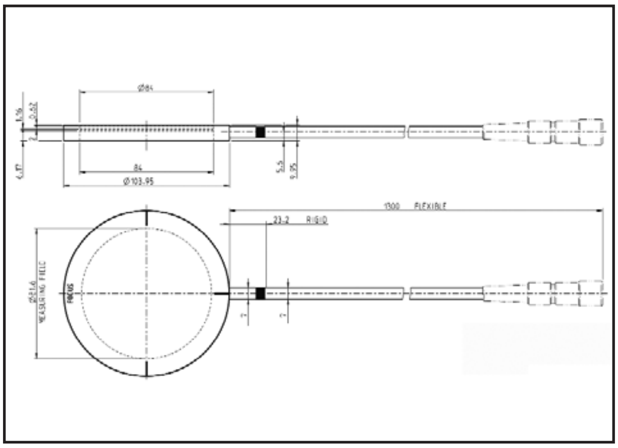
microSilicon 60023



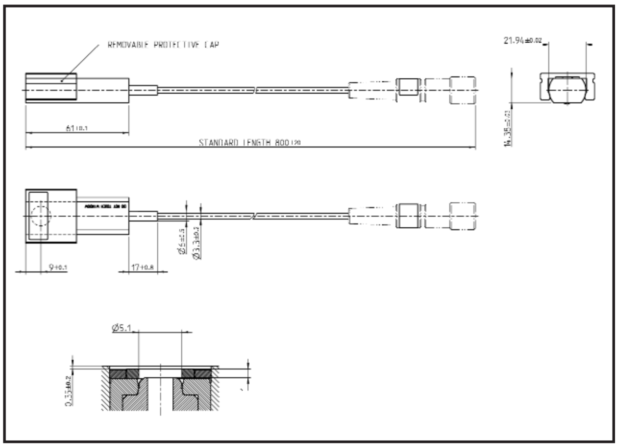
Dosimetry Diode P 60016



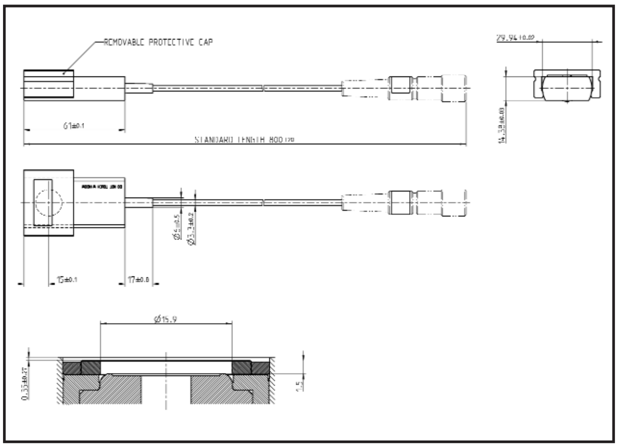
microDiamond 60019



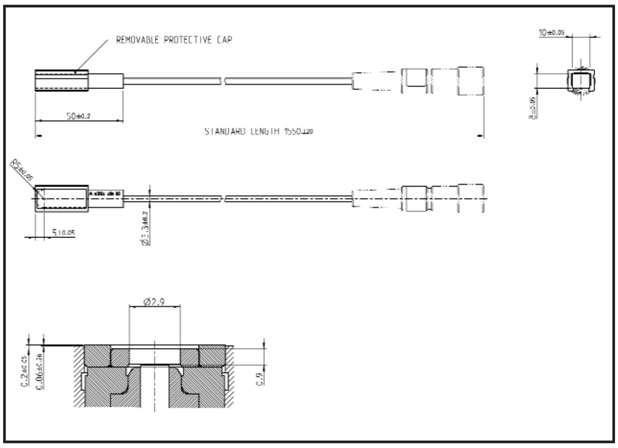
T-REF Chamber 34091



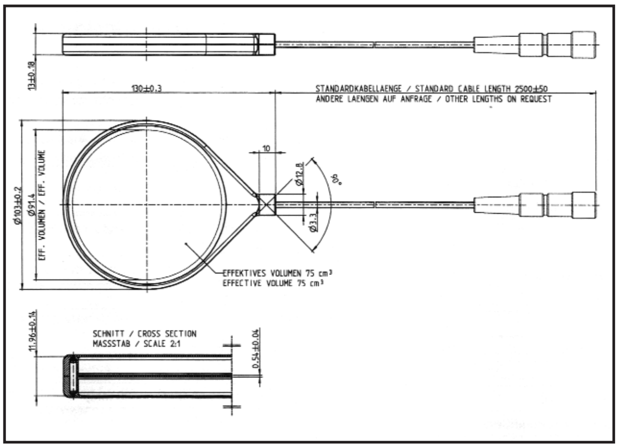
0.02 cm³ Soft X-Ray Chamber 23342



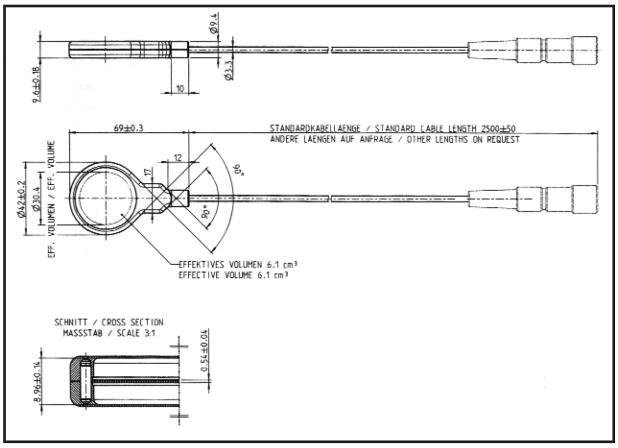
0.2 cm³ Soft X-Ray Chamber 23344



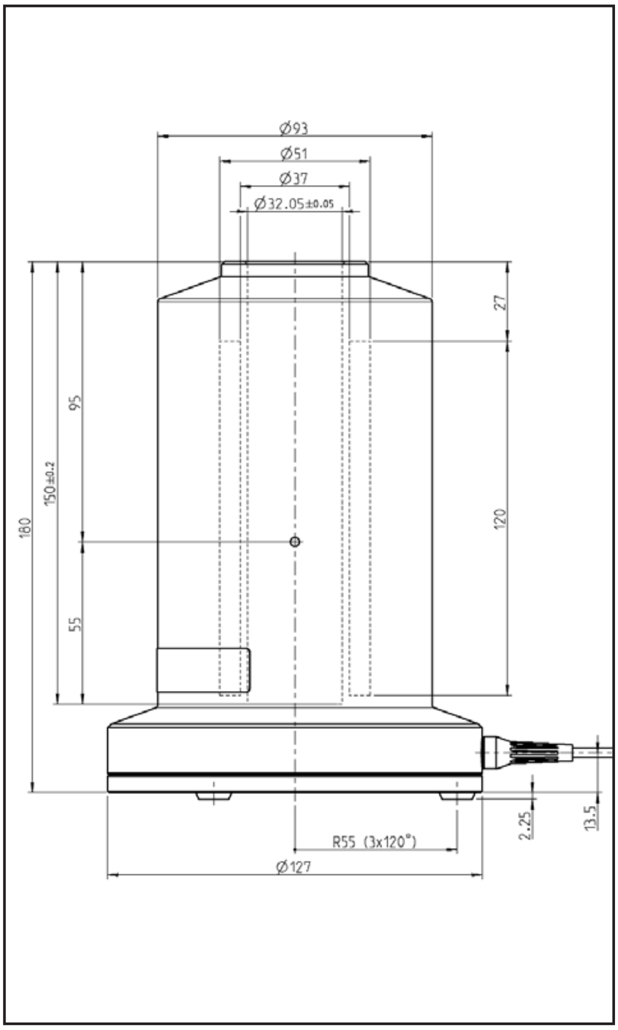
0.005 cm³ Soft X-Ray Chamber 34013



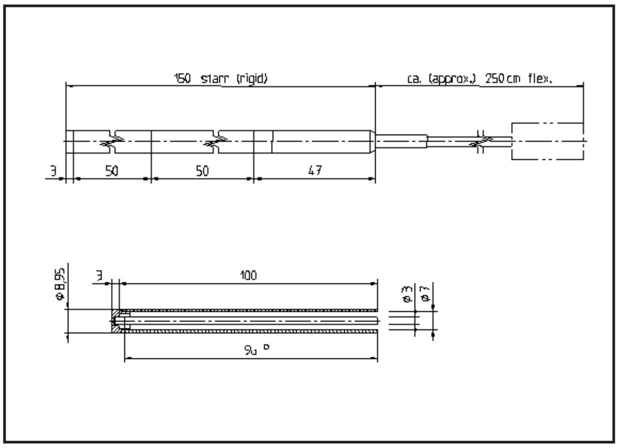
75 cm³ SFD Diagnostic Chamber 34060



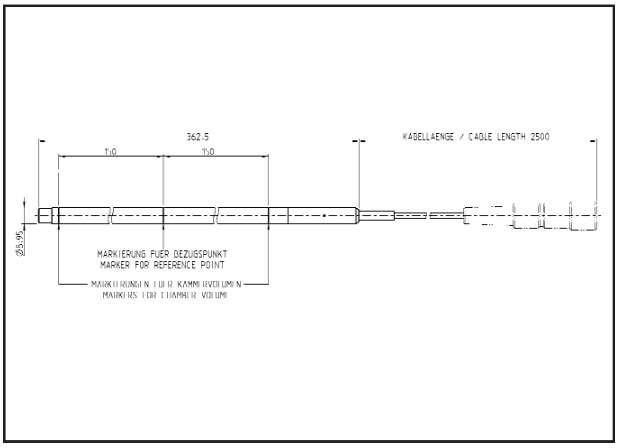
6 cm³ SFD Mammo Chamber 34069



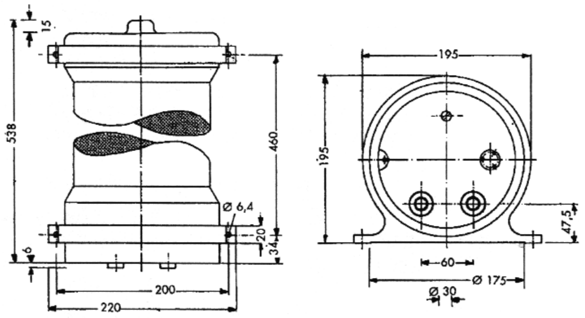
SOURCECHECK $^{4\pi}$ 33005



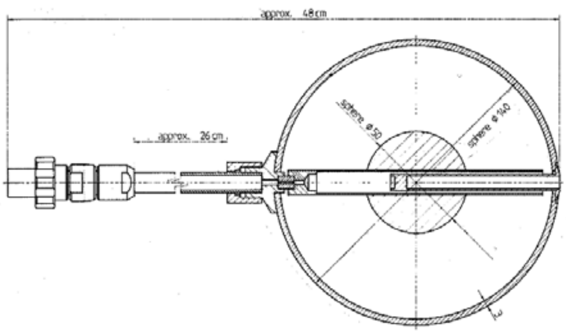
3.14 cm³ CT Chamber 30009



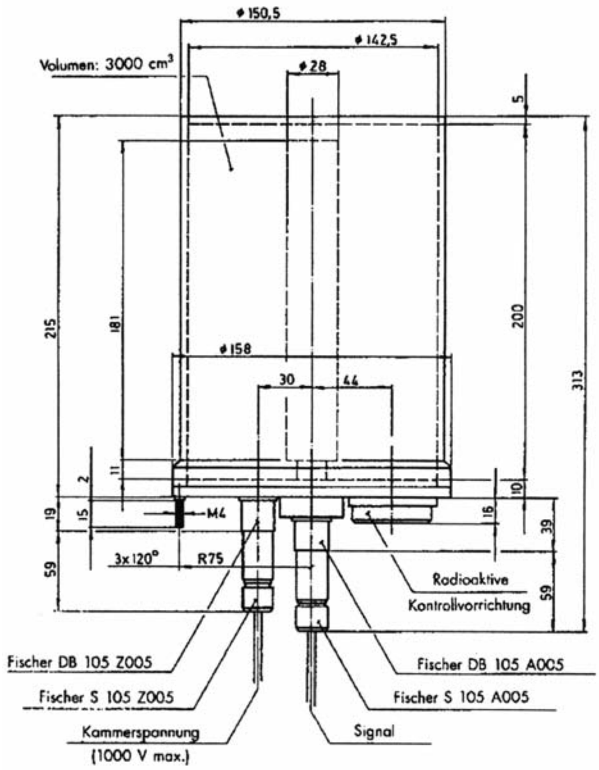
9.3 cm³ CT Chamber 30017



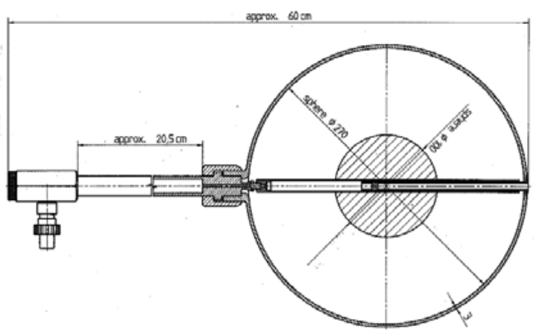
50 Liter Radiation Monitoring Chamber 7262



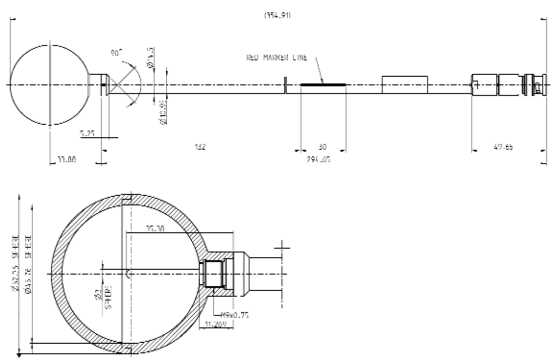
1 Liter Spherical Ionization Chamber 32002



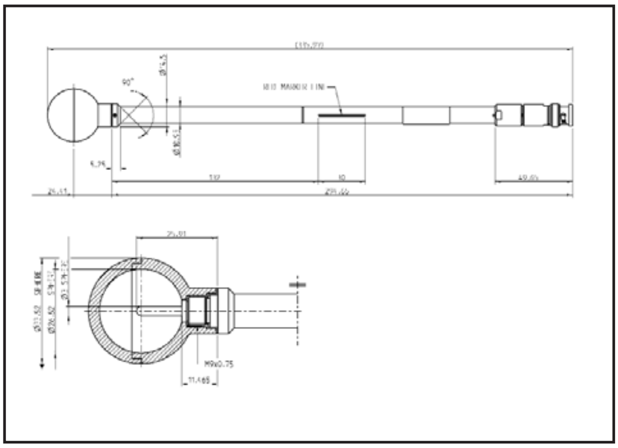
3 Liter Radiation Monitoring Chamber 34031



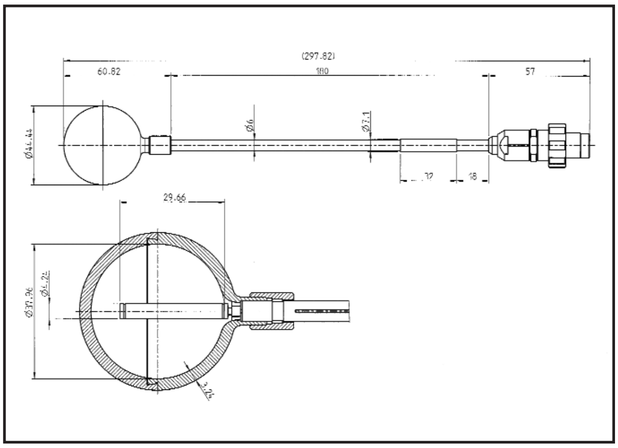
10 Liter Spherical Ionization Chamber 32003



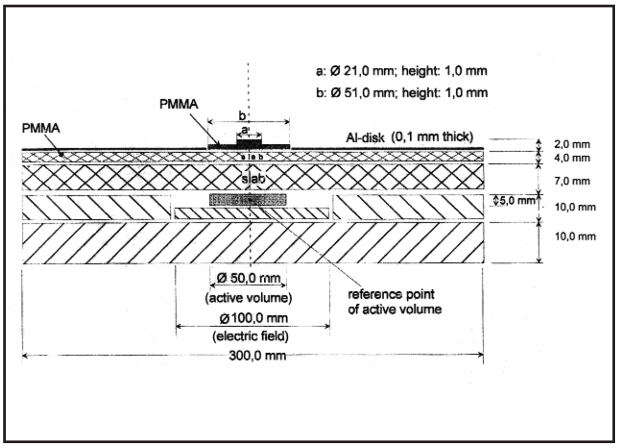
50 cm³ Spherical Ionization Chamber PS-50 32007S



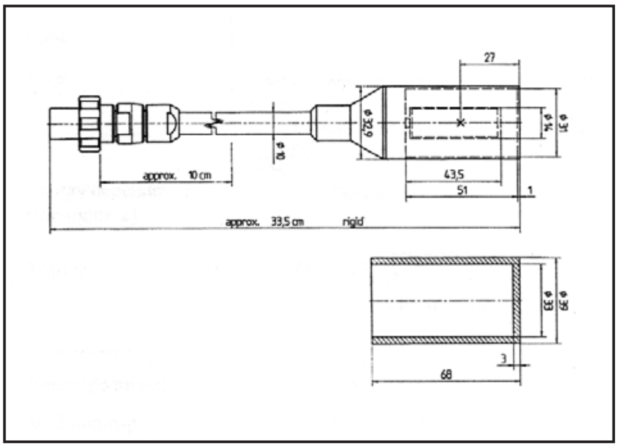
10 cm³ Spherical Ionization Chamber PS-10 32008S



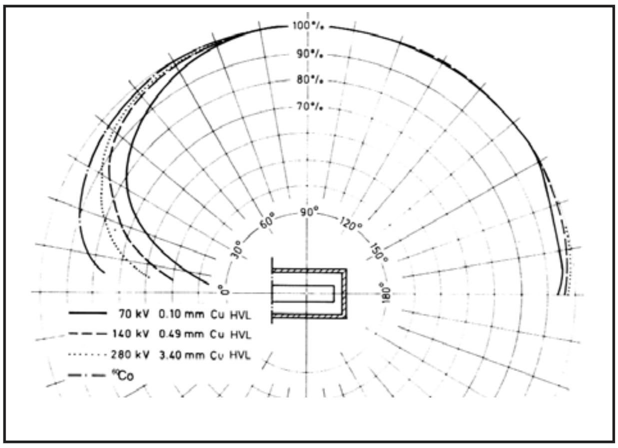
Spherical Ionization Chamber TK-30 32005



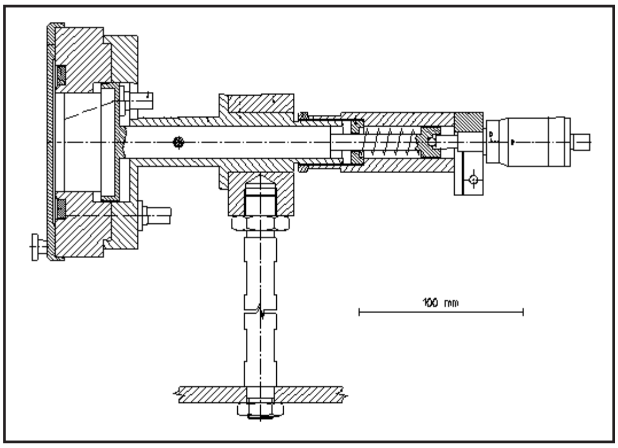
$H_p(10)$ Secondary Standard Chamber 34035



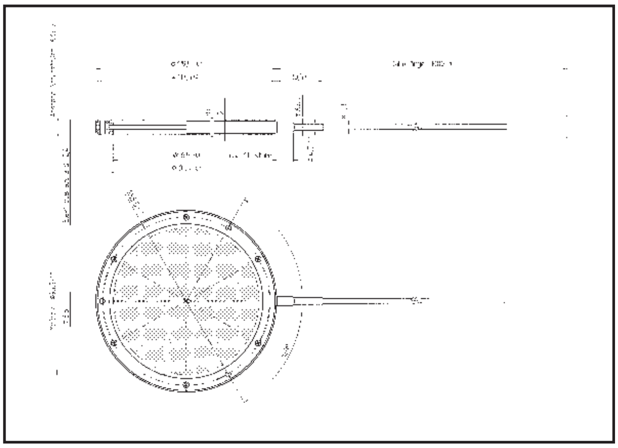
30 cm³ Cylinder Stem Ionization Chamber 23361



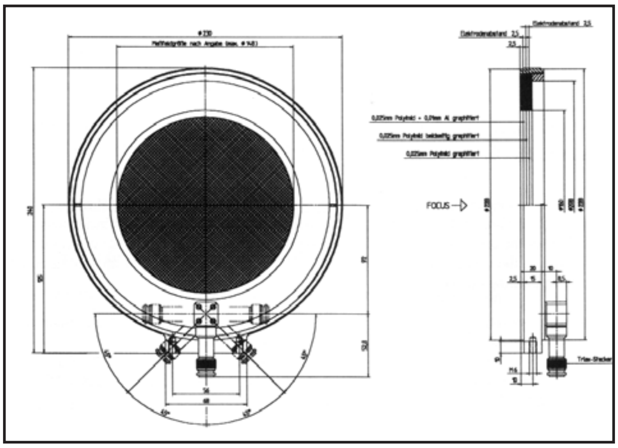
30 cm³ Cylinder Stem Ionization Chamber 23361
Directional response in air



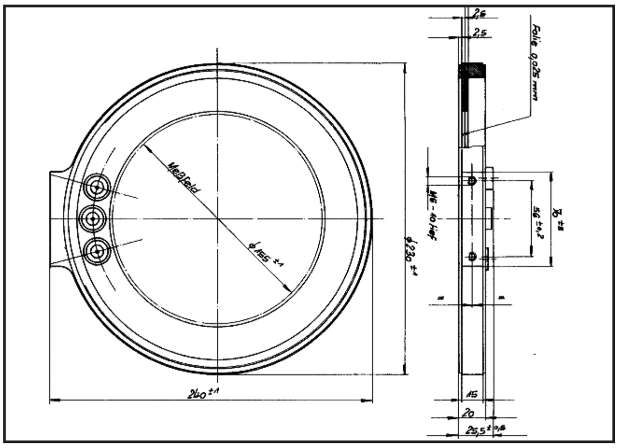
Böhm Extrapolation Chamber 23392



X-Ray Therapy Monitor Chamber 7862



Monitor Ionization Chamber 34014

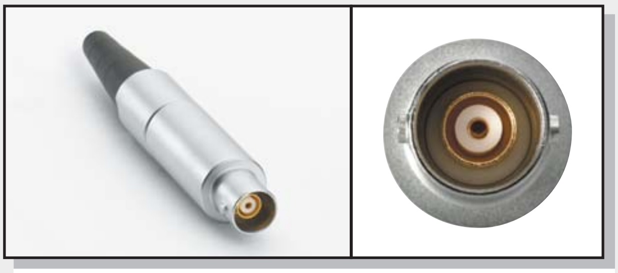


Monitor Ionization Chamber 786

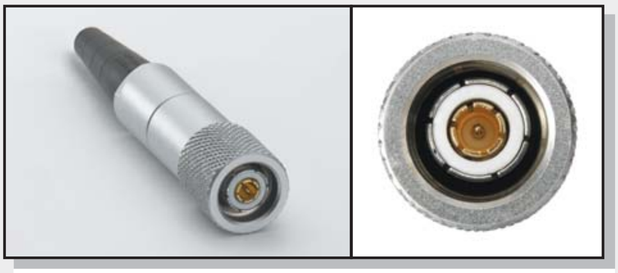
The Connector Design

The following overview of connecting systems facilitates the identification of the adequate connector to fit your measuring system. Outer shape, colors and the size of the housing may vary, depending on the production year and the manufacturer. Some connectors may have protective covers which veil the real shape of the connector. All connectors are displayed without such protective covers. The images are not full-scale. See table on page 67 for approximate outer connector diameters. Supply of detectors with BNC connectors with banana pin, BNC biax connectors and DIAMENTOR F type connectors upon request.

BNT Connector (N Type) male



BNT Connector (n type) female



TNC Connector (W type) male

TNC Connector (w type) female

Triax PTW Connector (M type) male

Triax PTW Connector (m type) female

BNC Connector with Banana Pin (B type) male

BNC Connector with Banana Pin (b type) female

LEMO Connector (L type) male

LEMO Connector (l type) female

DIAMENTOR Connector (V type) male

DIAMENTOR Connector (v type) female

DIAMENTOR Connector (A type) male

DIAMENTOR Connector (a type) female

DIAMENTOR Connector (F type) male

DIAMENTOR Connector (f type) female

PTW can provide adaptation cables for all combinations of detectors shown above. In practice not all combinations make sense and are dangerous respectively. The reason for this is among other things, that the different connecting systems have diverse uses for the outer shielding of the cable. While some connecting systems use the cable's outer shielding for the high voltage supply of the ionization chamber, other systems use it for the grounding of the chamber and connect it to the chamber housing. Unsuitable adaptation cables may result in improper grounding of the chamber and in the worst case in the risk of an electric shock. Touchable parts of the chamber may conduct high voltage.

Adaptations between Triax PTW (M type) and BNC with Banana (B type) are problem-free. Likewise are adaptations between BNT (N type) and TNC (W type) systems in general unproblematic. The same applies to our different DIAMENTOR connecting systems. For all other combinations of connecting systems we strongly dissuade from using adaptation cables. Any use of such adaptation cables is definitely out of the intended use and left to the user's responsibility.

As each manufacturer has its own manufacturing tolerances for connectors, PTW cannot guarantee that its TNC connectors fit to connectors supplied by other manufacturers.

The following table shows the possible connector combinations used in radiation therapy.

	N, n	W, w	M, m	B, b
N, n	✓	✓	✘	✘
W, w	✓	✓	✘	✘
M, m	✘	✘	✓	✓
B, b	✘	✘	✓	✓

✓ Suitable adaptation cable

✘ Unsuitable adaptation cable

Approximate outer connector diameters:

Connector Type	Outer Diameter
N, n	15 mm, 14 mm
W, w	16 mm, 14 mm
M, m	25 mm, 24 mm
B, b	18 mm, 18 mm
L, l	9 mm, 9 mm
V, v	15 mm, 16 mm
A, a	14 mm, 14 mm
F, f	18 mm, 19 mm

Guide to PTW Detectors

This guide gives a review of the complete range of PTW radiation detectors arranged in the order of their scope. Some of the detectors are suitable for various applications. Especially the ion chambers designed for absolute dosimetry in radiotherapy can also be used for therapy beam analysis. All ionization chambers are supplied with vented sensitive volumes, open to the surrounding. The type numbers in brackets represent former chamber types. Radiation detectors which are integrated components of radiation measuring systems, such as LA48 Linear Array, OCTAVIUS Detector, DIAMENTOR or CURIEMENTOR, are not listed in this guide.

Radiation Therapy

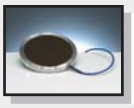
	30010	0.6 cm³ Farmer Chamber PMMA/Al	Thimble chamber with acrylic wall and Al electrode for measuring high-energy photon and electron radiation in air and phantom material. BNT, TNC or M connector	*page 10*
	30012	0.6 cm³ Farmer Chamber Graphite/Al	Thimble chamber with graphite wall and Al electrode for measuring high-energy photon and electron radiation in air and phantom material. BNT or TNC connector	*page 11*
	30013	0.6 cm³ Farmer Chamber Waterproof	Waterproof chamber with acrylic wall and Al electrode for measuring high-energy photon and electron radiation in air, water and phantom material. BNT, TNC or M connector	*page 12*
	31021	0.07 cm³ Semiflex 3D Chamber	Waterproof thimble chamber with 3D characteristics for measuring high-energy photon and electron radiation in air, water and phantom material. BNT, TNC or M connector	*page 13*
	31010	0.125 cm³ Semiflex Chamber	Waterproof thimble chamber for measuring high-energy photon and electron radiation in air, water and phantom material. BNT, TNC or M connector	*page 14*
	31013	0.3 cm³ Semiflex Chamber	Waterproof thimble chamber for measuring high-energy photon and electron radiation in air, water and phantom material. BNT, TNC or M connector	*page 15*
	30016	0.3 cm³ Rigid Stem Chamber	Thimble chamber with 25 cm rigid stem for measuring high-energy photon and electron radiation in air and phantom material. BNT, TNC or M connector	*page 16*
	34045	0.02 cm³ Advanced Markus Electron Chamber	Improved plane parallel chamber with thin membrane for measuring high-energy electron radiation in water and phantom material. BNT, TNC or M connector	*page 17*
	23343	0.055 cm³ Markus Electron Chamber	Classic plane parallel chamber with thin membrane for measuring high-energy electron radiation in water and phantom material. BNT, TNC or M connector	*page 18*
	34001	0.35 cm³ Roos Electron Chamber	Precision plane parallel chamber for absolute dosimetry of high-energy electron radiation in water and phantom material. BNT, TNC or M connector	*page 19*
	34070	10.5 cm³ Bragg Peak Chamber	Waterproof plane parallel chamber for measuring the exact location of the Bragg peak in proton beams. BNT, TNC or M connector	*page 20*
	34073	2.5 cm³ Bragg Peak Chamber	Waterproof plane parallel chamber for measuring the exact loacation of the Bragg peak in horizontal proton beams. BNT, TNC or M connector	*page 21*
	34089	34 cm³ Bragg Peak 150 Chamber	Very large waterproof plane parallel chamber for measuring the exact loacation of the Bragg peak in horizontal proton beams. BNT, TNC or M connector	*page 22*

	31023	0.015 cm^3 PinPoint Chamber	Ultra small-sized waterproof therapy chamber for dosmimetry in high-energy photon beams. BNT, TNC or M connector	*page 23*
	31015	0.03 cm^3 PinPoint Chamber	Small-sized waterproof therapy chamber for dosmimetry in high-energy photon beams. BNT, TNC or M connector	*page 24*
	31022	0.016 cm^3 PinPoint 3D Chamber	Ultra small-sized waterproof therapy chamber with 3D characteristics for dosmimetry in high-energy photon beams. BNT, TNC or M connector	*page 25*
	60023	microSilicon for Electrons and Photons	Waterproof silicon diode detector for dosimetry in high-energy electron and photon beams. BNT, TNC or M connector	*page 26*
	60016	Dosimetry Diode P for Photons	Waterproof p-type Si diode detector for dosimetry in high-energy photon beams. BNT, TNC or M connector	*page 27*
	60019	microDiamond	Waterproof small volume diamond detector for dosimetry in high-energy photon and electron beams. BNT, TNC or M connector	*page 28*
	34091	T-REF Chamber	Reference detector for small fields. BNT, TNC or M connector	*page 29*
	34013	0.005 cm^3 Soft X-ray Chamber	Plane parallel chamber with thin membrane for measuring small size therapeutic X-ray beams between 15 and 50 kV in air and phantom material. BNT, TNC or M connector	*page 30*
	23342	0.02 cm^3 Soft X-ray Chamber	Plane parallel chamber with thin membrane for measuring therapeutic X-ray beams between 10 and 100 kV in air and phantom material. BNT, TNC or M connector	*page 31*
	23344	0.2 cm^3 Soft X-ray Chamber	Plane parallel chamber with thin membrane for measuring therapeutic X-ray beams between 10 and 100 kV in air and phantom material. BNT, TNC or M connector	*page 32*
	33005	SOURCECHECK *4π* Well-type Chamber	Well-type ionization chamber for source strength measurements in brachytherapy. BNT, TNC or M connector	*page 33*

Diagnostic Radiology

	30009	3.14 cm^3 CT Chamber	Vented cylindrical chamber for dose length product measurements in computed tomography. BNT, TNC, M or L connector	*page 36*
	30017	9.3 cm^3 CT Chamber	Vented cylindrical chamber for dose length product measurements in computed tomography. BNT, TNC, M or L connector	*page 37*
	34060	75 cm^3 SFD Diagnostic Chamber	Shadow-free plane parallel chamber for absolute dosimetry in diagnostic radiology. BNT, TNC, M or L connector	*page 38*
	34069	6 cm^3 SFD Mammo Chamber	Shadow-free plane parallel chamber for absolute dosimetry in diagnostic radiology and mammography. BNT, TNC, M or L connector	*page 39*
	60004 60005	R/F/D Detector MAM Detector	Semiconductor detectors for diagnostic X-rays. TNC or L connector	*page 40*

Radiation Monitoring

	T34031 T32004	3 Liter Cylindrical Chamber	Cylindrical poly ethylene chamber for stationary low level gamma radiation measurement above 80 keV. Special connectors for signal and HV	*page 44*
	T7262	50 Liter Cylindrical Chamber	Cylindrical pressurized steel chamber for stationary lowest level gamma radiation measurement above 80 keV. Special connectors for signal and HV	*page 45*
	32002	1 Liter Spherical Chamber	Spherical chamber, 140 mm diameter, for low level gamma radiation protection measurements in the energy range of 45 keV to 50 MeV. BNT, TNC or M connector	*page 46*
	32003	10 Liter Spherical Chamber	Spherical chamber, 270 mm diameter, for lowest level gamma radiation protection measurements in the energy range of 45 keV to 50 MeV. BNT, TNC or M connector	*page 47*
	32007S	50 cm^3 Spherical Chamber PS-50	Spherical chamber, 53 mm diameter, for primary standard radiation protection measurements in ^{60}Co and ^{137}Cs beams. BNT connector	*page 48*
	32008S	10 cm^3 Spherical Chamber PS-10	Spherical chamber, 34 mm diameter, for primary standard radiation protection measurements in ^{60}Co and ^{137}Cs beams. BNT connector	*page 48*
	32005	30 cm^3 Spherical Chamber	Spherical chamber, 22 mm diameter, for gamma radiation protection measurements in the energy range of 25 keV to 1.3 MeV. BNT, TNC or M connector	*page 49*
	23361	30 cm^3 Cylindrical Chamber	Cylindrical reference chamber, 31 mm diameter, for gamma radiation protection measurements in the energy range of 30 keV to 50 MeV. BNT, TNC or M connector	*page 50*
	34035 L981937 L981938	$H_p(10)$ Secondary Standard Chamber	Plane parallel reference chamber embedded in an acrylic slab phantom for direct measurement of Personal Dose Equivalent $H_p(10)$. M or BNC/banana connector	*page 51*
	TN34014 TW34014 TM786	Transmission Monitor Chambers for Calibration Benches	Circular transmission chambers of 155 mm resp. 148 mm sensitive diameter for radiation monitoring of calibration benches. BNT, TNC, M or BNC/banana connector	*page 52*
	TM7862	Transmission Monitor Chamber for X-ray Therapy Units	Circular transmission chamber of 96.5 mm sensitive diameter for radiation monitoring of X-ray therapy units. M or BNC/banana connector	*page 53*
	T23392	Böhm Extrapolation Chamber	Precision extrapolation chamber with adjustable depth of the sensitive volume between 0.5 mm and 10.5 mm for dose measurements of Beta and soft X-rays. BNC sockets	*page 54*

Codes of Practice

Absorbed Dose Determination in Photon and High Energy Electron Beams

Based on Standards of Absorbed Dose to Water

1 Introduction

This document constitutes an excerpt of procedures and data from various dosimetry protocols for the determination of absorbed dose to water using ionization chambers. As most modern dosimetry protocols (e.g. IAEA, AAPM, DIN) refer to ionization chambers calibrated in absorbed dose to water, this document does not describe dose determination with ionization chambers having other calibration factors.[1]

The chapters referring to high energy radiation describe the formalisms outlined in IAEA TRS 398, AAPM TG-51 and DIN 6800-2 as these dosimetry protocols are widely used, see references [IAEA 398], [AAPM 51] and [DIN 6800-2]. The chapter referring to kilovoltage X-ray beams describes only the formalism outlined in the DIN standards as IAEA TRS 398 differs only slightly from DIN, and AAPM TG-51 does not address this energy range.

Although this document provides the reader with a concise overview of formulae and factors it shall not replace pertinent protocols and publications, nor is it intended to give all of the details that are important for accurate dosimetry. Also, the procedures outlined in this document are not the only ones described in the referenced literature, they constitute only one of several possibilities for absorbed dose determination.

The present document is limited to

- the use of open (vented) ionization chambers
- the use of plane-parallel chambers in case of low energy X-ray beams
- the use of cylindrical chambers in case of medium energy X-ray beams
- PTW chambers if factors are given that depend on the design of the ionization chamber.

NOTE
The terms 'Markus Chamber', 'Advanced Markus Chamber' and 'Roos Chamber' are the propriety of PTW-Freiburg. The published data specific to these chambers are not valid for chambers manufactured by other companies, even if they are sold as 'Markus' or 'Roos' type chambers.

A summary of PTW chamber data is given in Appendix A.

[1] Document D560.210.00 refers to chambers calibrated in Air Kerma, Absorbed Dose to Air, and Exposure.

2 General Instructions

2.1 Corrected reading *M*

All formulae in this document used for the determination of absorbed dose to water D_w refer to a dosemeter reading M which is corrected for the influence quantities given in chapters 2.4 - 2.7. The reader must compute the corrected reading M from the uncorrected reading M_{uncorr} and the reading without irradiation M_0 by

$$M = (M_{uncorr} - M_0) \cdot k_{elec} \cdot k_{TP} \cdot k_S \cdot k_{pol} \cdot k_h \qquad (2\text{-}1)$$

The correction factor k_{elec} corresponds to the calibration factor of the electrometer if the electrometer readout is in terms of charge or current [IAEA 398, AAPM 51]. If the electrometer and the ionization chamber are calibrated together and the readout is in terms of Gy or Gy/s, a value of unity is to be used for k_{elec}.

The correction factors k_{TP}, k_S, k_{pol} and k_h are described in chapters 2.4 - 2.7. For absorbed dose determination, additional factors are to be applied to the corrected reading M as described in chapters 3 - 6.

2.2 Measuring phantoms

This document assumes that all measurements are made in a water phantom, except for chapter 3.1 where the measurements are made at the surface of an acrylic (PMMA) phantom. If measurements are nevertheless made in other than water phantoms, the measures described in chapter 6 are to be taken. It should be noted, however, that most dosimetry protocols prescribe measurements in water only.

2.3 Chamber positioning

2.3.1 General rules

The dosemeter reading is obtained by positioning the ionization chamber at the point of interest in the phantom. Depending on the dosimetry protocol and radiation quality, either the effective point of measurement or the reference point of the ionization chamber is positioned at the point of interest. This document states the correct positioning method in each of the related chapters.

The effective point of measurement is defined as

- a point on the axis of a cylindrical chamber in case of photon beams with energy < 1.33 MeV
- a point shifted by $0.5\,r$ from the axis of a cylindrical chamber towards the focus[2] in case of high energy photon and electron beams (r is the inner radius of the measuring chamber volume) [IAEA 398, DIN 6800-2]
- a point at the center of the inner side of the entrance window of a plane-parallel chamber, independent of radiation quality. Care must be taken to scale the thickness of the entrance window to water-equivalent thickness.

The reference point is defined as

- a point on the central axis of a cylindrical chamber as stated by the manufacturer
- a point at the center of the inner side of the entrance window of a plane-parallel chamber.

[2] To measure dose at a focus distance of x cm, the axis of the cylindrical chamber must be positioned at a focus distance of x cm + $0.5\,r$, i.e. the chamber must be shifted <u>away</u> from the focus, i.e. downstream.

2.3.2 Plane-parallel chambers

Plane-parallel chambers usually have entrance windows which are not exactly water-equivalent. For the correct positioning of a plane-parallel chamber in water, the geometrical thickness d_p of the entrance window must be scaled to equivalent water thickness d_w. The effective point of measurement is then located behind the water-equivalent thickness d_w of the entrance window.

The scaling of the geometrical thickness (e.g. plastic thickness) d_p to water equivalent thickness d_w is done by [IAEA 398]

$$d_w = d_p \cdot \frac{\rho_p}{\rho_w} \qquad (2\text{-}1)$$

where ρ_p and ρ_w are the densities of the entrance window and water, respectively[3]. Using the area density σ_p and $\rho_\mathrm{w} = 1\,\mathrm{g/cm^3}$, equation (2-1) can be written as

$$d_w = \frac{\sigma_p}{\rho_w} = \frac{\sigma_p}{1\,g/cm^3} \qquad (2\text{-}2)$$

The area density σ_p of PTW plane-parallel chambers is given in Appendix A. For instance, the water-equivalent thickness of the entrance window of a Roos chamber type 34001 ($\sigma_\mathrm{p} = 132\,\mathrm{mg/cm^2}$) is $d_\mathrm{w} = 1.32\,\mathrm{mm}$. The entrance window of the Advanced Markus chamber (including protection cap, $\sigma_\mathrm{p} = 106\,\mathrm{mg/cm^2}$) has a water-equivalent thickness of $d_\mathrm{w} = 1.06\,\mathrm{mm}$.

Example

How to position the effective point of measurement of an Advanced Markus chamber with protection cap at a measuring depth of $z = 10\,\mathrm{mm}$ in water:

- according to Appendix A, the area density of the entrance window, including the protection cap and air gap, is $\sigma_\mathrm{p} = 106\,\mathrm{mg/cm^2}$
- according to (2-2) the water-equivalent thickness of the entrance window is $d_\mathrm{w} = 1.06\,\mathrm{mm}$, i.e. the effective point of measurement is located behind a 'water layer' of 1.06 mm from the chamber surface
- the measuring depth in water shall be $z = 10\,\mathrm{mm}$. As the entrance window contributes 1.06 mm, the chamber surface has to be positioned at a water depth of $10\,\mathrm{mm} - 1.06\,\mathrm{mm} = 8.94\,\mathrm{mm}$.

[3] DIN 6800-2 suggests to use the electron volume densities of the materials rather than the physical densities. The difference is neglected in this document.

2.3.3 The TRUFIX system

The task of positioning various types of ionization chambers precisely in their effective point of measurement can be quite challenging. The patented TRUFIX system (see Figure 1) facilitates this task considerably. TRUFIX can be used on automated PTW water phantoms (MP2, MP3, BEAMSCAN etc.) in connection with most PTW therapy detectors. A plastic tip lets you easily locate the water surface where the coordinate system is set to (0,0,0) (when using the BEAMSCAN water phantom system, the water surface is located automatically). Then the plastic tip is replaced by a holding device specific to each detector type, and the effective point of measurement is automatically placed at the tip's earlier position. The radius of cylindrical chambers, the water-equivalent window thickness of plane-parallel chamber windows and the chamber centers are automatically accounted for.

***Figure 1**: The TRUFIX chamber positioning system for PTW BEAMSCAN (above) and other PTW Water phantoms (below).*

2.4 Air density

2.4.1 The *T&P* method

Open (vented) ionization chambers must be corrected for air density according to [IAEA 398]

$$k_{TP} = \frac{P_0 \cdot (273.2 + T)}{P \cdot (273.2 + T_0)} \qquad (2\text{-}3)$$

T and P are the temperature and pressure in the measuring environment, the reference values are $P_0 = 101.3\,\text{kPa}$ and $T_0 = 20\,^{\circ}\text{C}$. Note that in some countries the reference temperature given in the calibration certificate is $22\,^{\circ}\text{C}$ instead of $20\,^{\circ}\text{C}$. AAPM TG-51 uses a value of $22\,^{\circ}\text{C}$ as reference and a value of $P_0 = 101.33\,\text{kPa}$ for the reference pressure.

Care must be taken to ensure the use of correct values for the barometric pressure P existing in the measuring environment. Details can be found in the literature [Christ 2004].

2.4.2 The check source method

Instead of using (2-3) measurements in a radioactive check source can be made. The temperature of the check source and the ionization chamber must be the same as the temperature of the phantom in which the dose measurements are performed. The reference value k_{protocol} of the check source reading is given in the calibration certificate for a given date and for reference conditions (e.g. $101.3\,\text{kPa}$, $20\,^{\circ}\text{C}$). The reader must correct the reference value k_{protocol} for the decay of the radioactive material. Then an actual check source reading k_{measured} is taken and the correction factor for air density is determined from

$$k_{TP} = \frac{k_{\text{protocol}}}{k_{\text{measured}}} \qquad (2\text{-}4)$$

NOTE

The results of (2-3) and (2-4) normally coincide better than 0.5 %. If not, the reason must be found.

NOTE

In the calibration certificates of PTW-Freiburg the reference reading k_{protocol} is described as k_p, the check reading k_{measured} is described as k_m. k_p and k_m must not be mixed up with correction factors described in other chapters of this document.

2.5 Ion recombination

2.5.1 The two-voltage method

Correction factors for insufficient charge collection in the measuring volume of the ionization chamber can be measured using the two-voltage method [IAEA 398, AAPM 51]. They depend on the geometry of the ionization chamber and on the dose rate or dose per pulse, respectively.

For pulsed or pulsed-scanned radiation the correction factor k_S can be determined from [IAEA 398]

$$k_S = \frac{M_1 / M_2 - 1}{V_1 / V_2 - 1} + 1 \qquad (2\text{-}5)$$

where M_1 and M_2 are the readings at two voltages V_1 and V_2. V_1 is the normally used voltage, and V_2 is a voltage reduced by a factor of at least 3. Formula (2-5) is valid for $k_S < 1.03$. If $k_S \geq 1.03$ refer to chapter 2.5.2.

For continuous radiation k_S is taken from [IAEA 398]

$$k_S = \frac{(V_1 / V_2)^2 - 1}{(V_1 / V_2)^2 - (M_1 / M_2)} \qquad (2\text{-}6)$$

Formula (2-5) assumes a linear relationship between $1/M$ and $1/V$, formula (2-6) a linear relationship between $1/M$ and $1/V^2$. New chambers should be tested in accordance with the following chapter.

2.5.2 Jaffé diagrams

A Jaffé diagram represents the inverse reading $1/M$ of an ionization chamber as a function of the inverse voltage $1/V$ ($1/V^2$ in case of continuous radiation). The reading M is corrected for polarity effect, i.e. M is the mean value of M_+ and M_-, see chapter 2.6. Figure 2 shows a Jaffé diagram for pulsed radiation with the axes normalized to the usual voltage V_1 and the corresponding reading M_1.

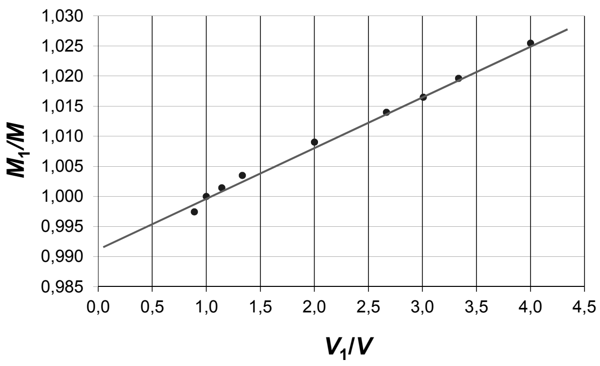


Figure 2: *Jaffé diagram of a typical Farmer chamber usually operated at* $V_1 = 400\,V$. *The regression line to the linear part intersects the* M_1/M *axis at 0.992 resulting in a correction factor* $k_S = 1/0.992 = 1.008$. *The dose per pulse was* $0.974\ mGy$.

The useful range for the chamber voltage should be limited to the linear part of the Jaffé diagram which is generally approx. 1/3 of the nominal voltage [DIN 6800-2]. This document suggests to measure Jaffé diagrams at the lowest and at the highest dose per pulse or dose rate for each radiation quality, and to determine the linear range for the used ionization chamber from these diagrams.

The two-voltage method (see chapter 2.5.1) can be applied only if both voltages V_1 and V_2 are within the linear range of the Jaffé diagram. If this is not the case, the ionization chamber should be operated at the highest voltage of the linear range of the Jaffé diagram, and the correction factor k_S should be determined by extrapolating the linear part of the Jaffé diagram to an infinite voltage ($1/V = 0$). It should be noted that operating an ionization chamber at a voltage other than stated in the calibration certificate may cause an error as the calibration factor sometimes depends on the applied voltage.

2.5.3 The DPP method

If the dose per pulse (DPP) of the accelerator at the point of measurement is known, the correction factor can be calculated by [DIN 6800-2]

$$k_S = 1 + \frac{\gamma}{U} + \frac{\delta}{U} \cdot D_P \qquad (2\text{-}7)$$

D_P is the absorbed dose to water per accelerator pulse, expressed in mGy, U is the chamber voltage in V and the coefficients γ and δ are listed in Table 1 [Bruggmoser 2007]. Formula (2-7) is only valid if the frequency of the accelerator pulses is smaller than the reciprocal of the ion collection time.

Chamber type	**γ** **V**	**δ** **V / mGy**	**Dose per pulse** **mGy**	**Chamber voltage** **V**
PTW 30006/30013 Farmer	0.01	3.44	0.15 – 0.35 > 0.35 – 42	100 - 300 300 – 400
PTW 23331 1 cm³ Rigid Stem	0.00	5.68	0.25 – 1.5	100 – 400
PTW 23332 0.3 cm³ Rigid Stem	0.13	1.05	0.15 – 0.5 > 0.5 – 5.5	100 – 250 250 – 400
PTW 31002/31010 0.125 cm³ Semiflex	0.38	2.40	0.15 – 0.6 > 0.6 – 5.5	100 – 300 300 – 400
PTW 31013 Semiflex	0.35	3.3	0.1 – 0.8	300
PTW 31021 0.07 cm³ Semiflex 3D	0.148	2.962	0.2 – 3	50 – 400
PTW 31022 0.016 cm³ PinPoint 3D	0.416	1.005	0.2 – 3	100 – 400

Chamber type	γ V	δ V / mGy	Dose per pulse mGy	Chamber voltage V
PTW 34001 Roos	0.06	1.69	0.15 – 0.5 > 0.5 – 42	50 – 200 200 – 300
PTW 34045 Advanced Markus	0.43	0.49	0.25–1.0 > 1.0 – 5.5	50 – 200 200 – 300
PTW 23343 Markus	0.32	1.99	0.15 – 0.55 > 0.55 – 3.0	100 – 250 250 – 300

Table 1: Coefficients γ and δ for formula (2-7), applicable within the stated dose per pulse and voltage ranges, according to [Bruggmoser 2007, Bruggmoser 2008].

2.6 Polarity effect

The polarity effect depends on the radiation beam quality Q. The correction factor can be determined by [IAEA 398, DIN 6800-2]

$$k_{\text{pol}} = \frac{\left[\left(M_+ + M_-\right)/M_+\right]_Q}{\left[\left(M_+ + M_-\right)/M_+\right]_{\text{Co}}} \qquad \text{(2-8)}$$

M_+ = positive reading obtained with the usual polarity

M_- = positive reading obtained with the opposite polarity

The index Co refers to the readings obtained in a ^{60}Co beam during calibration. This value is normally not given in the calibration certificate. If ^{60}Co is available the user should measure this value, if not, this value should be requested from the calibration laboratory [IAEA 398, AAPM 51] or should be measured with the lowest available photon energy [DIN 6800-2]. If the effect of this value is smaller than 0.3 % for 6 MV photon beams (or lower energy), the denominator in formula 2-8 can be set to 2, otherwise it must be taken into account [AAPM 51].

2.7 Humidity

A correction factor for humidity has to be applied only if the ^{60}Co calibration factor refers to dry air [IAEA 398]:

$$k_{\text{h}} = 0.997 \qquad \text{(2-9)}$$

Usually the ^{60}Co calibration factor refers to a relative humidity of 50 %; in this case k_{h} is taken as 1.000.

3 Kilovoltage X-Ray Beams

3.1 10 kV to 100 kV

$$D_w = k_Q \cdot N_w \cdot M \qquad (3\text{-}1)$$

D_w = absorbed dose to water [DIN 6809-4]

k_Q = energy dependent correction factor, given in the calibration certificate for several radiation qualities. PTW offers calibrations at 15, 30, 50, and 70 kV

N_w = calibration factor for absorbed dose to water for the reference radiation quality stated in the calibration certificate

M = corrected reading of the dosemeter, see chapter 2.1. Measurements are to be made at the surface of an acrylic (PMMA) phantom. For measurements at other depths, water-equivalent material is to be added

Influence Quantity	Reference Condition
Phantom material	PMMA
Chamber	plane-parallel, Type PTW 23342, 23344, or 34013
Depth	phantom surface
Chamber positioning	outer surface of entrance window
SDD	as stated in calibration certificate
Field size	as stated in calibration certificate, or 3 cm diameter at the measuring plane

NOTE

DIN 6809-4 suggests the use of a 0.1 mm water-equivalent plastic foil in front of the ionization chamber when measuring above 50 kV. This foil should provide adequate build-up and eliminate low energy electrons scattered upstream. IAEA TRS 398 suggests total material thicknesses (build-up foils plus entrance window) depending upon radiation quality (IAEA Table 8.1. Foil thicknesses should read µm). Ideally, the chamber and the build-up foils should be calibrated together, but this calibration is not available from PTW. If the user decides to use build-up foils, he should determine a correction factor for each beam geometry and radiation quality used.

3.2 100 kV to 300 kV

$$D_w = k_F \cdot k_Q \cdot N_w \cdot M \qquad (3\text{-}2)$$

D_w = absorbed dose to water [DIN 6809-4]

k_F = correction factor for field sizes other than 10 cm x 10 cm

k_Q = energy dependent correction factor, given in the calibration certificate for several radiation qualities. PTW offers calibrations at 100, 140, 200, 280 kV, and ^{60}Co.

N_w = calibration factor for absorbed dose to water for ^{60}Co

M = corrected reading of the dosemeter, see chapter 2.1

Influence Quantity	Reference Condition
Phantom material	water
Chamber	cylindrical
Depth	5 cm
Chamber positioning	chamber axis
SDD	100 cm
Field size	as stated in calibration certificate, or 10 cm x 10 cm at the phantom surface

4 High Energy Photon Beams

4.1 IAEA TRS 398

$$D_w = k_Q \cdot N_w \cdot M \qquad (4\text{-}1)$$

D_w	=	absorbed dose to water
k_Q	=	energy dependent correction factor, see Table 2
N_w	=	calibration factor for absorbed dose to water for ^{60}Co
M	=	corrected reading of the dosemeter, see chapter 2.1

Influence Quantity	Reference Condition
Phantom material	water
Chamber	cylindrical
Depth	10 g · cm^{-2} (or 5 g · cm^{-2}) for $TPR_{20,10} < 0.7$ 10 g · cm^{-2} for $TPR_{20,10} \geq 0.7$
Chamber positioning	chamber axis
SSD / SDD	100 cm
Field size	10 cm x 10 cm SSD setup: field size defined at surface SDD setup: field size defined in detector plane

The tissue phantom ratio $TPR_{20,10}$ is measured for each nominal accelerating voltage. $TPR_{20,10}$ is defined as the ratio M_{20} / M_{10} of two ionization readings of a dosemeter at different depths. M_{20} is obtained at 20 cm depth of water, M_{10} at 10 cm depth of water at a fixed source-detector-distance *SDD* = 100 cm and a field size of 10 cm x 10 cm at the depth of measurement.

NOTE

In case $TPR_{20,10}$ values are not available, they can be determined from [IAEA 398]

$$TPR_{20,10} = 1.2661 \cdot PDD_{20,10} - 0.0595$$

where $PDD_{20,10}$ is the ratio of the percent depth doses at 20 cm and 10 cm depth, respectively. The PDD values must be measured at $SSD = 100\,cm$ with a field size of 10 cm x 10 cm at the phantom surface.

For beam quality specification measurements with a cylindrical chamber, the chamber axis should be positioned at the measuring depth. It is allowed to use a plane-parallel chamber to determine beam quality.

Photon Beam Quality $TPR_{20,10}$	PTW 23331 1.0 cm³ Rigid Stem	PTW 23332 0.3 cm³ Rigid Stem	PTW 23333/ 30001/ 30010 Farmer	PTW 30002/ 30011 Farmer	PTW 30004/ 30012 Farmer	PTW 30006/ 30013 Farmer	PTW 31002/ 31010 0.125 cm³ Semiflex	PTW 31003/ 31013 0.3 cm³ Semiflex	PTW 31014/ 31015/ 31016 PinPoint	PTW 31021 Semiflex 3D
0.50	1.004	1.004	1.004	1.006	1.006	1.002	1.003	1.003	1.004	-
0.53	1.003	1.003	1.003	1.004	1.005	1.002	1.002	1.002	1.003	-
0.56	1.000	1.001	1.001	1.001	1.002	1.000	1.000	1.000	1.001	-
0.59	0.999	0.999	0.999	0.999	1.000	0.999	0.999	0.999	0.999	-
0.62	0.997	0.997	0.997	0.997	0.999	0.997	0.997	0.997	0.998	-
0.65	0.993	0.994	0.994	0.994	0.996	0.994	0.994	0.994	0.995	0.992
0.68	0.990	0.990	0.990	0.992	0.994	0.990	0.990	0.990	0.992	0.988
0.70	0.988	0.988	0.988	0.990	0.992	0.988	0.988	0.988	0.989	0.985
0.72	0.985	0.984	0.985	0.987	0.989	0.984	0.984	0.984	0.985	0.981
0.74	0.982	0.980	0.981	0.984	0.986	0.980	0.980	0.980	0.980	0.977
0.76	0.978	0.976	0.976	0.980	0.982	0.975	0.975	0.975	0.975	0.972
0.78	0.971	0.968	0.969	0.973	0.976	0.968	0.968	0.968	0.967	0.966
0.80	0.964	0.961	0.962	0.967	0.969	0.960	0.960	0.960	0.959	0.959
0.82	0.956	0.954	0.955	0.959	0.962	0.952	0.952	0.952	0.952	0.950
0.84	0.945	0.943	0.943	0.948	0.950	0.940	0.940	0.940	0.941	0.941

Table 2: Typical k_Q values for PTW cylindrical chambers [IAEA 398], [IAEA 398/2]. For ^{60}Co beams k_Q is 1.000. The chamber types 31015, 31016 and 31021 have been added by PTW-Freiburg.

4.2 AAPM TG-51

$$D_w = k_Q \cdot N_w \cdot M \qquad (4\text{-}2)$$

D_w	=	absorbed dose to water
k_Q	=	energy dependent correction factor, see Tables 3a, 3b. The values can be used for both flattened and flattening filter free beams
N_w	=	calibration factor for absorbed dose to water for ^{60}Co
M	=	corrected reading of the dosemeter, see chapter 2.1. In non-uniform beams, e.g. FFF beams, the reading must be averaged over the dimensions of the active volume of the ionization chamber

Influence Quantity	**Reference Condition**
Phantom material	water
Chamber	cylindrical, PTW chambers as listed in Table 3a
Depth	10 cm
Chamber positioning	chamber axis
SSD/SDD	100 cm
Field size	10 cm x 10 cm SSD setup: field size defined at surface SDD setup: field size defined in detector plane

The beam quality specifier $\%dd(10)_x$ is the percentage depth dose at 10 cm depth in a water phantom due to photons only. $\%dd(10)_x$ is defined at $SSD = 100$ cm for a field size of 10 cm x 10 cm at the phantom surface.

When measuring a depth dose curve for the determination of $\%dd(10)_x$ a lead foil should be used

i) at energies about 10 MV and above if highest precision is desired

ii) for measurements of flattening filter free (FFF) beams at all energies.

The lead foil should be 1 mm in thickness (± 20 %) and it should be placed (50 ± 5) cm or, if this is impossible, (30 ± 1) cm above the phantom surface.

The beam quality specifier is obtained from the corresponding value $\%dd(10)_{Pb}$ by one of the following formulae

lead foil at (50 ± 5) cm and $\%dd(10)_{Pb} \geq 73\,\%$

$$\%dd(10)_x = (0.8905 + 0.0015 \cdot \%dd(10)_{Pb}) \cdot \%dd(10)_{Pb} \qquad (4\text{-}3)$$

lead foil at (30 ± 1) cm and $\%dd(10)_{Pb} \geq 71\,\%$

$$\%dd(10)_x = (0.8116 + 0.00264 \cdot \%dd(10)_{Pb}) \cdot \%dd(10)_{Pb} \qquad (4\text{-}4)$$

If $\%dd(10)_{Pb}$ is below the above thresholds, $\%dd(10)_x$ equals $\%dd(10)_{Pb}$.

NOTE
The lead foil is used for beam quality specification only. Remove the lead foil for dose measurements.

For beam quality specification measurements with a cylindrical chamber, the chamber axis must be shifted downstream by $0.6\,r$, where r is the inner radius of the measuring volume. It is allowed to use a plane-parallel chamber to determine beam quality.

Chamber Type	Photon Beam Quality *%dd (10)ₓ*					
	58	**63**	**66**	**71**	**81**	**93**
PTW 30001/ 30006 Farmer	1	0.996	0.992	0.984	0.967	0.945
PTW 30002 Farmer	1	0.997	0.994	0.987	0.97	0.948
PTW 30004 Farmer	1	0.998	0.995	0.988	0.973	0.952
PTW 30010 Farmer	1	0.997	0.993	0.986	0.968	–
PTW 30011 Farmer	1	0.997	0.994	0.986	0.969	–
PTW 30012 Farmer	1	0.998	0.995	0.988	0.971	–
PTW 30013 Waterproof Farmer	1	0.996	0.992	0.985	0.967	–
PTW 31003/31013 Semiflex	1	0.997	0.993	0.986	0.967	–
PTW 31021 Semiflex 3D	1	0.996	0.992	0.985	0.967	–

Table 3a: Typical k_Q values for PTW cylindrical chambers [AAPM 51], [AAPM 51/2]. For ^{60}Co beams k_Q is 1.000. [AAPM 51/2] does not recommend the 0.125 cm³ Semiflex chambers PTW 31002 and 31010 as reference class chambers. PTW suggests the use of the same k_Q values as for the 0.3 cm³ Semiflex chamber PTW 31013. The data for the 31021 Semiflex 3D have been added by PTW-Freiburg.

Chamber Type	**A**	**B**	**C**
PTW 30010 Farmer	1.0093	0.926	-1.771
PTW 30011 Farmer	0.9676	2.061	-2.528
PTW 30012 Farmer	0.9537	2.440	-2.750
PTW 30013 Waterproof Farmer	0.9652	2.141	-2.623
PTW 31003/31013 Semiflex	0.9725	1.957	-2.498
PTW 31021 Semiflex 3D	0.9874	1.420	-2.056

Table 3b: Fit parameters for k_Q values for PTW cylindrical chambers [AAPM 51/2]. k_Q is obtained from the following formula which holds for beam specifiers between 63 and 86:

$$k_Q = A + B \cdot 10^{-3} \cdot \%dd(10)_x + C \cdot 10^{-5} \cdot (\%dd(10)_x)^2$$

4.3 DIN 6800-2

$$D_w = k_r \cdot k_Q \cdot N_w \cdot M \quad (4\text{-}5)$$

D_w	=	absorbed dose to water
k_r	=	1 + 0.003 r replacement correction factor (r is the inner radius of the measuring volume of a cylindrical chamber, given in mm). See Table 5
k_Q	=	energy dependent correction factor, see Table 4
N_w	=	calibration factor for absorbed dose to water for ^{60}Co
M	=	corrected reading of the dosemeter, see chapter 2.1

Influence Quantity	**Reference Condition**
Phantom material	water
Chamber	cylindrical
Depth	5 cm for ^{60}Co 10 cm for photons
Chamber positioning	effective point of measurement, see chapter 2.3
SSD	95 cm for ^{60}Co 100 cm for photons
Field size	10 cm x 10 cm at 5 cm depth for ^{60}Co 10 cm x 10 cm at phantom surface for photons

The beam quality index Q is to be measured for each nominal accelerating voltage. Q is defined as the ratio M_{20} / M_{10} of two ionization readings of a dosemeter at different depths. M_{20} is obtained at 20 cm depth of water, M_{10} at 10 cm depth of water at a fixed source-detector-distance *SDD* = 100 cm and a field size of 10 cm x 10 cm at the depth of measurement.

NOTE
In case M_{10} and M_{20} values are not available, Q can be determined from [*DIN 6800-2*]

$$Q = 1.2661 \cdot m - 0.0595$$

where m is the ratio of the percent depth doses at 20 cm and 10 cm depth, respectively. The percent depth doses must be measured at $SSD = 100$ cm with a field size of 10 cm x 10 cm at the phantom surface.

For beam quality specification measurements with a cylindrical chamber, the chamber axis must be shifted downstream by $0.5\,r$, where r is the inner radius of the measuring volume. It is allowed to use a plane-parallel chamber to determine beam quality.

Chamber Type	Beam Quality Index Q														
	0.50	**0.53**	**0.56**	**0.59**	**0.62**	**0.65**	**0.68**	**0.70**	**0.72**	**0.74**	**0.76**	**0.78**	**0.80**	**0.82**	**0.84**
PTW 23331/30015 Rigid Stem	1.0090	1.0053	1.0008	0.9987	0.9957	0.9907	0.9867	0.9841	0.9806	0.9771	0.9727	0.9652	0.9576	0.9487	0.9363
PTW 23332/30016 Rigid Stem	1.0071	1.0044	1.0015	0.9988	0.9962	0.9926	0.9880	0.9856	0.9812	0.9770	0.9727	0.9644	0.9570	0.9495	0.9376
PTW 23333	1.0078	1.0048	1.0016	0.9988	0.9960	0.9922	0.9875	0.9850	0.9816	0.9772	0.9719	0.9645	0.9581	0.9494	0.9363
PTW 30001/30010	1.0078	1.0048	1.0016	0.9988	0.9960	0.9922	0.9875	0.9850	0.9816	0.9772	0.9719	0.9645	0.9571	0.9494	0.9363
PTW 30002/30011	1.0099	1.0058	1.0016	0.9988	0.9960	0.9922	0.9895	0.9870	0.9836	0.9802	0.9759	0.9685	0.9620	0.9533	0.9412
PTW 30004/30012	1.0099	1.0068	1.0026	0.9998	0.9980	0.9942	0.9915	0.9890	0.9856	0.9822	0.9779	0.9715	0.9640	0.9563	0.9432
PTW 30006/30013	1.0058	1.0038	1.0006	0.9988	0.9960	0.9922	0.9875	0.9850	0.9806	0.9762	0.9709	0.9635	0.9551	0.9464	0.9333
PTW 31002/31010 Semiflex	1.0065	1.0036	1.0006	0.9988	0.9961	0.9924	0.9877	0.9853	0.9809	0.9766	0.9713	0.9640	0.9556	0.9469	0.9339
PTW 31003/31013 Semiflex	1.0065	1.0036	1.0006	0.9988	0.9961	0.9924	0.9877	0.9853	0.9809	0.9766	0.9713	0.9640	0.9556	0.9469	0.9339
PTW 31021 Semiflex 3D	1.0027	1.0018	1.0005	0.9989	0.9967	0.9939	0.9902	0.9872	0.9836	0.9793	0.9742	0.9682	0.9611	0.9527	0.9429
PTW 31014 PinPoint	1.0052	1.0036	1.0012	0.9989	0.9977	0.9944	0.9912	0.9880	0.9839	0.9788	0.9737	0.9656	0.9574	0.9502	0.9388
PTW 31023 PinPoint	1.0017	1.0011	1.0003	0.9992	0.9976	0.9953	0.9921	0.9893	0.9858	0.9814	0.9760	0.9692	0.9608	0.9504	0.9376
PTW 31016 PinPoint 3D	1.0052	1.0036	1.0012	0.9989	0.9977	0.9944	0.9912	0.9880	0.9839	0.9788	0.9737	0.9656	0.9574	0.9502	0.9388
PTW 31022 PinPoint 3D	1.0020	1.0013	1.0000	0.9991	0.9973	0.9950	0.9918	0.9890	0.9857	0.9816	0.9766	0.9706	0.9632	0.9544	0.9438

Table 4: k_Q values for PTW cylindrical chambers [DIN 6800-2]. For ^{60}Co beams k_Q equals 1.000. The data for the chamber types 30015, 30016, 31016, 31021, 31022 and 31023 have been added by PTW-Freiburg.

Chamber Type	Radius r [mm]	Correction Factor k_r
PTW 30010/30013 0.6 cm³ Farmer	3.05	1.009
PTW 31021 0.07 cm³ Semiflex 3D	2.40	1.007
PTW 31010 0.125 cm³ Semiflex	2.75	1.008
PTW 31013 0.3 cm³ Semiflex	2.75	1.008
PTW 23331/30015 1.0 cm³ Rigid Stem	3.95	1.012
PTW 23332/30016 0.3 cm³ Rigid Stem	2.50	1.008
PTW 31014/31023 0.015 cm³ PinPoint	1.00	1.003
PTW 31016/31022 0.016 cm³ PinPoint 3D	1.45	1.004

Table 5: Radius of the measuring volume of PTW cylindrical chambers and values for the correction factor k_r. For details see Appendix A.

5 High Energy Electron Beams

5.1 IAEA TRS 398

5.1.1 Chambers calibrated at ^{60}Co

$$D_w = k_Q \cdot N_w \cdot M \qquad (5\text{-}1)$$

D_w = absorbed dose to water

k_Q = energy dependent correction factor, see Table 6

N_w = calibration factor for absorbed dose to water for ^{60}Co

M = corrected reading of the dosemeter, see chapter 2.1

Influence Quantity	Reference Condition
Phantom material	water (for beams with $R_{50} < 4\ \text{g/cm}^2$ (approx. $E_0 \geq 10\ \text{MeV}$) a plastic phantom may be used)
Chamber	plane-parallel (for beams with $R_{50} \geq 4\ \text{g/cm}^2$ (approx. $E_0 \geq 10\ \text{MeV}$) a cylindrical chamber may be used)
Depth	$z_{ref} = 0.6 \cdot R_{50} - 0.1\ \text{g/cm}^2$ (z_{ref} and R_{50} in g/cm^2)
Chamber positioning	effective point of measurement, see chapter 2.3
SSD	100 cm
Field size	10 cm x 10 cm at phantom surface, or that used for normalization of output factors, whichever is larger

The beam quality is specified by R_{50}, the depth in water at which the absorbed dose is 50 % of its value at the absorbed dose maximum[4]. R_{50} is to be measured under the above reference conditions, but at field sizes of at least

10 cm x 10 cm for $R_{50} \leq 7\ \text{g/cm}^2$

20 cm x 20 cm for $R_{50} > 7\ \text{g/cm}^2$

From the depth ionization distribution measured with an air-filled ionization chamber, the quantity $R_{50,ion}$ is obtained. This quantity can be converted to R_{50} by

$$R_{50} = 1.029 \cdot R_{50,ion} - 0.06\ \text{g/cm}^2 \qquad (5\text{-}2)$$
($R_{50,ion} \leq 10\ \text{g/cm}^2$)

$$R_{50} = 1.059 \cdot R_{50,ion} - 0.37\ \text{g/cm}^2 \qquad (5\text{-}3)$$
($R_{50,ion} > 10\ \text{g/cm}^2$)

For beam quality specification measurements with a cylindrical chamber, the chamber axis must be shifted downstream by $0.5\,r$, where r is the inner radius of the measuring volume. For $R_{50} < 4\ \text{g/cm}^2$ a plane-parallel chamber must be used.

5.1.2 Cross-Calibration

IAEA TRS 398 recommends the cross-calibration of plane-parallel chambers against a cylindrical chamber which is calibrated at ^{60}Co. Dose measurements are performed under reference conditions (see chapter 5.1.1) using the highest available electron energy Q_{cross}.

Step 1: measure a reference dose $D_{w,Q_{cross}}$ with a cylindrical chamber which was calibrated at ^{60}Co, following the procedure described in chapter 5.1.1.

Step 2: irradiate the plane-parallel chamber with the same dose. Take the plane-parallel chamber's corrected reading M and determine its calibration factor for the energy used for cross-calibration

$$N_{w,Q_{cross}} = \frac{D_{w,Q_{cross}}}{M} \qquad (5\text{-}4)$$

[4] The mean energy E_0 can be estimated by $E_0 = 2.33 \cdot R_{50}$ (R_{50} in g/cm^2 and E_0 in MeV).

Step 3: use the cross-calibrated plane-parallel chamber to measure dose at any electron energy Q other than Q_{cross}

$$D_w = \frac{k_Q}{k_{Q_{cross}}} \cdot N_{w,Q_{cross}} \cdot M \qquad (5\text{-}5)$$

$k_{Q_{cross}}$ is the plane-parallel chamber's k_Q value for the cross-calibration energy Q_{cross}. Values for k_Q are obtained from Table 6.

Electron Beam Quality R_{50} [g/cm^2]	PTW 23343 Markus	PTW 34045 Advanced Markus	PTW 34001 Roos	PTW 30001/ 30010 Farmer	PTW 30002/ 30011 Farmer	PTW 30004/ 30012 Farmer	PTW 30006/ 30013 Farmer	PTW 31002/ 31010 0.125 cm^3 Semiflex	PTW 31003/ 31013 0.3 cm^3 Semiflex
1.0	—	0.966	0.965	—	—	—	—	—	—
1.4	—	0.956	0.955	—	—	—	—	—	—
2.0	0.925	0.945	0.944	—	—	—	—	—	—
2.5	0.920	0.938	0.937	—	—	—	—	—	—
3.0	0.916	0.932	0.931	—	—	—	—	—	—
3.5	0.913	0.926	0.925	—	—	—	—	—	—
4.0	0.910	0.921	0.920	0.911	0.916	0.920	0.911	0.912	0.912
4.5	0.907	0.917	0.916	0.909	0.914	0.918	0.909	0.910	0.910
5.0	0.904	0.912	0.912	0.907	0.912	0.916	0.907	0.908	0.908
5.5	0.901	0.909	0.908	0.905	0.910	0.915	0.905	0.906	0.906
6.0	0.899	0.905	0.904	0.904	0.909	0.913	0.904	0.905	0.905
7.0	0.894	0.899	0.898	0.901	0.906	0.910	0.901	0.901	0.901
8.0	0.889	0.893	0.892	0.898	0.903	0.907	0.898	0.898	0.898
10.0	0.881	0.883	0.882	0.893	0.897	0.902	0.893	0.893	0.893
13.0	0.870	0.871	0.870	0.885	0.890	0.894	0.885	0.885	0.885
16.0	0.860	0.861	0.860	0.877	0.882	0.887	0.877	0.877	0.877
20.0	0.849	0.849	0.848	0.868	0.873	0.877	0.868	0.867	0.867

Table 6: Typical k_Q values for PTW plane-parallel and cylindrical chambers [IAEA 398] [5]. The values for the Advanced Markus chamber and the Farmer chambers type 30006/30013 have been added by PTW-Freiburg. They were calculated according to IAEA TRS 398[6].

[5] With corrigendum STI/DOC/010/398
[6] For details refer to PTW's Technical Note D661.200.00

5.2 AAPM TG-51

5.2.1 Chambers calibrated at ^{60}Co

$$D_w = P_{gr}^{Q} \cdot k'_{R_{50}} \cdot k_{ecal} \cdot N_w \cdot M \qquad (5\text{-}6)$$

D_w = absorbed dose to water

P_{gr}^{Q} = correction for gradient effects, not needed for plane-parallel chambers. For cylindrical chambers with a cavity radius r the correction factor at the reference depth d_{ref} is obtained from
$P_{gr}^{Q} = M(d_{ref} + 0.5 \cdot r) / M(d_{ref})$

$k'_{R_{50}}$ = electron quality conversion factor, see formulae (5-9) and (5-10)

k_{ecal} = photon-electron conversion factor, see Table 9

N_w = calibration factor for absorbed dose to water for ^{60}Co

M = corrected reading of the dosemeter, see chapter 2.1

Influence Quantity	Reference Condition
Phantom material	water
Chamber	plane-parallel preferred for $R_{50} \leq 4.3$ cm (10 MeV) plane-parallel mandatory for $R_{50} \leq 2.6$ cm (6 MeV)
Depth	$d_{ref} = 0.6 \cdot R_{50} - 0.1$ cm
Chamber positioning	chamber axis for cylindrical chambers, effective point of measurement for plane-parallel chambers, see chapter 2.3
SSD	90 - 110 cm
Field size	≥ 10 cm x 10 cm at phantom surface for $R_{50} \leq 8.5$ cm (20 MeV), ≥ 20 cm x 20 cm at phantom surface for $R_{50} > 8.5$ cm

The beam quality is specified by R_{50}, the depth in water at which the absorbed dose is 50 % of its value at the absorbed dose maximum. R_{50} is to be measured under the above reference conditions, but at $SSD = 100$ cm and at field sizes at the phantom surface of at least

10 cm x 10 cm for $R_{50} \leq 8.5$ cm

20 cm x 20 cm for $R_{50} > 8.5$ cm

From the depth ionization distribution measured with an air-filled ionization chamber, the quantity I_{50} is obtained. This quantity can be converted to R_{50} by

$$R_{50} = 1.029 \cdot I_{50} - 0.06 \text{ cm} \quad (2 \leq I_{50} \leq 10 \text{ cm}) \qquad (5\text{-}7)$$

$$R_{50} = 1.059 \cdot I_{50} - 0.37 \text{ cm} \quad (I_{50} > 10 \text{ cm}) \qquad (5\text{-}8)$$

Chamber Type	k_{ecal}
PTW 34001 Roos	0.901
PTW 34045 Advanced Markus	0.905
PTW 23343 Markus	0.905
PTW 30001/30010 Farmer	0.897
PTW 30002/30011 Farmer	0.900
PTW 30004/30012 Farmer	0.905
PTW 30006/30013 Farmer	0.896
PTW 31003/31013 0.3 cm³ Semiflex	0.898
PTW 31002/31010 0.125 cm³ Semiflex	0.898
PTW 23331 1.0 cm³ Rigid Stem	0.896
PTW 23332/30016 0.3 cm³ Rigid Stem	0.898

Table 7: Values of the photon-electron conversion factor k_{ecal}. The values not listed in [AAPM 51] have been added by PTW-Freiburg; they were calculated according to [Rogers 1998].

For beam quality specification measurements with a cylindrical chamber, the chamber axis must be shifted downstream by $0.5\,r$, where r is the inner radius of the measuring volume. Cylindrical chambers should be used only for $R_{50} > 4.3$ cm.

The electron quality conversion factor is obtained from the following formulae with R_{50} expressed in cm.

For cylindrical chambers and $2 \leq R_{50} \leq 9$ cm

$$k'_{R_{50}} = 0.9905 + 0.071 \cdot e^{-\frac{R_{50}}{3.67}} \qquad (5\text{-}9)$$

and

for well-guarded plane-parallel chambers and $2 \le R_{50} \le 20$ cm

$$k'_{R_{50}} = 1.2239 - 0.145 \cdot (R_{50})^{0.214} \quad (5\text{-}10)$$

5.2.2 Cross-calibration

AAPM TG-51 recommends the cross-calibration of plane-parallel chambers against a cylindrical chamber which is calibrated at ^{60}Co. Dose measurements are performed under reference conditions (see chapter 5.2.1) using the highest available electron energy Q_{cross}.

Step 1: measure a reference dose $D_{\text{w},Q_{\text{cross}}}$ with a cylindrical chamber which was calibrated at ^{60}Co, following the procedure described in chapter 5.2.1.

Step 2: irradiate the plane-parallel chamber with the same dose. Take the plane-parallel chamber's corrected reading M and determine its calibration factor for the energy used for cross-calibration

$$N_{\text{w},Q_{\text{cross}}} = \frac{D_{\text{w},Q_{\text{cross}}}}{M} \quad (5\text{-}11)$$

Step 3: use the cross-calibrated plane-parallel chamber to measure dose at any electron energy Q other than Q_{cross}

$$D_{\text{w}} = \frac{k'_{R_{50}}}{k'_{R_{50},Q_{\text{cross}}}} \cdot N_{\text{w},Q_{\text{cross}}} \cdot M \quad (5\text{-}12)$$

$k'_{R_{50},Q_{\text{cross}}}$ is the plane-parallel chamber's $k'_{R_{50}}$ value for the cross-calibration energy Q_{cross}.
$k'_{R_{50}}$ values are obtained from formula (5-10).

5.3 DIN 6800-2

5.3.1 Chambers calibrated at ^{60}Co

$$D_{\text{w}} = k_{\text{r}} \cdot k_{\text{E}} \cdot N_{\text{w}} \cdot M \quad (5\text{-}13)$$

D_{w} = absorbed dose to water at z_{ref}
k_{r} = $1 + 0.03\,r$ replacement correction factor (r is the inner radius of the measuring volume of a cylindrical chamber, given in cm). k_{r} is not applicable for plane-parallel chambers.
k_{E} = $k'_{\text{E}} \cdot k''_{\text{E}}$ energy dependent correction factor, see chapter 5.3.3
N_{w} = calibration factor for absorbed dose to water for ^{60}Co
M = corrected reading of the dosemeter at z_{ref}, see chapter 2.1

Influence Quantity	Reference Condition
Phantom material	water
Chamber	plane-parallel for $R_{50} \ge 4$ cm a cylindrical chamber can be used
Depth	z_{ref} (see chapter 5.3.2)
Chamber positioning	effective point of measurement, see chapter 2.3
SSD	100 cm
Field size	20 cm x 20 cm at phantom surface

5.3.2 Determination of R_{50} and z_{ref}

R_{50} is defined as the depth at which the absorbed dose has dropped to 50 % of the maximum value. R_{50} is determined from the corresponding value $R_{50,\text{ion}}$ of a depth ionization curve, measured at $SSD = 100$ cm with a field size of 20 cm x 20 cm (optionally 10 cm x 10 cm for $R_{50} \le 7$ cm)

$$R_{50} = 1.029 \cdot R_{50,\text{ion}} - 0.06\,\text{cm} \; (R_{50,\text{ion}} \le 10\,\text{cm}) \quad (5\text{-}14)$$

$$R_{50} = 1.059 \cdot R_{50,\text{ion}} - 0.37\,\text{cm} \; (R_{50,\text{ion}} > 10\,\text{cm}) \quad (5\text{-}15)$$

The reference depth for dose measurements is defined as (z_{ref} and R_{50} in cm)

$$z_{\text{ref}} = 0.6 \cdot R_{50} - 0.1 \quad (5\text{-}16)$$

5.3.3 Determination of $k_E = k'_E \cdot k''_E$

k'_E is independent of the chamber type (R_{50} in cm)

$$k'_E = 1.106 - 0.1312 \cdot (R_{50})^{0.214} \qquad (5\text{-}17)$$

a) k''_E for **plane-parallel chambers** is determined from

$$k''_E = \frac{(p_{wall} \cdot p_{cav})_{R_{50}}}{(p_{wall} \cdot p_{cav})_{Co}} \qquad (5\text{-}18)$$

The relevant factors are listed in Table 8.

Chamber type	$(p_{cav})_{R_{50}}$	$\frac{(p_{wall})_{R_{50}}}{(p_{wall} \cdot p_{cav})_{Co}}$
PTW 34001 Roos	1.000	0.981
PTW 34045 Adv. Markus	1.000	0.985
PTW 23343 Markus	$1 - 0.037 \cdot e^{-0.27 \cdot R_{50}}$	0.982

Table 8: Perturbation correction factors for plane-parallel chambers at the reference depth z_{ref} [Christ 2002, Kapsch 2007, DIN 6800-2].

b) k''_E for **cylindrical chambers** at the reference depth z_{ref} is calculated from

$$k''_E = \frac{(p_{cav} \cdot p_{cel})_{R_{50}}}{(p_{wall} \cdot p_{cel})_{Co}} \qquad (5\text{-}19)$$

and

$$(p_{cav})_{R_{50}} = 1 - 0.0217 \cdot r \cdot e^{-0.153 \cdot R_{50}} \qquad (5\text{-}20)$$

with r in mm and R_{50} in cm. r can be taken from Table 5, $(p_{wall})_{Co}$ and $(p_{cel})_{R_{50}}/(p_{cel})_{Co}$ are listed in Table 9.

5.3.4 Dose measurements at depths other than z_{ref}

The dose at depth z is determined by

$$D_w(z) = k_r \cdot k_E \cdot k_{NR} \cdot N_w \cdot M(z) \qquad (5\text{-}21)$$

k_E is the correction factor at z_{ref} as described in chapter 5.3.3, k_{NR} is given by

$$k_{NR} = \frac{s^{\Delta}_{w,a}(z)}{s^{\Delta}_{w,a}(z_{ref})} \cdot \frac{p_{cav}(z)}{p_{cav}(z_{ref})} \cdot \frac{p_{wall}(z)}{p_{wall}(z_{ref})} \qquad (5\text{-}22)$$

and

$$s^{\Delta}_{w,a}(z) = \frac{a + bx + cx^2 + dy}{1 + ex + fx^2 + gx^3 + hy} \qquad (5\text{-}23)$$

where $x = \ln(R_{50})$ and $y = z / R_{50}$ (z and R_{50} in cm) and

a = 1.0752 b = - 0.50867 c = 0.08867

d = - 0.08402 e = - 0.42806 f = 0.06463

g = 0.003085 h = - 0.1246

The cavity perturbation factor depends on the chamber type

a) **Roos and Advanced Markus chambers**

$$p_{cav}(z) = p_{cav}(z_{ref}) = 1.000$$

b) **Markus chambers**

$$p_{cav}(z) = \frac{1}{1 + e^{a \cdot \left(\frac{z}{R_{50}} + b + c \cdot R_{50} + d \cdot z\right)}} \qquad (5\text{-}24)$$

with z and R_{50} in cm and with

a = 0.1498 b = -21.7336 c = -4.3379
d = 4.0487

c) **Cylindrical chambers**

$$p_{cav}(z) = 1 - 0.02155 \cdot r \cdot e^{-0.2525 \cdot R_{50} \cdot \left[1 - \frac{z}{1.271 \cdot R_{50} - 0.23}\right]} \qquad (5\text{-}25)$$

with r in mm, z and R_{50} in cm.

Chamber type	$(p_{wall})_{Co}$	$\frac{(p_{cel})_{R_{50}}}{(p_{cel})_{Co}}$
PTW 23331 1 cm³ Rigid Stem	1.001	1.005
PTW 30015 1 cm³ Rigid Stem	1.000	1.005
PTW 23332 0.3 cm³ Rigid Stem	1.001	1.005
PTW 30016 0.3 cm³ Rigid Stem	0.999	1.005
PTW 23333 Farmer (3 mm build-up cap)	1.001	1.005
PTW 23333 Farmer (4.6 mm build-up cap)	1.001	1.005
PTW 30001/30010 Farmer	1.001	1.005
PTW 30002/30011 Farmer	0.991	1.000
PTW 30004/30012 Farmer	0.991	1.005
PTW 30006/30013 Farmer	1.001	1.005
PTW 31002/31010 0.125 cm³ Semiflex	1.001	1.005
PTW 31003/31013 0.3 cm³ Semiflex	1.001	1.005
PTW 31014/31015 PinPoint	0.998	1.005
PTW 31016 PinPoint 3D	0.998	1.005

Table 9: Perturbation and central electrode correction factors for cylindrical chambers [DIN 6800-2]. Chambers not listed in DIN 6800-2 have been added by PTW-Freiburg.

6 Measurements in Acrylic Phantoms

6.1 General

For dosimetry in high energy photon or electron beams all dosimetry protocols described in this document (IAEA TRS 398, AAPM TG-51, DIN 6800-2) require absorbed dose measurements in real water. Solid state phantoms may only be used for routine QA measurements, and a transfer factor has to be established [AAPM 51]. The phantom should extend at least 5 cm beyond all sides of the field and at least 5 cm beyond the maximum depth of measurement [IAEA 398].

This chapter helps to establish transfer factors and 'equivalent' measuring depths for measurements in acrylic (PMMA, Perspex, $C_5H_8C_2$) phantoms.

6.2 High energy photons

6.2.1 Conversion of measuring depth

Photon beams are attenuated and scattered differently in water and solid phantoms. To take these differences into account, correction procedures have to be carried out.

Differences in photon beam attenuation are determined by the ratio of the mean linear attenuation coefficients of water and PMMA. The measuring depth in water z_w can be determined from the measuring depth in PMMA z_p assuming the same source-detector-distance [AAPM 21]

$$z_w = 1.136 \cdot z_p \qquad \text{for } ^{60}\text{Co - 35 MV} \qquad (6\text{-}1)$$

6.2.2 Excess scatter correction

In PMMA phantoms the fraction of scattered photons is increased compared with water phantoms. To convert measuring values from PMMA to water, the measuring value has to be multiplied by a correction factor k_{ESC} (Excess Scatter Correction). Table 10 shows k_{ESC} values as a function of accelerator voltage and field size [AAPM 21].

6.3 High energy electrons

Solid phantoms may be used below 10 MeV to determine absorbed dose at z_{ref} [IAEA 398]. The measuring depth in water z_w can be determined from the measuring depth in PMMA z_p assuming the same source-detector-distance

$$z_w = \rho \cdot c_{pl} \cdot z_p = 1.159 \cdot z_p \qquad (6\text{-}2)$$

c_{pl} is the depth scaling factor and ρ the nominal density of PMMA [IAEA 398/2]. The reading in the PMMA phantom M_p must be corrected by the fluence scaling factor h_{pl} to obtain the equivalent reading in water M

$$M = h_{pl} \cdot M_p = 1.009 \cdot M_p \qquad (6\text{-}3)$$

Energy (MV)	Depth (cm)	Field size at depth (cm²)			
		5x5	10x10	20x20	30x30
^{60}Co	0.5	0.997	0.996	0.995	0.996
	5.0	0.986	0.987	0.989	0.991
2	0.4	0.998	0.994	0.997	—
	5.0	0.984	0.982	0.989	—
4	1.0	0.998	0.997	0.998	—
	5.0	0.994	0.993	0.993	—
6	1.5	0.999	0.998	0.998	—
	5.0	0.994	0.994	0.996	—

Table 10: k_{ESC} as a function of energy and field size.

7 References

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Appendix A: Summary of PTW Chamber Data

PTW Cylindrical Chambers

Type No.	Chamber Name	Measuring Volume [cm³]	Wall	Electrode	Wall Area Density [mg/cm²]	Radius of Measuring Volume [mm]	Ion Collection Time at nominal HV
30001	Farmer	0.6	0.275 mm PMMA + 0.15 mm C	Al ∅1 mm	45 *(1)*	3.05	0.14 ms (400 V)
30010	Farmer	0.6	0.335 mm PMMA + 0.09 mm C	Al ∅1.1 mm	57 *(2)*	3.05	0.14 ms (400 V)
30011 30002	Farmer, all graphite	0.6	0.425 mm C	C ∅1 mm	79 *(2)*	3.05	0.14 ms (400 V)
30012 30004	Farmer	0.6	0.425 mm C	Al ∅1.1 mm	79 *(2)*	3.05	0.14 ms (400 V)
30013 30006	Farmer, waterproof	0.6	0.335 mm PMMA + 0.09 mm C	Al ∅1.1 mm	57 *(2)*	3.05	0.14 ms (400 V)
31002	Semiflex	0.125	0.55 mm PMMA + 0.15 mm C	Al ∅1 mm Graphite coated	78 *(1)*	2.75	0.10 ms (400 V)
31010	Semiflex	0.125	0.55 mm PMMA + 0.15 mm C	Al ∅1.1 mm	78 *(1)*	2.75	0.12 ms (400 V)
31021	Semiflex 3D	0.07	0.57 mm PMMA + 0.09 mm C	Al ∅ 0.8 mm	84 *(2)*	2.4	0.118 ms (400 V)
31003	Semiflex	0.3	0.55 mm PMMA + 0.15 mm C	Al ∅1.5 mm Graphite coated	78 *(1)*	2.75	0.08 ms (400 V)
31013	Semiflex	0.3	0.55 mm PMMA + 0.15 mm C	Al ∅0.9 mm	78 *(1)*	2.75	0.12 ms (400 V)
23331	Rigid Stem	1.0	0.40 mm PMMA + 0.15 mm C	Al ∅1.5 mm Graphite coated	60 *(1)*	3.95	0.21 ms (400 V)
30015	Rigid Stem	1.0	0.4 mm PMMA + 0.135 mm C	Al ∅1.1 mm	73 *(2)*	3.95	0.24 ms (400 V)
23332	Rigid Stem	0.3	0.35 mm PMMA + 0.15 mm C	Al ∅2 mm Graphite coated	54 *(1)*	2.5	0.04 ms (400 V)
30016	Rigid Stem	0.3	0.35 mm PMMA + 0.135 mm C	Al ∅0.85 mm	67 *(2)*	2.5	0.08 ms (400 V)
31014	PinPoint	0.015	0.57 mm PMMA + 0.09 mm C	Al ∅0.3 mm	85 *(2)*	1.0	0.02 ms (400 V)
31023	PinPoint	0.015	0.57 mm PMMA + 0.09 mm C	Al ∅0.6 mm	85 *(2)*	1.0	0.013 ms (300 V)
31015	PinPoint	0.03	0.57 mm PMMA + 0.09 mm C	Al ∅0.3 mm	85 *(2)*	1.45	0.04 ms (400 V)
31016	PinPoint 3D	0.016	0.57 mm PMMA + 0.09 mm C	Al ∅0.3 mm	85 *(2)*	1.45	0.06 ms (400 V)
31022	PinPoint 3D	0.016	0.57 mm PMMA + 0.09 mm C	Al ∅0.6 mm	85 *(2)*	1.45	0.045 ms (300 V)

(1) Graphite density 0.82 g/cm³
(2) Graphite density 1.85 g/cm³

PTW Plane Parallel Chambers

Type No.	Chamber Name	Measuring Volume [cm^3]	Entrance Window	Electrode Diameter [mm]	Window Area Density [mg/cm^2]	Electrode Distance [mm]	Ion Collection Time at nominal HV
34001	Roos	0.35	1.01 mm PMMA + 0.02 mm C + 0.1 mm Varnish	15.6	132	2	0.13 ms (200 V)
34045	Advanced Markus	0.02	0.87 mm PMMA + 0.4 mm Air + 0.03 mm PE *(3)*	5	106 *(3)*	1	0.02 ms (300 V)
23343	Markus	0.055	0.87 mm PMMA + 0.4 mm Air + 0.03 mm PE *(3)*	5.3	106 *(3)*	2	0.09 ms (300 V)
23342	Soft X-Ray	0.02	0.03 mm PE	3	2.8	1	0.02 ms (300 V)
23344	Soft X-Ray	0.2	0.03 mm PE	13	2.8	1.5	0.04 ms (400 V)
34013	Soft X-Ray	0.005	0.03 mm PE	1.4	2.8	0.9	0.01 ms (400 V)

(3) with protection cap in place

Notes

Notes

Product Index

Item Number Index

The item numbers below are without the leading letters. For complete ordering numbers, indicating the connecting system, see the according product page.

Some former detector types are not included in this catalogue as they have been replaced by new types. The following table shows discontinued detector types and their replacements.

Detector name	Discontinued type	New type
Farmer, PMMA/Al	30001	30010
Farmer graphite/Al	30004	30012
Farmer, waterproof	30006	30013
0.125 cm^3 semiflex	31002	31010
0.3 cm^3 semiflex	31003	31013
0.3 cm^3 rigid stem	23332	30016
PinPoint 0.015 cm^3	31014	31023
PinPoint 0.03 cm^3	31009	31015
PinPoint 3D 0.016 cm^3	31016	31022
Dosimetry Diode P	60008	60016

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