Phantoms
for X-ray Imaging

Including Codes of Practice

QRM A PTW COMPANY

QRM - A PTW Company

A milestone in the history of both companies

In 1922, PTW started being a pioneer in medical radiation measurements. Since then, PTW has always been and will continue to be at the forefront of advancing patient safety through innovation and cutting-edge measurement technology.
In 1994, QRM (Quality Assurance in Radiology and Medicine) was founded by Professor Willi A. Kalender as a university spin-off of the Institute of Medical Physics in Erlangen, Germany, for the development, design, construction, and production of phantoms for quality assurance in X-ray imaging and associated procedures.
Since April 2020 QRM is a subsidiary of PTW Freiburg GmbH.

Phantoms for your needs

We look back on more than 25 years of experience in designing and manufacturing phantoms for medical imaging modalities. Our first products were designed for lung imaging in Computed Tomography (CT) and bone densitometry in DXA and CT. Since starting manufacturing phantoms in the early '90s, our range of phantoms has increased substantially over the years. Today, we offer products for different imaging modalities in clinical routine, research, development, and science, as well as customized and OEM products.

Our engineers design dedicated phantoms for many applications in the field of medical imaging. Our customers are physicians, scientists, and manufacturers all over the world. Our main focus is on developing products for diagnostic X-ray, CT, and micro-CT imaging. We offer phantoms to analyze image quality (IQ), calibrate HU-levels as well as for dosimetry issues.

QRM phantoms are professionally designed and manufactured with highest precision. The components are carefully selected and adapted to the specific imaging modality. Our machinery uses the latest technology to produce and manufacture phantoms with high accuracy.

Standard as well as custom-made phantoms undergo a quality control test according to their use. Therefore, different types of medical imaging devices (e.g. DXA, CT, C-arm, Micro-CT, MRI, etc.) are used for our test setups.

Our core competence is the development and production of customized phantoms in cooperation with our customers. We successfully collaborate with manufacturers in medical and industrial X-ray markets as well as with scientists and physicians working on research projects and studies worldwide. All standard phantoms can be modified according to your needs. We also offer customized phantoms for: PET, SPECT, radiation therapy, and for other modalities.

Are you interested in a completely new, specially designed phantom for a specific study, project, or new application?

Contact us - we provide phantoms for your needs.

Contents

Customized Solutions

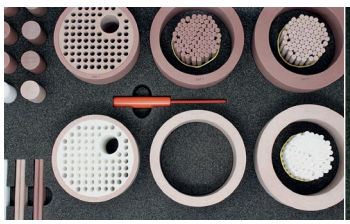
QRM additionally offers customized phantoms for: MRI, PET, SPECT, radiation therapy, and other imaging modalities.

Are you interested in a completely new, specially designed phantom for a specific study, project or new application? Or do you need a special OEM product?

Contact us - we provide phantoms for your needs.

Just follow these steps to get your specific phantom:

- Send an inquiry
  If you send us a request for a custom-made phantom, we will provide a proposal of what is technically possible and what would be the best way to realize your ideas. This will be the basis for the following discussion or you will accept our first draft.
- Mention the imaging modality
  Please let us know the modality where the phantom will be used.
  For dedicated imaging modalities we have to use different components or materials for the phantom.
- Give a brief description
  Give us a brief description of the phantom. The more details we know prior, the better our draft/proposal will be.
- Send a short drawing or line sketch
  Provide us a short drawing or a line sketch. This will be the easiest way to understand what you are looking for. You can simply use MS® Word® or Powerpoint® to draw your phantom. Or just send us a scanned manual sketch. We also acccept CAD-files (e.g. .dxf or .stl).
- Please feel free to contact us by E-mail or give us a call to discuss the design of your specific phantom.



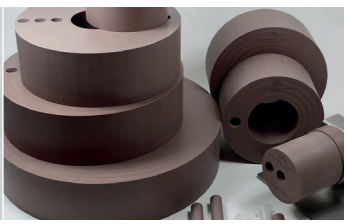
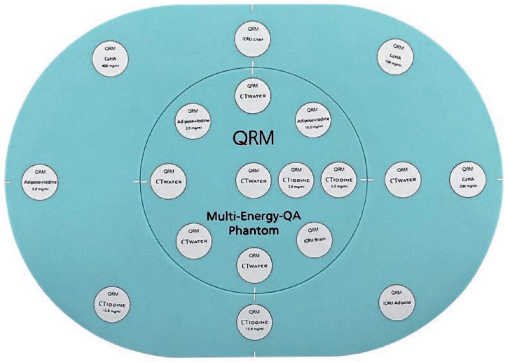



Image Quality Phantoms

Multi-Energy QA Phantom



For testing different types of CT modalities with dual-energy, multi-energy or photon-counting setups

- For different types of CT modalities with dual-energy, multi-energy, or photon-counting setups
- Test multi-energy spectral CT protocols and post-processing techniques
- Decompose Iodine and CaHA levels

Image acquisition and image processing at multiple energy levels is improving visualization for computed tomography. The QRM Multi-Energy QA phantom is ideally suited to test multi-energy spectral CT protocols and post-processing techniques.

The phantom consists of a removable/stand-alone head phantom (Ø 160 mm cylinder) with 10 holes (Ø 25 mm) to house different inserts and an oval (QRM-10150) or an optional circular (QRM-10151) body, equipped with 9 bores. Body and Head section are made of water-equivalent material (CTwater).

The phantom is equipped with a set of 26 inserts including rods enriched with several contrast media (water+iodine, adipose+iodine) as well as calcium (water+calcium hydroxyapatite), each material with different concentrations. Additionally, water- and soft tissue-equivalent inserts (adipose, liver, brain - ICRU Report 44 and 46) are included. Mass density, concentration and electron density are provided for all materials.

Other materials (e.g. blood+Iodine, various ICRU Tissues etc.) can be manufactured upon request.
Optionally, all inserts (recommended for/especially the higher attenuating materials) can be manufactured with reduced material diameter (e.g. Ø 10 mm) embedded in a water-equivalent shell (in total Ø 25 mm).

Specification

Body:	
Phantom diameter	250 mm x 350 mm
Phantom length	125 mm
Holes	9 pcs., 25 mm diameter
Head insert:	
Phantom diameter	160 mm
Phantom length	125 mm
Holes	10 pcs., 25 mm diameter
Material	CTwater (water-equivalent)
Inserts:	
Diameter	25 mm
Length	125 mm
Phantom weight	6.0 kg

Includes stand and transport case

Inserts

26 Inserts included:
CTwater (3 pcs.): 0 HU at (80 ... 140) kV[1]
Water + Iodine (6 pcs.):
0.5, 1.0, 2.0, 5.0, 10.0 and 15.0 mg/cm^3
Adipose + Iodine (6 pcs.):
0.5, 1.0, 2.0, 5.0, 10.0 and 15.0 mg/cm^3
Water + Ca hydroxyapatite (5 pcs.):
25, 50, 100, 200, 400 mg/cm^3
ICRU Liver + Iron (3 pcs.)
ICRU Adipose (1 pc.)
ICRU Brain (1 pc.)
Tube (Fillable rod) (1 pc.)

Calibration protocol:
Physical density, concentration, electron density, electron density relative to water
(Additional values upon request)

[1]Accuracy ± 5 HU of specified values

Ordering Information

QRM-10150 Multi-Energy QA Phantom with stand
QRM-10151 D320 Ring for Multi-Energy QA Phantom

Options

QRM-10152 MEP - Set of 6 Gadolinium rods
QRM-10153 MEP - Set of 11 ICRU Tissue Equivalents
QRM-10154 MEP - Set of CTwater rods (2 pcs.)
QRM-10155 MEP - Set of CTwater rods (15 pcs.)

For further information please visit qrm.de.

Spectral CT Phantom

For testing different types of CT modalities with dual-energy, multi-energy or photon-counting setups

- Test the accuracy and consistency of spectral CT
- Test the scanner performance
- Perform a material characterization and quantification of tissue-equivalent materials
- Decompose Iodine and CaHA levels
- Test the post-processing techniques of spectral CT

Image acquisition and image processing at multiple energy levels is improving visualization for computed tomography. The QRM-Spectral-CT Phantoms are ideally suited to test multi-energy spectral CT protocols and post-processing techniques.

The 100 mm cylinder contains 4 holes (QRM-10139) or 8 holes (QRM-10147) with 20 mm diameter to house different solid rods and fillable tubes that can be used with water or contrast media. The set of solid rods includes different concentrations of Iodine and Ca-Hydroxyapatite (CaHA) as well as water and soft tissue equivalents (adipose, muscle, bone, and lung according to ICRU Report 44 and 46). Mass density, electron density, and effective atomic number are provided for all materials.

Specification

Phantom diameter	100 mm
Phantom height	103 mm
Phantom weight	1.0 kg
Body material	Water-equivalent (CTwater, approx. 0 HU at (80 ... 140) kV[1])
Holes (Ø 20 mm)	4 pcs. (QRM-10139) or 8 pcs. (QRM-10147)
Insert diameter	20 mm
Insert height	103 mm

Inserts

4 plugs CTwater (QRM-10139) or
8 plugs CTwater (QRM-10147): 0 HU at (80 ... 140) kV[1]
12 test rods
- ICRU Adipose tissue
- ICRU Muscle tissue
- ICRU Lung tissue
- ICRU Liver tissue
- 4 different solid Iodine rods (CTIodine)[2] with 2, 5, 10 and 15 mg I/cm³
- 4 different CaHA rods (bone)[1] with 100, 200, 400 and 800 mg CaHA/cm³

2 fillable rods/tubes

[1]Accuracy ± 5 HU of specified values
[2]Specified values. Nominal values can vary due to manufacturing method and imaging device.

Ordering Information

QRM-10139 Spectral CT Phantom
QRM-10147 Spectral CT Phantom II
QRM-10143 D100 CTwater insert, 8 boreholes

Options

QRM-10145 Fillable Rod, D20
QRM-30101 ICRU Tissue rod, soft tissues
QRM-30102 ICRU Tissue rod, bone
QRM-10143 D100 CTwater insert, 8 boreholes
QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

For further information please visit qrm.de.

Dual-Energy Phantom, V2

Specially designed for dual-energy (DE) purposes and suitable for QA, scanner performance and evaluation of different DE post-processing techniques

- D100 compatible
- Create virtual non-contrast lesions
- CaHA and Iodine inclusions of different size and density

Dual-energy capable CT devices enable the differentiation of Ca and Iodine in clinical CT imaging. The QRM-10107 is easy-to-use and optimized to test CT-scanner performance and to evaluate different DE post-processing techniques by providing several virtual non-contrast lesions.

The different cylindrical lesions are enriched with CaHA (Ca-Hydroxyapatite) and CTIodine (solid Iodine) such that they cannot be differentiated in a standard scan (equivalent HU level at 120 kV), but generate contrast at other energies (e.g., 80 kV / 140 kV). Thus, the DE scan allows material separation between CaHA and Iodine.

There are several options available to be used with the D100 compatible QRM-10107 as, for example, our Thorax or Abdomen Phantom.

Specification

Phantom diameter	100 mm
Phantom height	100 mm
Phantom weight	1.0 kg

Inserts

8 cylindrical targets	Ø 10 mm / H 10 mm
8 cylindrical targets	Ø 5 mm / H 5 mm
1 calibration cylinder	Ø 25 mm / H 10 mm

CT values (HU) valid for 120 kV (± 5 HU)[1]:

Material

Phantom body	CTwater, 0 HU at (80 ... 140) kV[1]

Targets

Layer A
- CaHA 200 HU, 400 HU, 600 HU (Ø 5 mm)
- Iodine 200 HU, 400 HU, 600 HU (Ø 5 mm)

Layer B

Half cylinder (Ø 10 mm)
- CaHA 200 HU, 400 HU, 600 HU
- Iodine 200 HU, 400 HU, 600 HU

Full cylinder (Ø 10 mm)
- Iodine 25 HU, 50 HU, 100 HU

Layer C
- Adipose -140 HU (Ø 5 mm, Ø 10 mm)
- Adipose + Iodine 0 HU (Ø 5 mm, Ø 10 mm)

[1]Specified values. Effective values can vary due to manufacturing method and imaging device.

Ordering Information

QRM-10107 Dual Energy CT Phantom, V2

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

Dual-Energy Phantom, V5

Specially designed for dual-energy (DE) purposes and suitable for QA, scanner performance and evaluation of different DE post-processing techniques

- D100 compatible
- Create virtual non-contrast images
- CaHA and Iodine inclusions of different size and density

The phantom includes fat and soft tissue lesions with different Iodine and CaHA concentrations.

Dual-energy capable CT devices offer the opportunity to distinguish between different tissues and materials in CT images of clinical interest. In particular, the focus is on Calcium and Iodine.

It is an easy-to-use phantom with different virtual fat- and tissue-equivalent lesions, partially enriched with CaHA (Ca–Hydroxyapatite) and CT Iodine (solid Iodine). CaHA and Iodine enriched lesions appear on an equivalent HU level at a standard CT scan. The DE scan allows material separation between CaHA and Iodine.

There are several options available to be used with the D100 compatible QRM-10123 as, for example, our Thorax and Abdomen Phantom.

Specification

Phantom diameter	100 mm
Phantom height	100 mm
Phantom weight	1.0 kg

Inserts

18 cylindrical targets	Ø 10 mm / H 10 mm
1 calibration cylinder	Ø 25 mm / H 10 mm

CT values (HU) valid for 120 kV (± 5 HU)[1]:

Material

Phantom body	CTwater (0 HU at (80 ... 140) kV[1])
Calibration cylinder	0 HU at (80 ... 140) kV[1]

Targets

Layer A Fat + CaHA / Iodine*
- Fat -110/-100 HU at 80/140 kV
- Fat + CaHA 60 HU at 120 kV
- Fat + CaHA -50 HU at 120 kV
- Fat -110/-100 HU at 80/140 kV
- Fat + Iodine 60 HU at 120 kV
- Fat + Iodine -50 HU at 120 kV

Layer B Soft Tissue + CaHA / Iodine*
- Tissue 60/55 HU at 80/140 kV
- Tissue + CaHA 200 HU at 120 kV
- Tissue + CaHA 100 HU at 120 kV
- Tissue 60/55HU at 80/140 kV
- Tissue + Iodine 200 HU at 120 kV
- Tissue + Iodine 100 HU at 120 kV

Layer C Fat + Soft Tissue + CaHA / Iodine*
- Fat + Tissue -28/-24 HU at 80/140 kV
- Fat + Tissue + CaHA 140 HU at 120 kV
- Fat + Tissue + CaHA 30 HU at 120 kV
- Fat + Tissue -28/-24 HU at 80/140 kV
- Fat + Tissue + Iodine 140 HU at 120 kV
- Fat + Tissue + Iodine 30 HU at 120 kV

[1]Specified values. Effective values can vary due to manufacturing method and imaging device.

Ordering Information

QRM-10123 Dual Energy CT Phantom, V5

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

Cone-Beam Phantom, Expert and Basic

For evaluating the imaging performance of Computed Tomography (CT), Cone-Beam CT as well as various imaging systems

- Multipurpose phantom for comparison of different CT and CBCT scanner solutions
- Assess all relevant image quality metrics
- Provides different low contrast sections and spatial resolution bar patterns
- Allows MTF measurements in different orientations

The phantom is designed to cover the whole range of image quality parameters and offers the possibility to assess all relevant image quality metrics in accordance with national and international guidelines (e.g. TG-66) and standards (e.g. DIN IEC 61223-3-5 or DIN IEC 61223-2-6):

Low-contrast capabilities
CT value uniformity
CT value accuracy
Image noise
Contrast-to-noise ratio (CNR)
Spatial resolution (ESF, MTF, wedges)
Spatial resolution (visual, line pattern)
Geometric accuracy in-plane

It is essential to fully quantify the imaging performance of volumetric X-ray scanners and to compare different systems or technical solutions. The dedicated low contrast sections provide an ideal environment to test the system's low contrast resolution. The Cone-Beam Phantom Basic (QRM-10120) provides contrasts between -3 HU and -20 HU within one section. The Cone-Beam Phantom Expert (QRM-10103) accommodates three low contrast sections offering contrasts between -3 and -200 HU to consider the large variation in low contrast capabilities. Using the spatial resolution bar patterns you can assess the in-plane resolution of the system in a direct visual manner. Additional edge inserts determine the system's MTF in different orientations. The image contrast and HU-scale section quantifies the machine's HU-scale and the bone contrast achieved with different settings. Additionally, the geometric accuracy, the CNR and the image noise of the scanner can be evaluated.

For further infomation please visit qrm.de.

Specification

Phantom diameter	160 mm
Phantom height	163 mm (QRM-10120, Basic) 183 mm (QRM-10103, Expert)
Section height	20 mm
Body material	Soft tissue-equivalent plastic (at 120 kV)

The phantom body comprises 8 (Basic, QRM-10120) or 9 (Expert, QRM-10103) sections:

Section A - Contrast resolution (QRM-10103, Expert)
Section A1: contrast steps -60, -90, -120, -200 HU
Section A2: contrast steps -20, -25, -30, -45 HU
Section A3: contrast steps -3, -5, -10, -15 HU

Section A - Contrast resolution (QRM-10120, Basic)
Contrast steps of -3, -5, -10, -20 HU

Insert diameter in steps of 2, 4, 8, 16 and 32 mm, respectively.

Section B - Spatial resolution (QRM-10120 & QRM-10103)
14 circular aligned line patterns varying from 4 to 30 lp / cm.

Section C - Scaling & noise (QRM-10120 & QRM-10103)
3 inserts (Ø 24 mm) providing bone-equivalent material (400 mg CaHA / cm^3), water-equivalent (CTwater) and air.

Section D - MTF wedges (QRM-10120 & QRM-10103)
Two PTFE wedges (PTFE 20 mm x 16 mm x 80 mm) perpendicularly aligned for evaluating the MTF in different orientations.

Section E - Geometric distortion (QRM-10120 & QRM-10103)
Hole grid, consisting of 177 holes (Ø 3 mm) to measure the geometric distortion in the image.

Section O - Plain (QRM-10120 & QRM-10103)
Measure noise and homogeneity, optional space for custom-made adapter for individual mounting.

Ordering Information

QRM-10103 Cone-Beam Phantom, Expert
QRM-10120 Cone-Beam Phantom, Basic

Breast CT QA Phantom, Expert

For measurement of imaging performance of dedicated Breast-CT Systems and other 3D Cone-Beam tomography equipment

- Suitable for image quality check-ups, acceptance and constancy testing of Breast CT and other Cone-Beam CT Systems
- Determination of spatial resolution in any direction (3D-MTF)
- 4 different targets (air, -3% contrast, +3% contrast and bone)

The phantom is designed to perform quality checks and test the imaging performance of Breast- CT and Cone-Beam CT systems.

The following image quality metrics can be obtained:
CT value uniformity
CT value accuracy
Image noise
Contrast-to-noise ratio
Spatial resolution (3D MTF)

Specification

Phantom diameter	140 mm
Phantom height	180 mm
Body material	CTwater (water-equivalent)
Inserts length	17.5 mm

The phantom contains 3 defined sections:
Section I: 4 inserts with Ø 13 mm, height 25 mm
Section II: blank, water equivalent for noise, uniformity
Section III: Sphere for 3D-MTF, PTFE, Ø 12 mm

A dedicated evaluation software is currently not available.

Ordering Information

QRM-10136 Breast CT QA Phantom, Expert

2D Low Contrast Phantom

For evaluation of low-contrast resolution at various imaging systems as clinical CT or Cone-Beam CT (e.g. Dental-CBCT)

- Include several cylindrical low-contrast test objects of different sizes (5 ... 15) mm
- Contrast to background -20 HU and -10 HU in one phantom

The phantom is designed to evaluate the imaging capabilities of 3D X-ray imaging modalities in the x/y-plane. CT-scanners low-contrast resolution capabilities can be obtained by a single spiral scan and axial reconstruction. The phantom visualizes the impact of all scans, image reconstruction, and display parameters.

There are two sectors providing different contrasts of -10 HU and -20 HU, each with several cylindrical inserts (diameters of 5, 10 and 15 mm) located within the cylindrical body of homogeneous tissue-equivalent material.

There are several options available to be used with the D100 compatible QRM-10112 as, for example, our Thorax and Abdomen Phantom.

Specification

Phantom diameter	100 mm
Phantom height	103 mm
Phantom weight	0.9 kg
Body material	tissue-equivalent plastic at 120 kV

Contrast Inserts

Contrast values	-10 HU and -20 HU relative to background[1]
Dimensions	Ø 5, 10, 15 mm / H 100 mm

[1]Accuracy ± 3 HU of specified values

Ordering Information

QRM-10112 2D Low Contrast Phantom

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

2D Medium Contrast Phantom

For evaluation of low and medium contrast resolution at various imaging systems as clinical CT or Cone-Beam CT (e.g. Dental-CBCT)

- Includes several cylindrical medium contrast inserts of different sizes (2 ... 15 mm)
- 4 contrast steps in the phantom: -25, -50, -75 and -100 HU

The phantom is designed to evaluate the imaging capabilities of 3D X-ray imaging modalities in the x/y-plane. CT-scanners low-contrast resolution capabilities can be obtained by a single spiral scan and axial reconstruction. The phantom visualizes the impact of all scans, image reconstruction, and display parameters.

There are four sectors providing different contrast steps of -25, -50, -75 and -100 HU, each with several cylindrical inserts (diameters of 2, 4 ,6, 8 and 15 mm) located within the cylindrical body of homogeneous tissue-equivalent material. There are several options available to be used with the D100 compatible QRM-10100 as, for example, our Thorax and Abdomen Phantom.

Specification

Phantom diameter	100 mm
Phantom height	103 mm
Phantom weight	0.9 kg
Body material	tissue-equivalent plastic at 120 kV

Cylindrical Inserts

Contrast values	-25, -50, -75 and -100 HU relative to background[1]
Dimensions	Ø 2, 4, 6, 8 and 15 mm / H 100 mm

[1]Accuracy ± 3 HU of specified values

Ordering Information

QRM-10100 2D Medium Contrast Phantom

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

3D Low Contrast Phantom

For optimization of collimation, pitch value and image reconstruction to achieve isotropic spatial resolution in all types of clinical applications

- D100 compatible
- Includes several spherical low-contrast inserts arranged in two planes
- Contrast of -20 HU or -10 HU to background available

The phantom has been designed to evaluate the imaging capabilities of 3D X-ray imaging modalities in the x/y-plane as well as in the sagittal plane. Several series of low-contrast spheres (diameter varying from 3 mm to 8 mm) are located in the 100 mm diameter cylindrical body of homogeneous tissue-equivalent material.

The low-contrast resolution capability is obtained by a single spiral scan using axial images and coronal reformations. The phantom visualizes the impact of all scans, image reconstruction and display parameters. There are several options available to be used with the D100 compatible QRM-10109 and QRM-10110 as, for example, our Thorax and Abdomen Phantom.

Specification

Phantom diameter	100 mm
Phantom height	103 mm
Phantom weight	0.9 kg
Body material	tissue-equivalent plastic

Contrast Inserts

Contrast values	-10 HU (QRM-10109) or -20 HU (QRM-10110) relative to background[1]
Cylindrical contrast insert	Ø 20 mm / H 25 mm
Spherical contrast inserts	9 spheres Ø 3 mm 9 spheres Ø 4 mm 9 spheres Ø 5 mm 9 spheres Ø 6 mm 7 spheres Ø 8 mm

[1]Accuracy of ± 3 HU of specified values

Ordering Information

QRM-10109 3D Low Contrast Phantom (-10 HU)
QRM-10110 3D Low Contrast Phantom (-20 HU)

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

Slice Sensitivity Phantom

Suitable tool to optimize collimation, pitch and image reconstruction for improved slice profile and axial spatial resolution in all types of clinical applications

- Measure and evaluate the slice sensitivity in spiral CT volume scans
- Houses a 25 micron thin (Ø 1 mm) and centrally placed gold foil

The phantom is designed to evaluate the slice sensitivity of a CT scanner's spiral/helical scan modes, i.e. the response of the entire imaging system to a delta-shaped object. It contains a circular 25 micron thin metal foil (Au), embedded in a cylinder of uniform tissue-equivalent plastic.

The heavy metal foil is designed to evaluate all collimations from 0.5 mm to 10 mm (and more) with adequate image contrast. We suggest analyzing the maximum CT number of the high-contrast insert for a series of axial images (sequential scan) and to compare it to the profile extracted from a spiral scan with varying pitch factor and image reconstruction parameters.

Specification

Phantom diameter	23 mm
Phantom height	100 mm
Phantom material	tissue-equivalent plastic
	Metal (Au) foil: Ø 1 mm, thickness: 0.025 mm

Ordering Information

QRM-10114 Slice Sensitivity Phantom

3D Spatial Resolution Phantom, D100

For optimization of collimation, pitch value and image reconstruction to achieve isotropic spatial resolution in all types of clinical applications

- Evaluate spatial resolution in-plane and sagittal CT-images
- Provides several hole patterns in two planes

The high-contrast spatial resolution test phantom visualizes spatial resolution axial and sagittal plane of dedicated CT protocols and image reconstruction algorithms. The test pattern is a series of drilled holes with varying diameter and spacing from 4.0 mm down to 0.4 mm (see table) covering an order of magnitude in spatial frequency.

With spiral/helical CT, evaluating both axial images and coronal reformations, spatial 3D resolution can be tested by a single scan.

The table summarizes the geometrical properties of the test pattern: diameter of cylindrical drill holes, spacing between two drilled holes, and resulting spatial frequency in lp/cm. Each line of the pattern consists of five holes. In order to ease localization, markers are placed in the vicinity of two lines.

Table:

Diameter (mm)	Line pairs/cm
4.0	1.25
3.0	1.66
2.0	2.50
1.5	3.33
1.2	4.16
1.0	5.00
0.9	5.55
0.8	6.25
0.7	7.14
0.6	8.33
0.5	10.0
0.4	12.5

Specification

Phantom diameter	100 mm
Phantom height	70 mm (z)
Phantom weight	0.8 kg
Two plates with test patterns aligned perpendicular	Ø 100 mm x 10 mm 50 mm x 100 mm x 10 mm
Material	Acrylic plastic

Ordering Information

QRM-10101 3D Spatial Resolution Phantom, D100

Options

QRM-10111 3D Spatial Resolution Phantom
QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

3D Spatial Resolution Phantom

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3.0	1.66
2.0	2.50
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1.2	4.16
1.0	5.00
0.9	5.55
0.8	6.25
0.7	7.14
0.6	8.33
0.5	10.0
0.4	12.5

Specification

Phantom dimension	140 mm x 173 mm (in-plane)
Phantom height	194 mm (z)
Phantom weight	0.8 kg
Material	Acrylic plastic
Size of plates with test patterns	50 mm x 100 mm x 10 mm

Ordering Information

QRM-10111 3D Spatial Resolution Phantom

Wire Phantoms

Perfect tool to assess in-plane spatial resolution of any 3D X-ray imaging system

- 3 different versions available
- Assess in-plane spatial resolution of any 3D X-ray imaging system by evaluating the PSF and MTF

The phantoms contain a 50 micron thick wire aligned parallel to the phantom axis of rotation centrally in the cylindrical body. The wire is either surrounded by homogeneous solid material or placed in the air.

Using the phantom, the Point Spread Function (PSF) and Modulation Transfer Function (MTF) can easily be investigated.

Customizable: Different wire diameters are available upon request.

Specification

Wire Phantom, resin (QRM-10104)	
Phantom diameter	45 mm
Phantom height	60 mm
Phantom material	Proprietary resin
Wire Phantom, D100 (QRM-10105)	
Phantom diameter	100 mm
Phantom height	100 mm
Phantom material	Soft tissue-equivalent plastic
Wire Phantom, air (QRM-10138)	
Phantom diameter	45 mm
Phantom height	60 mm
Phantom housing	Durable plastic
Wire	typically tungsten
Thickness	0.05 mm

Ordering Information

QRM-10104 Wire Phantom, resin
QRM-10105 Wire Phantom, D100
QRM-10138 Wire Phantom, air

Beam Stop Phantom

For estimation of the scatter distribution of X-ray cone-beam CT and for developing scatter correction techniques

- Convenient performance of scatter measurements in radiological setups
- Array of lead cylinders embedded in a PMMA plate

The Phantom consists of an array of lead cylinders embedded in an acrylic (PMMA) plate. Lead blockers offer an attenuation sufficient to prevent primary radiation reaching the detector. The Beam Stop Phantom is a convenient tool to experimentally determine the X-ray scatter-to-primary-ratio for a given measurement setup for analog and digital radiography.

The Beam Stop array is placed between the object and the X-ray source or between the object and detector.

A measurement of the signal level behind each blocker gives the scatter intensity, whereas a measurement without the phantom represents the total intensity (scatter and primary signal). Dividing both values results in the scatter fraction.

Specification

Phantom dimension	240 mm x 240 mm
Phantom height	(5.5 ... 6) mm
Body material	PMMA

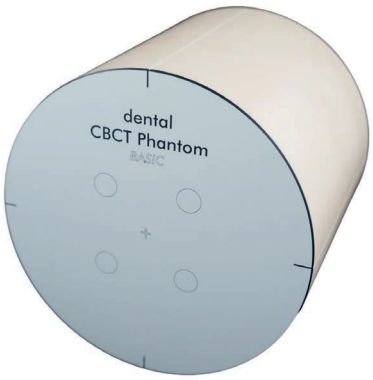
Lead Cylindrical Inlets

Height	(5 ... 6) mm
Diameter	3 mm
Spacing	20 mm

Ordering Information

QRM-10115 Beam Stop Phantom

Dental CBCT QA Phantom, Basic



For measurement of imaging performance of dental Cone-Beam CT equipment

- For testing the imaging performance of dental cone-beam CT systems
- A compact easy-to-use phantom for acceptance and constancy tests
- Allows 3D MTF measurements

The phantom is designed to evaluate the image quality parameters of Cone-Beam CT devices according to international guidelines (e.g. dental Cone-Beam CT, Digital Volume Tomography) and standards (e.g. DIN IEC 61223-3-5 or DIN IEC 61223-2-6).

The following image quality metrics can be obtained:
CT value uniformity
CT value accuracy
Image noise
Contrast-to-noise ratio (CNR)
Spatial resolution (3D MTF, sphere)

3 defined sections:
Section 1: 4 inserts in water: air, -3% contrast, +3% contrast and bone arranged concentrically
Section 2: Homogeneous water-equivalent slice
Section 3: Centrally placed high-attenuating sphere

Specification

Phantom diameter	160 mm
Phantom height	150 mm
Body material	CTwater 0 HU at (80 ... 140) kV

3 sections:
Inserts (length 17.5 mm):
Section 1: 4 inserts with Ø 13 mm
Section 2: blank, water equivalent for noise, uniformity
Section 3: Sphere for 3D-MTF, Al, Ø 12 mm

Ordering Information

QRM-10130 Dental CBCT QA Phantom, Basic

Dental CBCT QA Phantom, Expert

For measurement of imaging performance of dental Cone-Beam CT equipment

- For testing the imaging performance of dental cone-beam CT systems
- A compact easy-to-use phantom for acceptance and constancy tests
- Allows 3D MTF measurements

The phantom is designed to evaluate the image quality parameters of Cone-Beam CT devices according to international guidelines (e.g. dental Cone-Beam CT, Digital Volume Tomography) and standards (e.g. DIN IEC 61223-3-5 or DIN IEC 61223-2-6).

The following image quality metrics can be obtained:
CT value uniformity
CT value accuracy
Image noise
Contrast-to-noise ratio (CNR)
Spatial resolution (3D MTF, sphere)
Spatial resolution (visual, hole pattern)
Artifact behavior metal/bone / soft tissue

5 defined sections:
Section 1: 4 inserts in water: air, -3% contrast, +3% contrast and bone arranged concentrically
Section 2: Centrally placed high-attenuating sphere
Section 3: Homogeneous water-equivalent slice
Section 4: Acrylic resolution pattern
Section 5: Titanium rods and tissue-equivalent inserts

Specification

Phantom diameter	100 mm
Phantom height	100 mm
Body material	CTwater 0 HU at (80 ... 140) kV

5 sections:
Inserts (length 17.5 mm):
Section 1: 4 inserts with Ø 13 mm
Section 2: Sphere for 3D-MTF, Al, Ø 12 mm
Section 3: blank, water equivalent for noise, uniformity
Section 4: Hole grid Ø 0.3 to 1.0 mm in-plane and coronal, spatial resolution
Section 5: artificial dental arch, 7 bone inserts (100 mg CaHA/cm^3) with Ø 3 mm
2 metal inserts (Titanium) with Ø 3 mm
3 soft tissue inserts (-8 % / 0 % / +8 %) with Ø 9 mm
Metal artifact behaviour in bone and soft tissue

Extension ring	Ø 160 mm, height 100 mm

Ordering Information

QRM-10131 Dental CBCT QA Phantom, Expert

Water Tank Phantom

For the evaluation of noise and homogenity in CT images

- D100 compatible
- Evaluate noise and homogeneity of a 3D scan
- Samples and small phantoms can be placed in water

The phantom can be attached to the Thorax (QRM-20100) or Abdomen (QRM-20118) Phantom but can as well be used as a stand-alone phantom.

The PMMA Water Tank Phantom can be filled with water and allows the evaluation of noise and homogeneity of a 3D scan. Furthermore, smaller samples or phantoms can be placed and measured in the cylindrical unit.

A support for custom phantoms to be placed in water is available upon request.

Specification

Phantom height	200 mm
Phantom width	120 mm
Phantom length	228 mm
Phantom weight	0.6 kg
Phantom material	PMMA
Cylinder diameter	100 mm
Cylinder length	108 mm
Cylinder wall thickness	3.0 mm

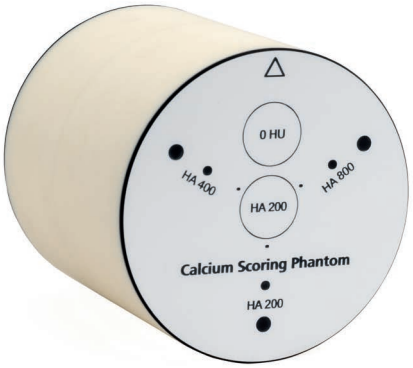
Ordering Information

QRM-10113 Water Tank Phantom

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

Calcium Scoring Phantom, D100



A calibration standard for cardiac CT to achieve reproducible scoring results

- Calibration standard for cardiac CT
- Investigate the detectability of coronary calcifications
- Achieve reproducible scoring results
- Include CaHA targets in different sizes and density

It is ideally suited to investigate the influence of scan parameters on the detectability of calcifications.

The phantom contains nine cylindrical calcification inserts in varying size and density of calcium hydroxyapatite (CaHA). Furthermore, there are two larger calibration inserts (water-equivalent and CaHA material). All inserts are embedded in a soft tissue-equivalent material (approx. 30 HU at 120 kV).

In order to obtain absolute values for the calcium mass, a calibration measurement with the central calibration insert of known CaHA density of 200 mg CaHA/cm³ can be carried out. The water-equivalent insert serves as a further calibration standard. In practice the CT number of water should always be checked in the given set up. If the measured value deviates from zero, the known deviation can be taken into account in the applied scoring method.

In combination with the optional available thorax phantom, the set provides the opportunity to receive realistic calcium scores.

Specification

Phantom diameter	100 mm
Phantom height	100 mm
Phantom weight	0.9 kg
Body material	Soft tissue-equivalent (approx. 30 HU at 120 kV)

Inserts

3 cylindrical inserts (200, 400, 800 mg CaHA /cm³): Ø 5 mm / H 5 mm
3 cylindrical inserts (200, 400, 800 mg CaHA /cm³): Ø 3 mm / H 3 mm
3 cylindrical inserts (200, 400, 800 mg CaHA /cm³): Ø 1 mm / H 1 mm

Ordering Information

QRM-10146 Calcium Scoring Phantom, D100

High Contrast Resolution Phantom, D100

A perfect tool to assess in-plane resolution of CT and CBCT X-ray systems in a direct visual manner

- Evaluation of in-plane resolution of CT and CBCT X-ray systems in a direct visual manner
- D100 compatible

The high-contrast resolution phantom visualizes the impact of scan protocols and image reconstruction algorithms. The test pattern is a series of high contrast bars with varying width and spacing from 0.63 mm to 0.1 mm (see table) allowing for an order of magnitude in spatial frequency.

Table:

lp/cm	lp/mm	Line (mm)
8	0.8	0.63
10	1.0	0.5
12	1.2	0.42
14	1.4	0.36
16	1.6	0.31
18	1.8	0.28
20	2	0.25
22	2.2	0.23
24	2.4	0.21
26	2.6	0.19
28	2.8	0.18
30	3	0.17
40	4	0.13
50	5	0.1

There are several options available to be used with the D100 compatible QRM-10140 as, for example, our Thorax and Abdomen Phantom.

Specification

Phantom diameter	100 mm
Phantom height	100 mm
Phantom weight	0.9 kg
Body material	Soft tissue-equivalent, approx. 35 HU at 120 kV

Two sections:
Section 1: bar pattern from (8 ... 22) lp/cm in steps of 2 lp/cm
line width: (0.6 ... 0.2) mm
Section 2: bar pattern from (20 ... 50) lp/cm in steps of 2 lp/cm
line width: (0.25 ... 0.1) mm

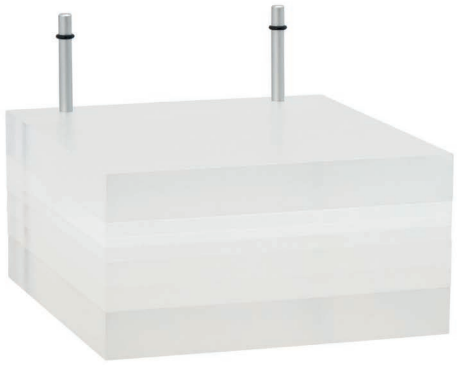
Ordering Information

QRM-10140 High Contrast Resolution Phantom, D100

Options

QRM-20100: Thorax Phantom
QRM-20118: Abdomen Phantom
QRM-20115: Oval Body Phantom, Tissue
QRM-20116: Oval Body Phantom, CTwater
QRM-10141: Extension Ring CTwater, 160mm
QRM-10142: Extension Ring CTwater, 320mm

MAM Phantoms



Technician and operator sets for mammography stereotactic biopsy systems

- For acceptance and constancy tests for prone mammography stereotactic biopsy systems
- Designed in accordance with DIN 6868-163

Both sets offer the possibility to perform acceptance and constancy tests according to DIN 6868-163. The phantoms are made of PMMA and can be positioned between X-ray tube and detector of the mammography unit using two aluminium rods (included).

Specification

Technician set for MAM 6868-163 (QRM-10148):

1x Test plate	150 mm x 150 mm x 6 mm
2x Absorber plate	150 mm x 150 mm x 20 mm
2x Absorber plate	150 mm x 150 mm x 10 mm
1x Absorber plate	150 mm x 150 mm x 6 mm
1x Absorber plate	150 mm x 150 mm x 4 mm

Operator set for MAM 6868-163 (QRM-10149):

1x Test plate	150 mm x 150 mm x 6 mm
1x Absorber plate	150 mm x 150 mm x 40 mm

All plates have two bore holes, such that they can be attached to the aluminum holder (two rods, diameter: 6 mm, length: 120 mm)

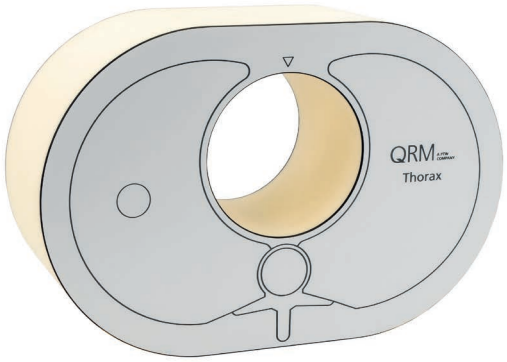
Ordering Information

QRM-10148 Technician set for MAM 6868-163
QRM-10149 Operator set for MAM 6868-163

Notes

Anthropomorphic Phantoms

Thorax Phantom



A (semi-) anthropomorphic surrounding for all D100 compatible image quality inserts

- D100 compatible
- Includes spine and lung lobes
- Customizable

The phantom comprises artificial lung lobes and a bone-like spine insert (spongiosa and corticalis) surrounded by soft tissue-equivalent material.
The plastics used in this phantom mimic human tissues in the thorax with respect to density and X-ray attenuation characteristics of a human thorax.

The QRM-20100 is a compact functional phantom as it can be easily positioned on the patient couch in order to successfully conduct all measurement tasks.

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	103 mm
Phantom weight	2.7 kg
Diameter of borehole	100 mm
Body material	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV
Lung	approx. -800 HU at 120 kV
Spine	corticalis / spongiosa, bone-like, approx. 550 HU / 200 HU at 120 kV

Ordering Information

QRM-20100 Thorax Phantom

Options

The Thorax Phantom is also available with drilled holes according to CTDI specifications:

QRM-40104 Thorax Dosimetry Phantom

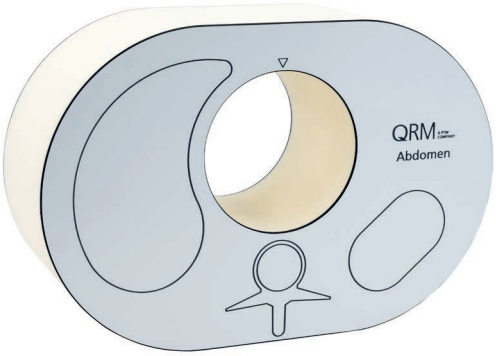
There are multiple standard cylinders for image quality purposes available. The following D100 Insert are available:

QRM-10108 D100 Soft Tissue Insert
QRM-10112 2D Low Contrast Phantom
QRM-10100 2D Medium Contrast Phantom
QRM-10109 3D Low Contrast Phantom (-10 HU)
QRM-10110 3D Low Contrast Phantom (-20 HU)
QRM-10101 3D Spatial Resolution Phantom, D100
QRM-10140 High Contrast Resolution Phantom, D100
QRM-10105 Wire Phantom, D100
QRM-10113 Water Tank Phantom
QRM-10107 Dual Energy Phantom, V2
QRM-10123 Dual Energy Phantom, V5
QRM-10139 Spectral CT Phantom
QRM-10147 Spectral CT Phantom II
QRM-10143 D100 CTwater insert, 8 boreholes
QRM-10146 Calcium Scoring Phantom, D100
QRM-40106 Dose Insert D100
QRM-90110 Electron Density Phantom, D100

Further, there are extension rings available to mimic obese patients:

QRM-20104 Extension Ring Soft Tissue, M
QRM-20105 Extension Ring Soft Tissue, L
QRM-20106 Extension Ring Soft Tissue, XL
QRM-20107 Extension Ring Fat, M
QRM-20108 Extension Ring Fat, L
QRM-20109 Extension Ring Fat, XL

Abdomen Phantom



A (semi-) anthropomorphic surrounding for our multiple D100 imaging inserts

- D100 compatible
- Includes organs (liver, spleen)

The phantom comprises a bone-like spine insert (spongiosa and corticalis) and fixed liver and spleen inserts providing the appropriate CT values of real tissues. All organs are embedded in soft tissue-equivalent material.

The plastics of this phantom mimic human tissues with respect to density and X-ray attenuation characteristics of a human abdomen.

There are multiple standard cylinders (D100) for image quality purposes available (see options section).

Customizable: The phantom can be manufactured with exchangeable/removable liver and spleen inserts.

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	103 mm
Phantom weight	3.2 kg
Diameter of borehole	100 mm
Body material	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV
Liver/Spleen	tissue-equivalent, approx. 60 HU at 120 kV
Spine	corticalis / spongiosa, bone-like, approx. 550 HU / 200 HU at 120 kV

Ordering Information

QRM-20118 Abdomen Phantom

Options

The Abdomen Phantom is also available with drilled holes according to CTDI specifications:

QRM- 40105 Abdomen Dosimetry Phantom

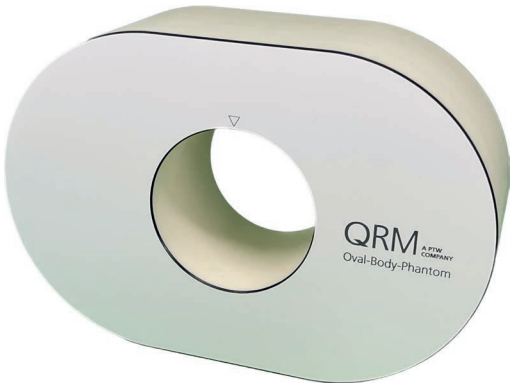
There are multiple standard cylinders for image quality purposes available. The following D100 Insert are available:

QRM-10108 D100 Soft Tissue Insert
QRM-10112 2D Low Contrast Phantom
QRM-10100 2D Medium Contrast Phantom
QRM-10109 3D Low Contrast Phantom (-10 HU)
QRM-10110 3D Low Contrast Phantom (-20 HU)
QRM-10101 3D Spatial Resolution Phantom, D100
QRM-10140 High Contrast Resolution Phantom, D100
QRM-10105 Wire Phantom, D100
QRM-10113 Water Tank Phantom
QRM-10107 Dual Energy Phantom, V2
QRM-10123 Dual Energy Phantom, V5
QRM-10139 Spectral CT Phantom
QRM-10147 Spectral CT Phantom II
QRM-10143 D100 CTwater insert, 8 boreholes
QRM-10146 Calcium Scoring Phantom, D100
QRM-40106 Dose Insert D100
QRM-90110 Electron Density Phantom, D100

Further, there are extension rings available to mimic obese patients:

QRM-20104 Extension Ring Soft Tissue, M
QRM-20105 Extension Ring Soft Tissue, L
QRM-20106 Extension Ring Soft Tissue, XL
QRM-20107 Extension Ring Fat, M
QRM-20108 Extension Ring Fat, L
QRM-20109 Extension Ring Fat, XL

Oval Body Phantom



A (semi-)anthropomorphic surrounding for multiple D100 inserts to investigate the influence of scan parameters in CT and CBCT

- D100 compatible
- (Semi-)anthropomorphic surrounding

The oval phantom body comprises a shell of water-equivalent or soft tissue-equivalent material.
The plastic used in this (semi-) anthropomorphic phantom mimics the human body with respect to density and X-ray attenuation characteristics.

It provides a centrally placed 100 mm diameter bore hole to place multiple standard test cylinders for image quality purposes and various other measurement tasks. Furthermore, this phantom is also available as a dosimetry version (see options section).

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	103 mm
Phantom weight	2.6 kg
Diameter of borehole	100 mm
Body material	
QRM-20115	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV[1]
QRM-20116	Water-equivalent (CTwater), approx. 0 HU at (80 ... 140) kV[1]

[1]Accuracy of ± 5 HU of specified values

Ordering Information

QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Ovel Body Phantom, CTwater

Options

There are multiple standard cylinders for image quality purposes available. The following D100 Insert are available:

QRM-10108 D100 Soft Tissue Insert
QRM-10112 2D Low Contrast Phantom
QRM-10100 2D Medium Contrast Phantom
QRM-10109 3D Low Contrast Phantom (-10 HU)
QRM-10110 3D Low Contrast Phantom (-20 HU)
QRM-10101 3D Spatial Resolution Phantom, D100
QRM-10140 High Contrast Resolution Phantom, D100
QRM-10105 Wire Phantom, D100
QRM-10113 Water Tank Phantom
QRM-10107 Dual Energy Phantom, V2
QRM-10123 Dual Energy Phantom, V5
QRM-10139 Spectral CT Phantom
QRM-10147 Spectral CT Phantom II
QRM-10143 D100 CTwater insert, 8 boreholes
QRM-10146 Calcium Scoring Phantom, D100
QRM-40106 Dose Insert D100
QRM-90110 Electron Density Phantom, D100

Further, there are extension rings available to mimic obese patients:

QRM-20104 Extension Ring Soft Tissue, M
QRM-20105 Extension Ring Soft Tissue, L
QRM-20106 Extension Ring Soft Tissue, XL
QRM-20107 Extension Ring Fat, M
QRM-20108 Extension Ring Fat, L
QRM-20109 Extension Ring Fat, XL

Dosimetry version with drilled holes according to CTDI specifications for dosimetry purposes:

QRM-40100 CDTI CTwater phantom

Extension Rings

The Extension Rings for the simulation of obese patients that fit on our standard phantoms such as the Thorax, Abdomen and Liver Nodule Phantom

- To simulate obesity of patients
- Compatible with standard phantoms
- Available in soft tissue-, fat- or water-equivalent
- Dosimetry option with available

The Extension Rings are a good choice for testing the influences/impact of higher attenuation due to an increased abdominal or chest girth on image quality in CT and other 3D imaging techniques.
To mimic different degrees of obesity, the Extension Rings are available in sizes M, L and XL. Further, you can choose between tissue-equivalent and fat-equivalent material for all ring sizes.

Upon request all rings can be manufactured from other materials as water-equivalent material (CTwater).

Specification

Extension Ring M:	
Outside dimensions	250 mm x 350 mm
Inside dimensions	200 x 300 mm
Height	103 mm
Extension Ring L:	
Outside dimensions	300 mm x 400 mm
Inside dimensions	200 mm x 300 mm
Height	103 mm
Extension Ring XL:	
Outside dimensions	450 mm x 600 mm
Inside dimensions	300 mm x 400 mm
Height	103 mm

Please note: The XL Extension Ring has to be used in combination with the Extension Ring in size L.

Body materials	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV Fat-equivalent, approx. -(70 ... 90) HU at 120 kV

Ordering Information

QRM-20104 Extension Ring Soft Tissue, M
QRM-20105 Extension Ring Soft Tissue, L
QRM-20106 Extension Ring Soft Tissue, XL
QRM-20107 Extension Ring Fat, M
QRM-20108 Extension Ring Fat, L
QRM-20109 Extension Ring Fat, XL

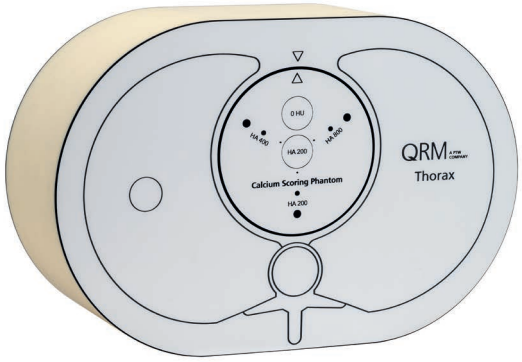
All Extension Rings are also available as dosimetry version:

QRM-40107 Dosimetry Extension Ring Soft Tissue, M
QRM-40108 Dosimetry Extension Ring Soft Tissue, L
QRM-40109 Dosimetry Extension Ring Soft Tissue, XL
QRM-40110 Dosimetry Extension Ring Fat, M
QRM-40111 Dosimetry Extension Ring Fat, L
QRM-40112 Dosimetry Extension Ring Fat, XL

Options

QRM-20100 Thorax Phantom
QRM-20103 Calcium Scoring Phantom Set
QRM-20118 Abdomen Phantom
QRM-20119 Liver Nodule Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater

Calcium Scoring Phantom Set



A calibration standard for cardiac CT to achieve reproducible scoring results

- Calibration standard for cardiac CT
- Investigate the detectability of coronary calcifications
- Achieve reproducible scoring results
- Include CaHA targets in different sizes and density

The phantom is ideally suited to investigate the influence of scan parameters on the detectability of calcifications. It is designed in a modular construction principle. It is made up of two parts: Thorax Phantom (QRM-20100) and Calcium Scoring Phantom, D100 (QRM-10146)

The Thorax Phantom (QRM-20103) comprises artificial lung lobes and a bone-like spine insert (spongiosa and corticalis) surrounded by soft tissue-equivalent material. The plastics used in this phantom mimic human tissues in the thorax with respect to density and X-ray attenuation characteristics of a human thorax.

The Calcium Scoring Phantom, D100 (QRM-10146) contains nine cylindrical calcification inserts in varying size and calcium hydroxyapatite (CaHA) density (see Table). Furthermore, there are two larger calibration inserts (water-equivalent and CaHA material). All inserts are embedded in a soft tissue-equivalent material (approximately 30 HU at 120 kV).

In order to obtain absolute values for the calcium mass, a calibration measurement with the central calibration insert of known CaHA density of 200 mg CaHA/cm^3 can be carried out. The water-equivalent insert serves as a further calibration standard. In practice the CT number of water should always be checked in the given set up. If the measured value deviates from zero, the known deviation can be taken into account in the applied scoring method.

The phantom contains nine cylindrical calcification inserts in varying size and calcium hydroxyapatite (CaHA) density (see Table). Furthermore, there are two larger calibration inserts (water-equivalent and CaHA material). All inserts are embedded in a soft tissue-equivalent material (approximately 30 HU at 120 kV).

HA density (mg/cm^3)	Length (mm)	Diameter (mm)	Volume (mm^3)	Area (mm^2)	HA mass (mg)
200	5.0	5.0	98.2	19.6	19.6
200	3.0	3.0	21.2	7.1	4.2
200	1.0	1.0	0.8	0.8	0.2
400	5.0	5.0	98.2	19.6	39.3
400	3.0	3.0	21.2	7.1	8.5
400	1.0	1.0	0.8	0.8	0.3
800	5.0	5.0	98.2	19.6	78.5
800	3.0	3.0	21.2	7.1	17
800	1.0	1.0	0.8	0.8	0.6

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	103 mm
Phantom weight (total)	3.6 kg
Weight of cardiac insert	0.9 kg
Body material	Soft tissue-equivalent approx. 30 HU at 120 kV

Inserts

3 cylindrical inserts	200, 400, 800 mg CaHA /cm^3, Ø 5 mm / H 5 mm
3 cylindrical inserts	200, 400, 800 mg CaHA /cm^3, Ø 3 mm / H 3 mm
3 cylindrical inserts	200, 400, 800 mg CaHA /cm^3 Ø 1 mm / H 1 mm
Lung	approx. -800 HU at 120 kV
Spine	corticalis / spongiosa, bone-like, approx. 550 HU / 200 HU at 120 kV

Ordering Information

QRM-20103 Calcium Scoring Phantom Set

Liver Nodule Phantom

The (semi-)anthropomorphic phantom comprises an exchangeable liver insert with multiple liver nodules for the examination of low contrast details in the liver region in CT and FD-CT

- Analyze computer-aided diagnoses (CAD) procedures
- Customizable

It is ideally suited/a good choice to analyze computer-aided diagnoses (CAD) procedures. The phantom allows to test the capability of the setup to differentiate different kinds of nodules within the human liver. The modular design comprises a removable liver insert containing multiple oval and spherical lesions of different size, shape, and density. Positioned in two layers there are multiple hypo- and hyperdense nodules generating different contrast levels relative to the iodinated liver background. The surrounding abdomen comprises a bone-like spine insert (spongiosa and corticalis) and a homogeneous spleen insert surrounded by soft tissue-equivalent material.

The shape and density of the nodules in the Liver insert can be customized upon request.

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	103 mm
Phantom weight	4.2 kg

Nodules (one hypo- and one hyperdense nodule in each size arranged in two layers within the liver):

Elliptical	40 mm x 55 mm
	36 mm x 45 mm
	24 mm x 35 mm
	16 mm x 20mm
	12 mm x 15 mm
Spherical	Ø 25 mm
	Ø 20 mm
Body material	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV
Liver/Spleen	mimics iodine-enriched tissue, approx. 90 HU at 120 kV
Hypodense Nodules	approx. 45 HU at 120 kV
Hyperdense Nodules	approx. 180 HU at 120 kV
Spine	corticalis / spongiosa, bone-like, approx. 550 HU / 200 HU at 120 kV

Ordering Information

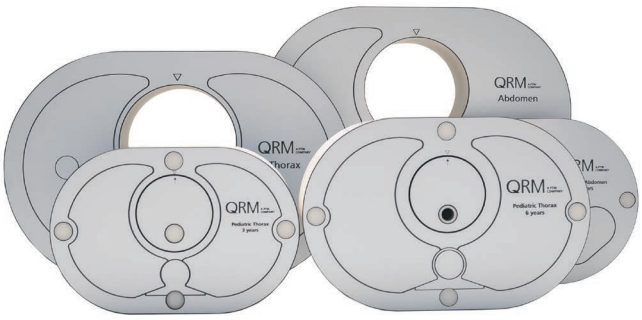
QRM-20119 Liver Nodule Phantom

Options

There are extension rings available to mimic obese patients:

QRM-20104 Extension Ring Soft Tissue, M
QRM-20105 Extension Ring Soft Tissue, L
QRM-20106 Extension Ring Soft Tissue, XL
QRM-20107 Extension Ring Fat, M
QRM-20108 Extension Ring Fat, L
QRM-20109 Extension Ring Fat, XL

Pediatric Thorax and Pediatric Abdomen Phantom



An excellent tool to validate IQ parameters or dose in a (semi-) anthropomorphic surrounding for pediatric applications

- For image quality purposes and/or dose estimation
- Different sizes available (newborn, 1-, 3-, 6-, 12- or 15-years)
- Dosimetry versions available

The pediatric thorax and abdomen phantoms in the size of a newborn up to a young child are an excellent tool to validate IQ parameters or dose in a (semi-)anthropomorphic surrounding.

The anthropomorphic-shaped phantoms cover different ages and, hence, provide an opportunity for realistic measurements of dose and image quality in X-ray diagnostics.

The phantoms are designed to provide realistic organs and shapes. The Pediatric Thorax comprises artificial lung lobes and a spine insert embedded within a shell of soft tissue-equivalent material. The Pediatric Abdomen comprises a liver, a spleen and a spine insert embedded within a shell of soft tissue-equivalent material. Dose bores are positioned in accordance to the CTDI recommendations.
All materials used mimic the physical X-ray attenuation properties and density of real human tissues.

The pediatric phantoms house a central replaceable insert adjusted to the size of the phantom. A tissue-equivalent insert with dose bore is included. Optional image quality test inserts (e.g. low contrast, spatial resolution, etc.) can be requested as a custom-made solution.

Specification

Phantom dimensions:

Thorax/Abdomen	xy (mm)	z (mm)	Circumf. (mm)	BMI
Newborn	135x90	150	330	
1 year	150x100	150	415	17
3 years	180x120	150	497	16
6 years	210x140	150	580	16
12 years	240x160	150	663	18
15 years	270x180	150	745	20
18 years/adults	300x200	100	828	21

Phantom materials:

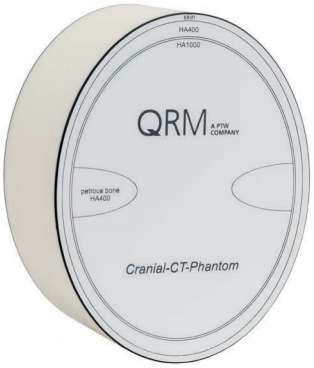
Body material	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV
Lung	approx. -800 HU at 120 kV
Liver/Spleen	tissue-equivalent, approx. 60 HU at 120 kV
Spine	corticalis / spongiosa, bone-like[1]

[1]Offers approximate attenuation properties as trabecular and cortical bone of the specific age

Ordering Information

QRM-20120 Pediatric Thorax Phantom, newborn
QRM-20137 Pediatric Thorax Phantom, 1 year
QRM-20138 Pediatric Thorax Phantom, 3 years
QRM-20121 Pediatric Thorax Phantom, 6 years
QRM-20123 Pediatric Thorax Phantom, 12 years
QRM-20139 Pediatric Thorax Phantom, 15 years
QRM-20125 Pediatric Abdomen Phantom, newborn
QRM-20140 Pediatric Abdomen Phantom, 1 year
QRM-20141 Pediatric Abdomen Phantom, 3 years
QRM-20142 Pediatric Abdomen Phantom, 6 years
QRM-20143 Pediatric Abdomen Phantom, 12 years
QRM-20144 Pediatric Abdomen Phantom, 15 years

Cranial CT Phantom



For mimicing the human skull and brain anatomy for CT/CBCT imaging

- Mimics the human skull and brain anatomy for CT imaging
- Investigate low contrast, beam hardening, partial volume artefacts etc.

The phantom is based on a brain-equivalent plastic with a constant CT-number for different kV settings surrounded by bone structures imitating the X-ray absorption of the human skull.

The inner part of the phantom comprises two different sections. One section includes the base of the skull with uniform brain tissue and bony structures equivalent to the temporal bones. This section is suitable to demonstrate and evaluate the image quality in the base of the skull, especially affected by beam hardening effects, partial volume effects and artifacts caused by scanner instabilities, e.g., anode wobble.

The second section is designed to test the low-contrast capabilities of the imaging system. Several low-contrast structures (grey matter) within the uniform brain tissue (white matter) simulate typical cortex structures and central low-contrast structures of the brain.

Specification

Phantom dimension	140 mm x 180 mm
Phantom height	88 mm
Phantom weight	2.0 kg
Body material	Brain tissue, approx. 35 HU at (80 ... 140) kV[1]
Low contrast structures	+ 7 HU above surrounding tissue[1]
Medium dense bone	HA 400 (400 mg CaHA / cm^3)
Dense bone	HA 1000 (1000 mg CaHA / cm^3)

[1]Accuracy ± 3 HU of specified values.

Ordering Information

QRM-20113 Cranial CT Phantom

Lung Nodule Phantom

For assessment of the detectability of various lung nodules within the lung region in pulmonary CT examinations

- (Semi-)anthropomorphic phantom
- Includes multiple spherical nodules of different densities and dimensions

It houses multiple spherical nodules of different densities and dimensions arranged randomly within both lung lobes. The nodules are designed to cover various imaging scenarios with respect to nodule type and grey value (e.g., ground glass opacity). The enclosed lung material consists of homogeneous and heterogeneous lung granulate which can be optionally filled into the lung lobes by the end user.

In order to mimic a (semi-)anthropomorphic surrounding it contains a bone-like spine (corticalis and spongiosa). The body is made of soft tissue-equivalent material.

The QRM-20114 is a compact functional phantom and can be easily positioned on the patient couch.

Nodule size:

Nodule/ diameter	2 mm	4 mm	6 mm	8 mm	10 mm
20 HU	1	2	1	1	1
50 HU	2	1	1	1	1
80 HU	1	1	2	1	2
-650 HU	1	2	1	1	1
-750 HU	1	1	1	2	1
-850 HU	2	1	1	1	1

Nodules with core and shell:

Nodule No.	Core	Shell	D Core	D Shell
1	50 HU	-750 HU	2	4
2	50 HU	-750 HU	2	6
3	50 HU	-750 HU	4	8

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	200 mm (210 mm including both cover plates)
Phantom weight	3.0 kg
Body material	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV
Lung-equivalent granules	approx. -900 HU at 120 kV
Spine	corticalis / spongiosa, bone-like, approx. 550 HU / 200 HU at 120 kV

Ordering Information

QRM-20114 Lung Nodule Phantom

D100 Insert Phantoms

The ingenious D100 concept for the combination of our multiple D100 insert phantoms with (semi-) anthropomorphic phantoms (e.g. Thorax and Abdomen)

There are various D100 Inserts Phantoms covering a variety of image quality, multi-energy, and radiotherapy purposes.

All of the inserts fit into our (semi-) anthropomorphic phantoms as, for example, the QRM-Thorax or the QRM-Abdomen Phantoms.

Ordering Information

QRM-10108 D100 Soft Tissue Insert
QRM-10112 2D Low Contrast Phantom
QRM-10100 2D Medium Contrast Phantom
QRM-10109 3D Low Contrast Phantom (-10 HU)
QRM-10110 3D Low Contrast Phantom (-20 HU)
QRM-10101 3D Spatial Resolution Phantom, D100
QRM-10140 High Contrast Resolution Phantom, D100
QRM-10105 Wire Phantom, D100
QRM-10113 Water Tank Phantom
QRM-10107 Dual Energy Phantom, V2
QRM-10123 Dual Energy Phantom, V5
QRM-10139 Spectral CT Phantom
QRM-10147 Spectral CT Phantom II
QRM-10143 D100 CTwater insert, 8 boreholes
QRM-10146 Calcium Scoring Phantom, D100
QRM-40106 Dose Insert D100
QRM-90110 Electron Density Phantom, D100

All of the above Insert Phantoms can be combined with:

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater

Notes

Tissue-Equivalent Materials

CTwater

A proprietary water-equivalent resin that exhibits the same x-ray attenuation properties as liquid water over the tube voltage range of 80 kV to 140 kV

- Water-equivalent material for clinical X-ray modalities
- High long-term stability
- Specified properties certified with state-of-the-art CT scanners
- Can be manufactured in any shape

It is a very stable (solid) material and can be produced in large quantities and in a variety of ways with a high degree of homogeneity and uniformity to measure the imaging performance of X-ray modalities. Its accuracy is typically about 0 HU ± 5 HU (± 3 HU) which depends on various parameters such as application area, quantity, or shape. CTwater is also the basis for some QRM phantoms, like the European Spine Phantom (ESP) or Dual Energy Phantom. It is a well-established and widely used material for calibration purposes.

The material is long-term stable and can be manufactured in any shape.

The accuracy of the specified features is evaluated using the latest CT scanners and approved by our quality management.

Specification

Material	proprietary water-equivalent plastic
Accuracy	0 HU ± 5 HU in the range of (80 ... 140) kV tube voltage
Density	1.03 mg / cm^3

Ordering Information

Please contact qrmphantoms@ptwdosimetry.com

Bone

Suitable for HU vs. CaHA calibrations of Bone Mineral Densitometry assessment, as calcium hydroxyapatite (CaHA) is the basic component of human bone

- Solid material that mimics human bone
- Available in different forms and concentrations of calcium hydroxyapatite (in mg HA/cm^3)

It mimics real human bone in terms of its physical X-ray attenuation properties.

Some examples of applications where bone material can be used as follows:

- bone mineral density calibration
- bone density measurements
- bone (spine, hip, etc.) in anthropomorphic phantoms
- Ca-plugs and stenosis in coronary arteries
- high attenuating spheres

The base material, mixed with the specific fraction of CaHA, is available as CTwater (water-equivalent resin), tissue-equivalent, or fat.

Different CaHA concentrations (bone mineral densities) or specified CT HU values are available upon request.

Specification

Material	Calcium hydroxyapatite (CaHA)
Density	(0 ... 1000) mg HA / cm^3, for Computed Tomography (0 ... 1200) mg HA / cm^3, for Micro-CT

Ordering Information

Please contact qrmphantoms@ptwdosimetry.com

ICRU Tissues

Solid plastics that mimic human tissues with respect to their physical X-ray attenuation properties

- Mimic the physical X-ray attenuation properties of the human tissues
- Represent the real tissues regarding their physical density and electron density
- In accordance with ICRU reports 44 and 46
- Customizable: different densities or CT-values (HU) and different shapes and designs

All tissue equivalents mimic the physical X-ray attenuation properties of the human organs and represent the real tissues regarding their physical density and electron density (acc. to ICRU Report 44 and 46).
Remarkably, bones in the high-density range also provide realistic tissue simulation.

Electron density, effective atomic number and elemental composition can be provided on demand.

Our standard materials (see Table) include various ICRU Tissues as well as solid water-equivalent material. Additional tissue-equivalent materials are available upon request.

ICRU Tissue	ρ (g/cm³)	ρ_e rel. to water	Z_{eff}	CT-values (HU) (80 ... 140) kV
Water	1	1	7.4	0
Adipose	0.95	0.95	6.3	-95 ... -70
Skin	1.09	1.08	7.3	71 ... 75
Brain	1.04	1.03	7.4	40 ... 37
Breast (fibroglandular)	1.02	1.01	6.9	-9 ... 3
Breast (50/50)	0.96	0.96	6.7	-70 ... -53
Eye lens	1.07	1.05	7.2	45 ... 50
Blood (whole)	1.06	1.05	7.5	60 ... 55
GI tract (intestine)	1.03	1.02	7.4	22 ... 23
Heart (blood filled)	1.06	1.05	7.5	60 ... 55
Kidney	1.05	1.04	7.4	45 ... 43
Liver	1.06	1.05	7.5	56 ... 53
Spleen	1.06	1.05	7.5	57 ... 54
Testis	1.04	1.03	7.4	37 ... 35
Thyroid	1.05	1.04	7.9	112 ... 73
Lung (deflated)	1.05	1.04	7.5	48 ... 44
Lung (inflated)	0.26	0.25	7.5	-740
Lymph	1.03	1.03	7.5	31 ... 28
Muscle	1.05	1.04	7.4	45 ... 42
Ovary	1.05	1.04	7.5	48 ... 45
Pancreas	1.04	1.03	7.3	31 ... 32
Skeleton-cartilage	1.1	1.08	7.9	116 ... 98
Skeleton-yellow marrow	0.98	0.98	6.2	-70 ... -28
Skeleton-red marrow	1.03	1.02	7.0	4 ... 14
Skeleton-spongiosa	1.18	1.15	9.8	392 ... 258
Skeleton-femur	1.33	1.28	11.1	762 ... 495
Skeleton-humerus	1.46	1.39	11.7	1032 ... 678
Skeleton-mandible	1.68	1.58	12.5	1516 ... 998
Skeleton-cortical bone	1.68	1.78	13.2	2083 ... 1366

Besides the standard dimensions (rods or slab, see specifications), all materials can be manufactured in various shapes as rods, slaps, cubes, spheres, and custom designs. Therefore, our materials are ideal for custom phantom design as well as single samples dedicated to calibration and research purposes in diagnostic X-ray imaging and radiation therapy.

Furthermore, we design materials which exhibit specific energy-dependent CT-values (defined by the customer).

Specification

ICRU Soft tissue/bone rod (QRM-30101, QRM-30102)

Diameter	20 mm
Height	100 mm

ICRU Soft tissue/bone slab (QRM-30101, QRM-30102)

Dimension	300 mm x 300 mm x 10 mm

Ordering Information

Please contact qrmphantoms@ptwdosimetry.com

CTIodine

A solid material produced using a base (e.g. water, blood, or liver) with molecularly bound iodine

- Solid material optimized for 80 kVp to 140 kVp
- Used in CT and other X-ray imaging modalities

Contrast enhancement is an important issue in diagnostic imaging, such as Dual Energy applications in Computed Tomography (CT). CTIodine replaces iodinated contrast media in water or blood for contrast enhancement applications in diagnostic X-ray procedures and provides equivalent properties to iodinated contrast media. Optimized for the diagnostic X-ray energy range from 80 kV to 140 kV. It is available based on CTwater, blood equivalent resin and standard resin.

While the concentration of liquid contrast media is given in mg iodine/cm^3, CTIodine based on CTwater is given in the same way (mg iodine/cm^3) but as a solid and easy-to-use material.

Different concentrations of iodine or CT-numbers (HU) are available upon request.

Specification

Following base materials can be selected:
- CTwater
- Blood-equivalent material
- ICRU Tissue-equivalent materials

Ordering Information

Please contact qrmphantoms@ptwdosimetry.com

Notes

Dosimetry Phantoms

CTDI CTwater Phantom

Water-equivalent dosimetry phantoms, traced back on the standards for CTDI evaluation in Computed Tomography (CT/CBCT)

- For CTDI measurements in accordance with IEC / DIN EN 61223-3-5 and IEC 61223-2-44
- Different adapter plugs available for diverse pencil shaped ion chambers

The phantoms are manufactured from CTwater, a proprietary resin which exhibits the same X-ray attenuation characteristics as liquid water in the range of 80 kV to 140 kV tube voltage.

There are two different versions available, both in a modular design with a removable head phantom fitting tightly into a circular body (QRM-40100) or oval body (QRM-40101, specially designed to mimic the human body shape).

The phantoms are designed according to the guidelines for CTDI measurements (IEC 61223-3-5 and IEC 60601-2-44) and are equipped with nine dose bore holes. The head cylinder offers one central and four peripheral holes to accommodate standard ion chambers. The body has four peripheral bores. The phantom is delivered with nine CTwater solid rods to plug the holes not in use, and one adapter plug to house a standard pencil shaped ion chamber.

More adapter plugs can be manufactured upon request.

Specification

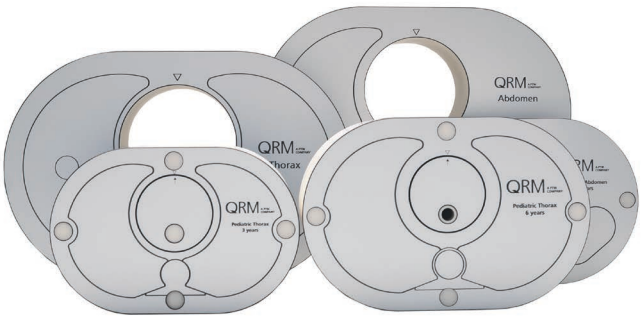
CTDI CTwater Phantom (QRM-40100):	
Phantom diameter (body)	Ø 320 mm
Phantom diameter (head)	Ø 160 mm
Phantom height	150 mm
Borehole diameter	Ø 13 mm
Center position of peripheral holes	10 mm from phantom's margin
Body material	CTwater

Oval CTDI CTwater Phantom (QRM-40101):	
Phantom dimension (body)	380 mm x 220 mm
Phantom diameter (head)	Ø 160 mm
Phantom height	150 mm
Borehole diameter	Ø 13 mm
Center position of peripheral holes	10 mm from phantom's margin
Body material	CTwater

Ordering Information

QRM-40100 CTDI CTwater Phantom
QRM-40101 Oval CTDI CTwater Phantom

Thorax and Abdomen Dosimetry Phantoms



The (semi-)anthropomorphic Thorax and Abdomen Dosimetry Phantoms for optimization of dose protocols in CT and CBCT applications

- Optimize dose protocols in CT/CBCT
- Dose bores according to CTDI specifications
- D100 compatible

The phantoms can be traced back to the standards for CTDI evaluation in Computed Tomography.

The phantoms are optimized to house pencil shaped ionization chambers to measure dose length product (DLP) and equivalent computed tomography dose index (CTDI) in computed tomography (CT) and Cone-Beam CT (CBCT) applications.

Both phantoms include a D100 insert which can be easily replaced by other D100 Image Quality inserts (see options). The phantom has 5 dose bores (5 plugs are included) are placed in accordance with CTDI specifications: 4 peripheral bore holes and one central one. The center of all peripheral bore holes is placed 10 mm of the phantom's margin. They have a diameter of 13 mm and can house an adapter to fit your ion chamber.
If not otherwise specified, the phantom will come with an adapter for a 9 mm ion chamber.

The phantom height can be adjusted (e.g. 150 mm, 200 mm) upon demand.

Specification

Phantom dimension	200 mm x 300 mm
Phantom height	103 mm
Phantom weight	2.7 kg (Thorax), 3.2kg (Abdomen), 0.9 kg (Insert)
Diameter of borehole	100 mm
Phantom materials:	
Body/Insert material	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV
Lung	approx. -800 HU at 120 kV
Liver/Spleen	tissue-equivalent, approx. 60 HU at 120 kV
Spine	corticalis / spongiosa, bone-like, approx. 550 HU / 200 HU at 120 kV

Ordering Information

QRM-40104 Thorax Dosimetry Phantom
QRM-40105 Abdomen Dosimetry Phantom
QRM-40106 Dose Insert D100

Options

There are multiple standard cylinders for image quality purposes available. The following D100 Insert are available:

QRM-10108 D100 Soft Tissue Insert
QRM-10112 2D Low Contrast Phantom
QRM-10100 2D Medium Contrast Phantom
QRM-10109 3D Low Contrast Phantom (-10 HU)
QRM-10110 3D Low Contrast Phantom (-20 HU)
QRM-10101 3D Spatial Resolution Phantom, D100
QRM-10140 High Contrast Resolution Phantom, D100
QRM-10105 Wire Phantom, D100
QRM-10113 Water Tank Phantom
QRM-10107 Dual Energy Phantom, V2
QRM-10123 Dual Energy Phantom, V5
QRM-10139 Spectral CT Phantom
QRM-10147 Spectral CT Phantom II
QRM-10143 D100 CTwater insert, 8 boreholes
QRM-10146 Calcium Scoring Phantom, D100
QRM-40106 Dose Insert D100
QRM-90110 Electron Density Phantom, D100

Further, there are extension rings available to mimic obese patients:

QRM-40113 Ion chamber adapter D13
QRM-40107 Dosimetry Extension Ring Soft Tissue, M
QRM-40108 Dosimetry Extension Ring Soft Tissue, L
QRM-40109 Dosimetry Extension Ring Soft Tissue, XL
QRM-40110 Dosimetry Extension Ring Fat, M
QRM-40111 Dosimetry Extension Ring Fat, L
QRM-40112 Dosimetry Extension Ring Fat, XL

For further information please visit qrm.de.

Extension Rings

The Dosimetry Extension Rings for the simulation of obese patients that fit on the standart phantoms such as the Thorax, Abdomen and Liver Nodule Phantom

- To simulate obesity of patients
- Compatible with standard phantoms
- Available in soft tissue-, fat- or water-equivalent
- Dosimetry option with available

Our Extension Rings are a good choice for testing the influences/impact of higher attenuation due to an increased abdominal or chest girth on image quality in CT and other 3D imaging techniques.
To mimic different degrees of obesity the Extension Rings are available in sizes M, L and XL. Further, you can choose between tissue-equivalent and fat-equivalent material for all ring sizes.

Upon request all rings can be manufactured from other materials (e.g. water-equivalent material).

Specification

Extension Ring M:	
Outside dimensions	250 mm x 350 mm
Inside dimensions	200 x 300 mm
Height	103 mm
Extension Ring L:	
Outside dimensions	300 mm x 400 mm
Inside dimensions	200 mm x 300 mm
Height	103 mm
Extension Ring XL:	
Outside dimensions	450 mm x 600 mm
Inside dimensions	300 mm x 400 mm
Height	103 mm

Please note: The XL Extension Ring has to be used in combination with the Extension Ring in size L.

Body materials	Soft tissue-equivalent, approx. 30 HU at (80 ... 140) kV Fat-equivalent, approx. -(70 ... 90) HU at 120 kV

Ordering Information

QRM-40107 Dosimetry Extension Ring Soft Tissue, M
QRM-40108 Dosimetry Extension Ring Soft Tissue, L
QRM-40109 Dosimetry Extension Ring Soft Tissue, XL
QRM-40110 Dosimetry Extension Ring Fat, M
QRM-40111 Dosimetry Extension Ring Fat, L
QRM-40112 Dosimetry Extension Ring Fat, XL

All Extension Rings are also available without bore holes for dosimetry:

QRM-20104 Extension Ring Soft Tissue, M
QRM-20105 Extension Ring Soft Tissue, L
QRM-20106 Extension Ring Soft Tissue, XL
QRM-20107 Extension Ring Fat, M
QRM-20108 Extension Ring Fat, L
QRM-20109 Extension Ring Fat, XL

Options

QRM-20100 Thorax Phantom
QRM-20103 Calcium Scoring Phantom Set
QRM-20118 Abdomen Phantom
QRM-20119 Liver Nodule Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater

Bone Densitometry Phantoms

European Spine Phantom (ESP)

The standard phantom for quality control in spine bone mineral densitometry by DXA and qCT

- International standard in spine bone mineral densitometry by DXA and qCT
- Must-have for multi-center studies or single place testing
- Three vertebrae with different bone mineral content

The European Spine Phantom (ESP) with its anthropomorphic design is the ideal tool for quality control tests of bone mineral densitometry in DXA and qCT.

The phantom is the standard for quality control - accuracy and repeatability - BMD quantification of the spine for more than two decades. Its closely anthropomorphic design with three internal lumbar vertebrae inserts allows to utilize standard patient protocols, both, in DXA and qCT.

The main body of the phantom consists of water-equivalent material. The three lumbar spine inserts contain different well-defined amounts of calcium hydroxyapatite (CaHA) to cover the entire physiological range of spongious and cortical bone densities of all age groups.

Each phantom is separately calibrated to the reference standard ESP, containing analytically determined bone mineral densities.

It allows checking reproducibility and accuracy of the following quantities:
- Area bone mineral density (area BMD) in g/cm^2 for DXA
- Trabecular and cortical volume bone mineral density (vol. BMD) in g/cm^3 for qCT
- Cortical thickness in mm for qCT
- Positioning accuracy in qCT

Extension rings in different sizes to mimic obese patients are available upon request.

Specification

Phantom dimension	260 mm x 180 mm
Phantom height	110 mm
Phantom weight	4.3 kg
Body material	Water-equivalent material (CTwater), 0 HU at (80 ... 140) kV[1]
Phantom accuracy	All CaHA materials are within ± 5% of specified values
Accuracy of calibrated values	area BMD: ± 5 mg/cm^2 vol. BMD: ± 2 mg/cm^3

Vertebra	Specified vol. BMD Spongiosa (g CaHA/cm^3)	DXA area BMD (AP) (g CaHA/cm^2)	Cortical wall and spinal arch (g CaHA/cm^3)	Spinal processes (g CaHA/cm^3)
L1	0.05	0.5	0.4	0.4
L2	0.1	1	0.8	0.4
L3	0.2	1.5	0.8	0.4

[1]Accuracy ± 5 HU of specified values

Ordering Information

QRM-50100 European Spine Phantom (ESP)

For further information please visit qrm.de.

European Forearm Phantom (EFP)

An excellent tool for the standard quality control checks of peripheral bone mineral densitometry in quantitative computed tomography (qCT)

- The standard phantom for the quality control checks of peripheral bone mineral densitometry in qCT
- Test reproducibility and accuracy in clinical installations and at manufacturers' sites
- Multiple trabecular bone inserts embedded in water-equivalent plastic

The phantom is especially designed for testing peripheral bone densitometry systems and provides the opportunity to test reproducibility and accuracy of machines, both, in clinical installations and at manufacturers' sites.

It consists of water- and bone-equivalent solid materials - the same materials used in the European Spine Phantom (ESP, QRM-50100). Therefore, it not only allows a comparison between trabecular bone examinations at different locations and on different machines, but also to compare axial and peripheral bone measurements.

A circular cross-section with flattened sides was chosen to model the forearm. The inserts simulate trabecular bone and provide the basis for linearity checks in qCT. There are two inserts with multiple sections mimicking large, medium and small bone with different calcium hydroxyapatite (CaHA) densities (according to the ESP).
The bone-like structure is completed with a thin cortical wall surrounding each section.

The following quantities can be determined:
- Spongiouse/trabecular and cortical volume bone mineral density (vBMD) in g/cm³
- Thickness of cortical bone in mm
- Measures of bone equivalent inserts
- Bone Mineral Content (BMC)

Specification

Phantom dimension	60 mm x 40 mm
Phantom height	60 mm
Phantom weight	140 g
Body material	Water-equivalent material (CTwater), 0 HU at (80 ... 140) kV[1]
Phantom accuracy	All CaHA materials are within ± 5% of specified values.
Accuracy of calibrated vBMD	± 2 mg/cm³

Insert Section	Spongious bone with specified vBMD (mg CaHA/cm³)	Cortical bone, vBMD (mg CaHA/cm³)	Inner Diameter (mm)	Outer Diameter (mm)	Height (mm)
I	200	800	25.6	28	15
II	100	800	18.6	19.8	15
III	50	800	11.6	14	15
IV	Water-equivalent	800	5	10	15
V	Water-equivalent	800	12	14	45
VI	Water-equivalent	800	5	10	15

[1]Accuracy ± 5 HU of specified values

Ordering Information

QRM-50111 European Forearm Phantom (EFP)

Forearm Phantom (BMF)

A convenient tool for quantitative Computed Tomography (qCT) measurements of the forearm to calibrate CT values to Bone Mineral Density (BMD)

- BMD phantom for qCT of the forearm
- Bone- and water-equivalent inserts embedded in a soft tissue-equivalent resin
- Optimized design allows placement directly under the object

It was developed for calibrating CT values to BMD. Its optimized design adapted to the anatomy of an adult forearm allows to place the phantom directly between the forearm and the CT couch.

It consists of two solid cylindrical inserts of water-equivalent and bone-equivalent material embedded in a soft tissue-equivalent plastic. The bone-equivalent inserts are enriched with CaHA (calcium hydroxyapatite) and have a specified bone mineral density of 0 and 200 mg CaHA/cm^3.

Specification

Phantom dimension	70 mm x 25 mm
Phantom height	150 mm
Phantom weight	225 g
Body material	soft tissue-equivalent plastic

Inserts

Diameter	14 mm
Height	150 mm
Center-to-center distance between two inserts	28 mm
Material	Water-equivalent[1], CTwater, approx. 0 HU at (80 ... 140) kV Bone-like[2], 200 mg CaHA/cm^3

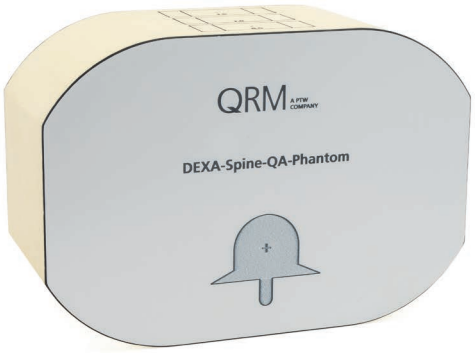
[1]Accuracy ± 5 HU of specified values

[2]Specified values. Nominal values can vary with respect to manufacturing method and imaging device

Ordering Information

QRM-50112 Forearm Phantom (BMF)

DXA Spine QA Phantom, 3 HA



A valuable tool for the quality assurance of DXA Bone Mineral Density Measurements of the spine

- Quality assurance of DXA measurements of the spine
- Cost-effective design
- 3 vertebrea with different CaHA densities

It is specially designed for quality control (e.g. constancy and acceptance tests) and stability monitoring of dual X-ray absorptiometry (DXA) devices. Based on the well-established European Spine Phantom, the DXA Spine QA Phantom comes with a simplified and cost-effective design of the vertebrae. It includes three vertebrea with different CaHA densities consisting of water-equivalent material enriched with calcium hydroxyapatite (CaHA) of appropriate grain size.

Using the DXA Spine QA phantom the areal Bone Mineral Density (aBMD) can be easily determined in AP and lateral projections.

Each phantom is separately calibrated to the QRM reference standard, containing analytically confirmed bone mineral densities.

The following quantities can be assessed:
- Bone mineral content (BMC) in g
- Area bone mineral density (aBMD) in g/cm^2 for DXA AP and lateral projections
- Projected area (A) in cm^2

Specification

Phantom dimension	260 mm x 180 mm (± 2 mm)
Phantom height	110 mm
Phantom weight	4.3 kg
Body material	soft tissue-equivalent at 120 kV
Phantom accuracy	All HA materials are within ± 5% of specified values
Accuracy of calibrated aBMD	± 5 mg/cm^2

Vertebra	DXA area density (AP) (g CaHA/cm^2)
L1	0.5
L2	1
L3	1.5

Ordering Information

QRM-50110 DXA Spine QA Phantom, 3 HA

Bone Density Calibration Phantom, 3

Perfect tool for HU vs. CaHA calibrations with respect to Bone Mineral Densitometry evaluation

- Measure bone mineral density (BMD) with quantitative CT
- Perform HU vs. CaHA
- For different regions such as shoulder, spine, hip, femur
- Place directly under test object with easy-to-use design

The Bone Density Calibration Phantom is a convenient tool to calibrate HU vs. CaHA with respect to bone mineral densitometry (BMD) evaluation.

The phantom houses three fixed cylindrical inserts providing different bone mineral densities with well-defined concentrations of calcium hydroxyapatite (CaHA) of 0 (water-equivalent), 100 and 200 mg CaHA/cm^3. The inserts are made of a solid water-equivalent plastic (CTwater) enriched with CaHA of appropriate grain size and embedded in a proprietary soft tissue-equivalent material.

The flat and slightly bent design allows the most convenient positioning of the phantom directly under an object on the couch. This easy-to-use geometry of the phantom facilitates the evaluation of the bone mineral density (BMD).

Each phantom is separately calibrated to the reference standard BDC, containing analytically confirmed bone mineral densities.

Other phantom lengths and CaHA concentrations are available upon request.

The BDC Phantoms with three inserts are ideally to be used in combination with the HIP-QC120 phantom (QRM-50131) or the Spine-QC120 phantom (QRM-50121).

Specification

Phantom dimension (slightly bent)	120 mm x 25 mm
Body material	soft tissue-equivalent at 120 kV
Phantom accuracy	All CaHA materials are within ± 5% of specified values
Accuracy of calibrated vBMD	± 2 mg/cm^3

Model	Insert 1 HA specified (mg CaHA/cm^3)	Insert 2 HA specified (mg CaHA/cm^3)	Insert 3 HA specified (mg CaHA/cm^3)	Height (mm)	Insert Diameter (mm)
QRM-50115	100	0	200	200	18
QRM-50118	100	0	200	300	18
QRM-50120	100	0	200	400	18
QRM-50116	100	0	200	500	18
QRM-50117	100	0	200	600	18
QRM-50119	100	0	200	700	18

Ordering Information

QRM-50115 Bone Density Calibration Phantom, 3 H200
QRM-50118 Bone Density Calibration Phantom, 3 H300
QRM-50120 Bone Density Calibration Phantom, 3 H400
QRM-50116 Bone Density Calibration Phantom, 3 H500
QRM-50117 Bone Density Calibration Phantom, 3 H600
QRM-50119 Bone Density Calibration Phantom, 3 H700

Bone Density Calibration Phantom, 6

Perfect tool for HU vs. CaHA calibrations with respect to Bone Mineral Densitometry evaluation

- Measure bone mineral density (BMD) with quantitative CT
- Perform HU vs. CaHA
- For different regions such as shoulder, spine, hip, femur
- Place directly under test object with easy-to-use design

The Bone Density Calibration Phantom is a convenient tool to calibrate HU vs. CaHA with respect to bone mineral densitometry (BMD) evaluation.

The phantom houses six cylindrical inserts providing different bone mineral densities with well-defined concentrations of calcium hydroxyapatite (CaHA) of 0 (water-equivalent), 100, 200, 400, 600, 800 mg CaHA/cm^3. The inserts are made of a solid water-equivalent plastic (CTwater) enriched with CaHA of appropriate grain size and embedded in a proprietary soft tissue-equivalent material.

The flat and slightly bent design allows most convenient positioning of the phantom directly under an object on the couch. This easy-to-use geometry of the phantom facilitates the evaluation of the bone mineral density (BMD).

Each phantom is separately calibrated to the reference standard BDC, containing analytically confirmed bone mineral densities.

Other phantom lengths and CaHA concentrations are available upon request.

Specification

Phantom dimension (slightly bent)	225 mm x 25 mm
Body material	soft tissue-equivalent at 120 kV
Phantom accuracy	All CaHA materials are within ± 5% of specified values
Accuracy of calibrated vBMD	± 2 mg/cm^3

Model	Insert 1 HA specified (mg CaHA/cm^3)	Insert 2 HA specified (mg CaHA/cm^3)	Insert 3 HA specified (mg CaHA/cm^3)	Height (mm)	Insert Diameter (mm)
QRM-50124	0	100	200	200	18
QRM-50125	0	100	200	300	18
QRM-50129	0	100	200	400	18
QRM-50126	0	100	200	500	18
QRM-50127	0	100	200	600	18
QRM-50128	0	100	200	700	18

Model	Insert 4 HA specified (mg CaHA/cm^3)	Insert 5 HA specified (mg CaHA/cm^3)	Insert 6 HA specified (mg CaHA/cm^3)	Height (mm)	Insert Diameter (mm)
QRM-50124	400	600	800	200	18
QRM-50125	400	600	800	300	18
QRM-50129	400	600	800	400	18
QRM-50126	400	600	800	500	18
QRM-50127	400	600	800	600	18
QRM-50128	400	600	800	700	18

Ordering Information

QRM-50124 Bone Density Calibration Phantom, 6 H200
QRM-50125 Bone Density Calibration Phantom, 6 H300
QRM-50129 Bone Density Calibration Phantom, 6 H400
QRM-50126 Bone Density Calibration Phantom, 6 H500
QRM-50127 Bone Density Calibration Phantom, 6 H600
QRM-50128 Bone Density Calibration Phantom, 6 H700

HIP Calibration Phantom, V2

A convenient tool to evaluate the bone mineral density (BMD) in quantitative Computed Tomography (qCT) of the hip/femur

- Evaluate BMD in quantitative Computed Tomography (qCT) of the hip/femur
- Two different cylindrical inserts with different bone mineral densities
- Optional: customizable inserts

The Phantom comprises a soft tissue-equivalent body and two replaceable cylindrical inserts that simulate different bone mineral densities. The base material of the inserts is CTwater (water-equivalent material) enriched with calcium hydroxyapatite (CaHA) of appropriate grain size. The inserts consist of spongious bone (with 100 and 200 mg CaHA/cm^3) and a cortical wall (800 mg CaHA/cm^3).

Different inserts with various BMD concentrations and metal implants to examine metal artifacts are available upon request.

Specification

Phantom dimension	360 mm x 160 mm
Phantom height	103 mm
Distance between inserts	200 mm
Body material	soft tissue-equivalent (approx. 30 HU at (80 ... 140) kV[1]

Inserts

Insert	Dimension	Core Dimension	Core Material: Spongious bone	Shell Dimension	Shell Material
1	Ø 30 mm, length 100 mm	Ø 20 mm, length 100 mm	100 mg CaHA/cm^3	thick-ness 5 mm, length 100 mm	800 mg CaHA/cm^3
2	Ø 30 mm, length 100 mm	Ø 20 mm, length 100 mm	200 mg CaHA/cm^3	thick-ness 5 mm, length 100 mm	800 mg CaHA/cm^3

[1]Accuracy ± 5 HU of specified values

[2]All CaHA materials are within ± 5% of specified values

Ordering Information

QRM-50113 HIP Calibration Phantom, V2

DXA Femur Phantom

A convenient tool for DXA constancy and acceptance tests

- Represents a general proximal femur of a 55-year-old white female
- For DXA constancy and acceptance testing
- Anthropomorphic design

The anthropomorphic femur represents a proximal femur of a 55-year-old white female. It is made of water-equivalent material enriched with calcium hydroxyapatite (CaHA) and embedded in a tissue-equivalent (at 120 kV) matrix.

Its anthropomorphic design allows checking reproducibility and accuracy of the following quantities:
- Bone mineral content (BMC) in g for DXA
- Bone mineral area density (aBMD) in g/cm^2 for DXA for different areas of the femur (femural neck, great trochanter, intertrochanteric region, Ward's triangle)
- Volume bone mineral density (vBMD) in g/cm^3 for qCT
- NHANES T- and Z-score

Specification

Phantom dimension	150 mm x 180 mm x 170 mm
Body material	tissue-equivalent plastic at 120 kV

Ordering Information

QRM-50146 DXA Femur Phantom

JIS Forearm Phantom

A suitable tool for the performance evaluation of X-ray bone densitometers (peripheral bone type PF) acc. the Japanese Industrial Standard JIS Z 4930[1]

- Performance evaluation of X-ray bone densitometers for peripheral bone type PF
- In accordance with the Japanese Industry Standard JIS Z 4930

It includes a soft tissue-equivalent plastic housing with a density of about 1.07 g/cm^3 and three different pairs of exchangeable inserts (PF-1, PF-2 and PF-3) with specified area bone mineral densities (aBMD) of 0.30 ± 0.01 g/cm^2 (low density, PF-1), 0.60 ± 0.01 g/cm^2 (medium density, PF-2) and 0.90 ± 0.01 g/cm^2 (high density, PF-3). The inserts consist of a soft tissue-equivalent core surrounded by an outer shell (cortical bone) with the appropriate bone mineral density.

Specification

Housing (consists of bottom and lid):	
Cross section	100 mm x 70 mm
Total height	40 mm
Phantom weight	400 g
Housing material	soft tissue-equivalent at 120 kV

Type PF BMD inserts:

Insert type	Quantity	area BMD (g/cm^2)	Dimension	Core	Shell
PF-1	2	0.30 ± 0.01	Ø 15 mm, length 90 mm	Ø 6 mm, length 90 mm	thickness 4.5 mm, length 90 mm
PF-2	2	0.60 ± 0.01	Ø 15 mm, length 90 mm	Ø 6 mm, length 90 mm	thickness 4.5 mm, length 90 mm
PF-3	2	0.90 ± 0.01	Ø 15 mm, length 90 mm	Ø 6 mm, length 90 mm	thickness 4.5 mm, length 90 mm

[1]The Phantom is manufactured in accordance with the Japanese Industry Standard JIS Z 4930: 2011, chapter 6.1.2.

Ordering Information

QRM-50139 JIS Forearm Phantom

Other available phantoms designed according to the Japanese Industry Standard are:

QRM-50140 JIS Lumbar Spine Phantom
QRM-50141 JIS Lumbar Phantom Block 50
QRM-50142 JIS Lumbar Phantom Block 100
QRM-50143 JIS Heel Phantom
QRM-50144 JIS Uniform Lumbar Phantom

JIS Heel Phantom

Suitable for the performance evaluation of X-ray bone densitometers (peripheral bone type PH) acc. the Japanese Industrial Standard JIS Z 4930[1]

- Suitable for the performance evaluation of X-ray bone densitometers.
- In accordance with the Japanese Industry Standard JIS-Z 4930

It includes a soft tissue-equivalent plastic housing with a density of about 1.07 g/cm^3 and three exchangeable inserts (PH-1, PH-2 and PH-3) with specified area bone mineral densities (aBMD) of 0.20 ± 0.01 g/cm^2 (low density, PH-1), 0.40 ± 0.01 g/cm^2 (medium density, PH-2) and 0.60 ± 0.01 g/cm^2 (high density, PH-3). The inserts consist of a soft tissue-equivalent core surrounded by an outer shell (cortical bone) with the appropriate bone mineral density.

Specification

Housing (consists of bottom and lid):	
Cross section	170 mm x 170 mm (L-shape)
Total height	40 mm
Housing material	soft tissue-equivalent at 120 kV

Type PH BMD inserts:

Insert type	Quantity	Area BMD (g/cm^2)	Dimension	Core	Shell
PH-1	1	0.20 ± 0.01	Ø 30 mm, length 50 mm	Ø 20 mm, length 50 mm	thick-ness 5 mm, length 50 mm
PH-2	1	0.40 ± 0.01	Ø 30 mm, length 50 mm	Ø 20 mm, length 50 mm	thick-ness 5 mm, length 50 mm
PH-3	1	0.60 ± 0.01	Ø 30 mm, length 50 mm	Ø 20 mm, length 50 mm	thick-ness 5 mm, length 50 mm

[1]The Phantom is manufactured in accordance with the Japanese Industry Standard JIS Z 4930: 2011, chapter 6.1.3.

Ordering Information

QRM-50143 JIS Heel Phantom

Other available phantoms designed according to the Japanese Industry Standard are:

QRM-50139 JIS Forearm Phantom
QRM-50140 JIS Lumbar Spine Phantom
QRM-50141 JIS Lumbar Phantom Block 50
QRM-50142 JIS Lumbar Phantom Block 100
QRM-50144 JIS Uniform Lumbar Phantom

Notes

Micro-CT and Micro-PET/SPECT Phantoms

Micro-CT Wire Phantom

A perfect tool to evaluate the in-plane spatial resolution of any micro-CT system by measuring

- For the assessment of in-plane spatial resolution of any micro-CT system
- Easy investigation of the Point Spread Function (PSF) and Modulation Transfer Function (MTF)
- Customizable: Different wire diameters, materials and positions can be provided

The cylindrical design of the phantom includes two tungsten wires aligned parallel to the phantom axis of rotation. One of the wires is slightly positioned off-center, the second one away from the center in order to allow estimating image quality in the periphery. The wires can be mounted in air or be embedded in resin, both providing enough contrast for evaluation of the PSF and MTF.

Dimensions other than those specified here can be produced upon request.

Specification

Micro-CT Wire Phantom air	
Phantom diameter	20 or 32 mm
Phantom height (inner)	40 mm
Phantom height (total)	58 mm
Phantom weight	7.5 g
Body material	protective housing, wall thickness of 0.3 mm
Wire material	tungsten
Wire diameters	3, 10 or 25 micron

Micro-CT Wire Phantom resin	
Phantom diameter	20 or 32 mm
Phantom height	43 mm
Phantom weight	35 g
Body material	resin (solid plastic)
Wire material	tungsten
Wire diameters	10 or 25 micron

Ordering Information

QRM-70100Micro-CT Wire Phantom air, D20, 10 micron
QRM-70101 Micro-CT Wire Phantom air, D20, 25 micron
QRM-70102 Micro-CT Wire Phantom air, D32, 10 micron
QRM-70103 Micro-CT Wire Phantom air, D32, 25 micron
QRM-70117 Micro-CT Wire Phantom air, D20, 3 micron
QRM-70118 Micro-CT Wire Phantom air, D32, 3 micron
QRM-70130 Micro-CT Wire Phantom resin, D32, 25 micron
QRM-70131 Micro-CT Wire Phantom resin, D32, 10 micron
QRM-70133 Micro-CT Wire Phantom resin, D20, 25 micron

Micro-CT Multi Disk Phantom

For testing cone beam artifacts resulting from different reconstruction algorithms in micro-CT systems

- Convenient test object to check cone beam artifacts in micro-CT scanners
- Includes 1 and 3 mm high- and low-density circular disks
- Phantom design following Defrise

It is the test object for demonstrating artifacts (e.g. cone-beam artifacts) originating from all kinds of approximate reconstruction algorithms.

It consists of a stack of eight high-density circular disks separated by low-density disks, such that the high-density disks are equally spaced with 3 mm intervals along the axis of rotation. The total density differences between high-and low-density disks are about 0.2 g/cm^3. The disk stack is covered with 10 mm thick PMMA layers on both sides of the phantom.

Specification

Phantom diameter	20 mm
Phantom height	49 mm
Phantom weight	19 g
Flanging outer layers	
Body material	PMMA
Thickness	10 mm for each side
High-density disk	
Diameter	20 mm
Thickness	1.0 mm
Density	1.38 g/cm^3
Low-density disk	
Diameter	20 mm
Thickness	3.0 mm
Density	1.18 g/cm^3
Tolerances	± 0.15 mm

Ordering Information

QRM-70104 Micro-CT Multi Disk Phantom

Micro-CT Contrast Scale Phantom

A convenient tool for evaluating high contrast materials in Micro-CT

- Evaluation of high contrast materials in preclinical Micro-CT
- Scaling of CaHA (bone) and Iodine
- Customizable

It houses two centrally placed CaHA (calcium hydroxyapatite) and iodine samples, i.e. the materials of highest interest in small-animal imaging.

It allows the evaluation of the Contrast Scale Factor obtained for a given substance concentration (specified in mg/cm^3), measured in Hounsfield Units (HU).

Dimensions other than those specified here can be produced upon request.

Specification

Phantom diameter	32 mm
Phantom height	43 mm
Phantom weight	35 g
Body material	resin

Inserts:

Concentration	
Iodine	approx. 10 mg I / cm^3
CaHA	approx. 1200 mg CaHA/cm^3
Density	
Iodine	approx. 1.13 g/cm^3
CaHA	approx. 1.9 g/cm^3
Dimension	
Iodine	Ø 5 mm
CaHA	Ø 5 mm
Height	
Iodine	20 mm
CaHA	20 mm

Ordering Information

QRM-70105 Micro-CT Contrast Scale Phantom

Micro-CT Dose Phantom

A suitable tool to measure DLP and CTDI using a standard pencil-shaped ionization chamber

- For dose measurements DLP (Dose Length Product) and CTDI (Computed Tomography Dose Index) on Micro-CT systems
- Soft tissue-equivalent plastic
- Central hole for standard pencil-shaped ionization chambers
- Customizable

The central borehole fits many standard pencil ionization chambers with a length of 100 mm. An additional (removable) plug is included.

Dimensions other than those specified here can be produced upon request.

Specification

Phantom diameter	32 mm
Phantom height	120 mm
Phantom weight	105 g
Central borehole diameter	9 mm[1]
Body material	soft tissue-equivalent plastic

[1]Other hole diameters can be offered upon request

Ordering Information

QRM-70106 Micro-CT Dose Phantom

Micro-CT HA Phantoms

The ideal tool for micro-CT bone mineral densitometry and calibrating CT-numbers vs. CaHA values

- Worldwide standard for measuring Bone Mineral Density (BMD) in small-animal micro-CT
- Calibrate CT numbers vs. HA values
- Provides accurate bone mineral density of CaHA for in-vivo or in-vitro micro-CT bone calibration
- Customizable

The five inserts provide most favorable densities of hydroxyapatite (CaHA) for in-vivo or in-vitro micro-CT bone densitometry.

Each phantom houses five cylindrical inserts containing Calcium hydroxyapatite (CaHA) in various densities ranging up from 50 to 1200 mg CaHA / cm^3. Besides bone density calibration, the phantoms are also suitable for high contrast resolution assessments.

Specification

Micro-CT HA Phantom, D32 (QRM-70107)

Phantom diameter	Ø 32 mm
Insert diameter	Ø 5 mm
Phantom height	approx. 41 mm
Phantom weight	35 g

Micro-CT HA Phantom, D25 (QRM-70129)

Phantom diameter	Ø 25 mm
Insert diameter	Ø 5 mm
Phantom height	approx. 41 mm
Phantom weight	35 g

Micro-CT HA Phantom, D20 (QRM-70126)

Phantom diameter	Ø 20 mm
Insert diameter	Ø 4 mm
Phantom height	approx. 41 mm
Phantom weight	35 g

Micro-CT HA Phantom, D10 (QRM-70127)

Phantom diameter	Ø 10 mm
Insert diameter	Ø 2 mm
Phantom height	approx. 41 mm
Phantom weight	35 g

Micro-CT HA Phantom, D4.5 (QRM-70128)

Phantom diameter	Ø 4.5 mm
Insert diameter	Ø 0.8 mm
Phantom height	5 mm
Phantom weight	35 g

Micro-CT HA set of 5 single CaHA rods (QRM-70134)

Insert diameter	Ø 5 mm
Phantom height	40 mm

Body material	resin

Densities for all HA Phantoms:

Specified HA (mg HA/cm^3)	Density ρ (g/cm^3)
0	1.13
50	1.16
200	1.26
800	1.65
1200	1.9

Ordering Information

QRM-70107 Micro-CT HA Phantom, D32
QRM-70129 Micro-CT HA Phantom, D25
QRM-70126 Micro-CT HA Phantom, D20
QRM-70127 Micro-CT HA Phantom, D10
QRM-70128 Micro-CT HA Phantom, D4.5
QRM-70134 Micro-CT HA set of 5 single rods

Micro-CT Mouse Phantom

For the performance of image quality tests at small-animal micro-CT systems

- Mimics the body of a small mouse
- Image Quality checks at small-animal micro-CT systems
- Different soft-bone-tissue inserts with different density

It mimics the body of a mouse and is specially designed to perform image quality tests of micro-CT systems for small-animal research. It consists of soft tissue-equivalent plastic and several bone and organ inserts, as well as an aorta and heart with a specific iodine uptake.

The two high contrast inserts are made up of different concentrations of iodine. The two small bones consist of calcium hydroxyapatite (CaHA) with a concentration of 100 mg CaHA/cm^3 and the three large bones have 200 mg CaHA/cm^3.

Specification

Phantom width	32 mm
Phantom height	24 mm
Phantom length	40 mm
Phantom weight	35 g
Body material	soft tissue-equivalent

Insert	Tissue	Dimension	HA/Iodine
Bone	HA200	Ø 5.0 mm	200 mg CaHA / cm^3
Bone	HA200	Ø 3.0 mm	200 mg CaHA / cm^3
Bone	HA100	Ø 2.0 mm	100 mg CaHA / cm^3
Aorta	I420	Ø 1.0 mm	15 mg I / cm^3
Heart	I100	2 mm x 4 mm	1 mg I / cm^3
Liver	Soft Tissue 2	6 mm x 12 mm	-
Air	Lung	6 mm x 8 mm	-

Ordering Information

QRM-70137 Micro-CT Mouse Phantom

Micro-CT Low Contrast Phantom

A useful tool for the assessment of the low-contrast resolution of micro-CT systems

- Evaluate low contrast detectability of micro-CT systems
- Customizable

The two available models contain cylindrical targets with varying diameters of a specified contrast with respect to the background. QRM-70108 model phantom houses four inserts of two different contrast levels (-4 % and -8 %), each in two different diameters. QRM-70124 model phantom houses nine inserts of three different contrast levels (- 3 % / -6 % / -9 %), each in three different diameters.

Actual values vary slightly depending on scanner geometry, calibration, and tube voltage.

Different sizes and inserts can be produced upon request.

Specification

Micro-CT Low Contrast Phantom, V1 (QRM-70108)	
Phantom diameter	32 mm
Phantom height	approx. 41 mm
Phantom weight	35 g
Body material	soft tissue-equivalent resin
Low contrast inserts:	
Inserts diameter	1 mm / 2.5 mm
Contrast levels	approx. - 4 % / - 8 %

Micro-CT Low Contrast Phantom, V2 (QRM-70124)	
Phantom diameter	32 mm
Phantom height	approx. 41 mm
Phantom weight	35 g
Body material	soft tissue-equivalent resin
Low contrast inserts:	
Inserts diameter	1 mm / 2 mm / 3 mm
Contrast levels	approx. - 3 % / -6 % / -9 %

Ordering Information

QRM-70108 Micro-CT Low Contrast Phantom, V1
QRM-70124 Micro-CT Low Contrast Phantom, V2

Micro-CT Slice Sensitivity Phantom

A convenient tool for evaluating the spatial resolution of micro-CT systems by measuring the SSP, slice thickness or axial MTF

- Evaluate the spatial resolution of micro-CT systems by measuring the SSP (slice sensitivity profile)
- Houses 10 micron thick centrally placed gold foil
- Customizable

It contains a high-attenuating 10 micron thick metal insert (Au foil) of 1 mm diameter centrally placed within the cylindrical phantom. The dimensions of the insert are tailored to the nominal slice thickness of micro-CT scanners.

Specification

Phantom diameter	32 mm
Phantom height	approx. 43 mm
Phantom weight	35 g
Body material	soft tissue-equivalent resin
Insert (Au) diameter	1 mm
Insert (Au) thickness	0.01 mm

Ordering Information

QRM-70109 Micro-CT Slice Sensitivity Phantom

Micro-CT Bar Pattern Phantom, air or resin

A perfect tool to assess axial and sagittal spatial resolution of many industrial and medical micro-CT systems in a direct visual manner

- Evaluate axial and sagittal spatial resolution in preclinical and industrial micro-CT
- Provides high resolution contrast
- Bar and point structures down to 5 microns (air, QRM-70113 and resin, QRM-70114)
- Corresponds to 3.3 to 100 lp /mm (air, QRM-70113 and resin, QRM-70114)

It offers a good alternative to indirect methods to evaluate spatial resolution in high resolution X-ray imaging modalities. The phantom comprises two silicon chips with various bar and point structures, one aligned axial and one aligned perpendicular (sagittal) to it.

The phantom is available in two versions:
- optimized for industrial CT: with the chips mounted on a slim support in a hollow (air-filled) cylinder (QRM-70113)
- optimized for small-animal micro-CT: embedded in soft tissue-equivalent resin (QRM-70114)

Each 5 x 5 mm^2 chip contains bar (trenches) and point structures with a width of 5 to 150 microns. The depth of the structures varies between 70 and 150 microns. The different structures on the chip are arranged over the chip in such a way that the spatial resolution can be evaluated in a single measurement both in the center and in the periphery of the image/chip.

The Micro-CT Bar Pattern resin (QRM-70114) is available in other diameters upon request. Besides, adapter/extension cylinders are available upon request. Please note that the chips are not intended to be used for planar radiography.

For further information please visit qrm.de.

Specification

Micro-CT Bar Pattern Phantom, air (QRM-70113)

Phantom diameter	20 mm
Phantom height	40 mm
Phantom wall thickness	0.2 mm
Phantom material	air / plastic
Contrast of pattern	silicon / air

Micro-CT Bar Pattern Phantom, resin (QRM-70114)

Phantom diameter	8 mm
Phantom height	40 mm
Phantom material	resin
Contrast of pattern	silicon / resin
Chip dimension	5 mm x 5 mm
Chip height	0.66 mm
Chip material	Silicon
Range of the bar and point structures on the chip (width)	(5 ... 150) microns (see Table)
Range of the bar and point structures on the chip (depth)	(70 ... 150) microns
Resolution	(100 ... 3.3) lp/mm

Table: number of lines and dots per section

Section	Line width (µm)	Lines per pattern	Dots (µm)	Dots per pattern
A	5, 10, 25, 50, 100, 150	5		
B	5, 10, 15, 20, 25, 30	5	5, 10, 15, 20, 25, 30	18
C	5, 10, 15, 20, 25, 30	5	5, 10, 15, 20, 25, 30	18
D			5, 10, 25, 50, 100, 150	18
E	5, 10, 25, 50, 100, 150	5		

Ordering Information

QRM-70113 Micro-CT Bar Pattern, air
QRM-70114 Micro-CT Bar Pattern, resin

Micro-CT Bar Pattern Phantom, NANO

A perfect tool to assess axial and sagittal spatial resolution of many industrial and medical micro-CT systems in a direct visual manner

- Evaluate axial and sagittal spatial resolution in preclinical and industrial micro-CT
- Provides high resolution contrast
- Bar and point structures down to 1 micron
- Corresponds to 500 to 50 lp/mm

The phantom offers a good alternative to indirect methods to evaluate spatial resolution in high resolution X-ray imaging modalities. The phantom comprises two silicon chips with various bar and point structures, one aligned axial and one aligned perpendicular (sagittal) to it. The chips are mounted on a solid plastic support.

Each 3 mm x 3 mm chip contains bar (trenches) and point structures with a width of 1 to 10 microns. The depth of the structures varies between 5 and 15 microns. The different structures on the chip are arranged over the chip in such a way that the spatial resolution can be evaluated in a single measurement both in the center and in the periphery of the image/chip.

In addition, a slented edge and a so-called Siemens-star (actinomorphic star) are placed on the chip. Specific mount/ holder for your micro-CT system is available upon request.

Specification

Phantom diameter	5.4 mm
Phantom height	19 mm
Phantom wall thickness	0.2 mm
Phantom material	air / plastic
Chip dimension	3 mm x 3 mm
Chip material	silicon
Chip height	0.66 mm
Contrast of pattern	silicon / air
Range of the bar and point structures on the chip (width)	(1 ... 10) microns (see Tables 1-3)
Range of the bar and point structures on the chip (depth)	(5 ... 15) microns
Resolution	(500 ... 50) lp /mm

For further information please visit qrm.de.

Table 1: Sections and structures on the chip section

Section	Description	Pattern / Resolution
1	bar and point pattern	1 to 10 µm structures
2 a-d	bar and point pattern in differ-ent orientation	1 to 5 µm structures
3	slanted edge	
4 + 5	36 actinomorphic star - test pattern	going down from 17.5 µm to 1 µm
6	point grid	10 to 2 µm points

Table 2: Line and point pattern

Row	Line thickness (µm)	Lines per pattern	Dots (µm)
A	2, 4, 6, 8, 10	50 ... 250	
B			2, 4, 6, 8, 10
C	1, 2, 3, 4, 5	100 ... 500	
D	1, 2, 3, 4, 5	100 ... 500	
E			2, 4, 6, 8, 10
F	2, 4, 6, 8, 10	50 ... 250	

Table 3: Line and point pattern

Row	Line thickness (µm)	Line pairs/mm	Points (µm)
A	10, 8, 6, 4, 2	50 ... 250	
B	10, 8, 6, 4, 2 (tilt 90°)	50 ... 250	
C			2, 4, 6, 8, 10
D			10, 8, 6, 4, 2
E			1, 2, 3, 4, 5 5, 4, 3, 2, 1
F	1, 2, 3, 4, 5 5, 4, 3, 2, 1	500 ... 100	
G	1, 2, 3, 4, 5 5, 4, 3, 2, 1 (tilt 90°)	500 ... 100	

Ordering Information

QRM-70119 Micro-CT Bar Pattern Phantom, NANO

Micro-CT Water Phantom

The ideal tool for measuring noise, homogeneity, and uniformity

- Water-fillable phantom to measure noise and homogeneity
- Bubble-free design: extra cavity for air bubbles
- Different diameters available (D60 mm, D32 mm, D20 mm)

The phantoms can easily be filled with water - bubble-free due to the optimized design providing an extra 'air' cavity.

They offer an intake/outlet screw in a convex closure head such that they can be used in a rotating gantry or in upright position. They provide a small cavity in the upper part, detaining air bubbles if used in a horizontal position, thus providing a bubble-free cylindrical space for the measurements.

There are 3 available models, all made of transparent low density (1.0 g/cm^3) plastic providing a high mechanical stability.

Different sizes other than those specified here can be produced upon request.

Specification

Micro-CT Water Phantom, D60 (QRM-70110)	
Phantom inner diameter	60 mm
Phantom height	135 mm
Phantom inner height	110 mm
Phantom wall thickness	0.5 mm
Body material	durable plastic or PMMA

Micro-CT Water Phantom, D32 (QRM-70111)	
Phantom diameter (inner)	32 mm
Phantom height	66 mm
Phantom inner height	44 mm
Phantom wall thickness	0.4 mm
Body material	durable plastic or PMMA

Micro-CT Water Phantom, D20 (QRM-70112)	
Phantom inner diameter	20 mm
Phantom height	62 mm
Phantom inner height	40 mm
Phantom wall thickness	0.4 mm
Body material	durable plastic or PMMA

It is recommended to use the phantoms with distilled water (e.g. HPLC-grade).

Ordering Information

QRM-70110 Micro-CT Water Phantom, D60
QRM-70111 Micro-CT Water Phantom, D32
QRM-70112 Micro-CT Water Phantom, D20

Micro-PET IQ Phantom, NEMA NU4

For evaluation of the IQ, attenuation accuracy and to perform scatter corrections in micro-PET systems in accordance with the NEMA NU 4-2008 standard

- Performance measurements of small-animals' positron emission tomography (PET)
- Design in accordance with the NEMA NU 4-2008 standard
- Measure image quality, accuracy of attenuation and perform scatter corrections

The NEMA NU 4-2008 standard proposes a standard methodology for evaluating the performance of positron emission tomography (PET) designed for small-animal imaging.

The phantom is made of PMMA and has a large cavity (Ø = 30 mm) in one half of the phantom that can be filled with a radioisotope (hot region). This large cavity houses two separate smaller cavities that can be filled with water and air (cold regions). In the other half the phantom contains five small cavities with different diameters (Ø = 1, 2, 3, 4 and 5 mm) that are arranged circular around the longitudinal axis of the phantom providing a connection to the first large radioisotope-filled cavity (hot region).

Specification

Phantom (outer) diameter	33.5 mm
Phantom height	63 mm
Body material	PMMA

Phantom cavities:

Hot regions - fillable with isotope:	
Large cavity	
Diameter (inner)	Ø 30 mm
Height	30 mm
Group of 5 cavities arranged circular, connected to large cavity	
Diameter	Ø 1, 2, 3, 4 and 5 mm
Height	20 mm

Cold regions - fillable with water and air:	
2 separate cavities embedded in large cavity	
Diameter (inner)	Ø 8 mm
Height	15 mm

Ordering Information

QRM-70115 Micro-PET IQ Phantom, NEMA NU4

The NEMA NU 4-2008 report is not part of the phantom described here. It must be ordered separately at www.nema.org.

Micro-PET Scatter Phantom

For evaluation of the performance of positron emission tomography (PET) systems in accordance with NEMA NU 4-2008 standards

- Performance evaluation of positron emission tomography (PET) systems for small-animal imaging
- Design in accordance with the NEMA NU 4-2008 standard
- Mouse, Rat, and Monkey size

The NEMA NU 4-2008 standard recommends a standardized methodology for evaluating the performance of micro-PET systems designed for small-animal imaging. The scatter phantoms are suitable tools for the evaluation of scatter fraction, counting losses and random coincidence measurements of micro-PET systems according to this methodology. It is possible to measure the relative system sensitivity to scattered radiation and to quantify the effects of system dead time and the occurrence of random coincidence events at various levels of source activity.

Three different sizes are available, representing mouse, rat, or monkey size. The phantoms are made of high- density polyethylene.

The scatter phantom is delivered with PE tubes and adapters (luer/lock) for connecting standard syringes.

Specification

Micro-PET Scatter Phantom Mouse (QRM-70116)

Phantom diameter	25 mm
Phantom height	70 mm
Phantom material	high-density polyethylene (HD PE)
Borehole diameter	3.2 mm
Borehole position	10 mm off-center (parallel to the central axis)

Micro-PET Scatter Phantom Rat (QRM-70120)

Phantom diameter	50 mm
Phantom height	150 mm
Phantom material	high-density polyethylene (HD PE)
Borehole diameter	3.2 mm
Borehole position	17.5 mm off-center (parallel to the central axis)

Micro-PET Scatter Phantom Monkey (QRM-70122)

Phantom diameter	100 mm
Phantom height	400 mm
Phantom material	high-density polyethylene (HD PE)
Borehole diameter	3.2 mm
Borehole position	30 mm off-center (parallel to the central axis)

Ordering Information

QRM-70116 Micro-PET Scatter Phantom, Mouse
QRM-70120 Micro-PET Scatter Phantom, Rat
QRM-70122 Micro-PET Scatter Phantom, Monkey

The NEMA NU 4-2008 report is not part of the phantom described here. It must be ordered separately at www.nema.org.

Micro-PET Hot Rod Phantom

An excellent tool for evaluating the spatial resolution of micro-PET and SPECT systems designed for small-animal imaging

- Evaluation of the spatial resolution of small-animal micro-PET and SPECT systems
- Bubble-free design: extra cavity for air bubbles

The phantom is made of PMMA and is designed for a FOV smaller than 40 mm. It consists of a cylinder that can be filled with radioisotope. The top of the phantom contains an extra cavity (bubble reservoir) that traps air bubbles to provide a bubble-free cylindrical space for measurements. This extra space prevents air bubbles from entering the scan area when the phantom is placed horizontally in the scanner.

Two spacers can be used to align the resolution part in the center of the phantom. The spacers can be replaced with two full-body PMMA inserts to prevent excessively high signal of the isotope inside the phantom.

Specification

Phantom (outer) diameter	35 mm
Phantom height	70 mm
Body material	PMMA
Hot rod Insert	(see table)
Hole pattern resolution inserts diameter	0.6, 0.8, 1.0, 1.2, 1.5, 2.0 mm
Insert (outer) diameter	29 mm
Insert height	12 mm

Table:

Ø (mm)	Quantity	Center-to-center (mm)
0.6	43	1.2
0.8	26	1.6
1.0	19	2.0
1.2	13	2.4
1.5	8	3.0
2.0	6	4.0

Ordering Information

QRM-70121 Micro-PET Hot Rod Phantom

Notes

Radiation Therapy

Comprehensive Electron Density Phantom

An excellent tool for the calibration of Hounsfield Unit (HU) vs. electron density of radiotherapy treatment plans to optimize the dose delivered to the patient (CT/CBCT)

- Calibration of radiation oncology treatment plans
- Optimization of the delivered dose to the patient
- Provides realistic tissue simulation and values within the higher density range (bones)
- Further/multiple tissue-equivalent inserts are available upon request

The Comprehensive EDP phantom is ideally suited for the creation of a HU vs the electron density table for treatment planning CT (4DCT). It consists of a water-equivalent body section and a removable/stand-alone head section with in total 16 holes for exchangeable inserts that mimic real human tissue regarding its physical and electron density according to the ICRU Report 44 and 46. Remarkably, the phantom provides realistic tissue also in the higher density range (bone).

The phantom comes with a protocol displaying physical density, electron density, electron density relative to water and effective atomic number (other values are optional).

The phantom is not only suitable for the high energy ranges (MeV electron, photon, and proton therapy systems), but is also a valuable tool for kV-energies in diagnostic imaging (e.g. Multi-Energy CT).

Specification

Body:	
Phantom dimension	250 mm x 350 mm
Phantom height	150 mm
Holes	8 pcs., Ø 25 mm
Head insert:	
Phantom diameter	160 mm
Phantom height	150 mm
Holes	8 pcs., Ø 25 mm
Body material	Water-equivalent (CTwater), approx. 0 HU at (80 ... 140) kV[1]
Phantom weight	6.0 kg
Tissue-equivalent rods	Ø 25 mm, height 150 mm

Standard Configuration

CTwater (2 pcs.)
Lung I (inflated)
Lung II
Lung III
Adipose
Breast (50/50)
Brain
Muscle
Liver
Cartilage
Skeleton-Spongiosa
Skeleton-Femur
Skeleton-Humerus
Skeleton-Mandible
Skeleton-Cortical Bone

[1]Accuracy ± 5 HU of specified values

Ordering Information

QRM-90114 Comprehensive Electron Density Phantom

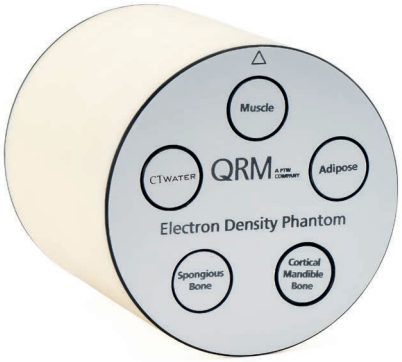
Options

QRM-90115 CED - Rod D25/D10, Titanium core
QRM-90116 CED - Rod D25/D10, Stainless Steel core
QRM-90117 CED - Rod D25/D10, Aluminum core
QRM-90118 CED - Set 6 rods CaHA, 25 - 400 mg HA/cc
QRM-90119 CED - Set 6 rods Iodine, 1 - 15 mg I/cc

For further information please visit qrm.de.

Electron Density Phantom, D100

An important tool for the calibration of Hounsfield Unit (HU) vs. electron density of radiotherapy treatment plans to optimize the dose delivered to the patient (CT/CBCT)



- D100 compatible
- Calibration of radiation oncology treatment plans
- Optimization of the delivered dose to the patient
- Provides realistic tissue simulation and values within the higher density range (bones)
- Further/multiple tissue-equivalent inserts are available upon request

It houses 5 exchangeable inserts providing different tissue-equivalent materials. All tissue equivalents represent the real human tissue regarding its physical density and electron density (acc. to ICRU Report 44 and 46) which are of highest interest in radiation oncology treatment planning. Remarkably, the phantom provides realistic tissue also in the higher density range (bone).

The phantom comes with a protocol displaying physical density, electron density relative to water and effective atomic number (other values are optional).

All materials are not only suitable for the high-energy range (MeV electron, photon, and proton therapy), but exhibit tissue-equivalency also for kV-energies in diagnostic imaging (80 kV to 140 kV tube voltage).

There are several options available to be used with the D100 compatible QRM-90110 as, for example, the Oval Body Phantom (QRM-20116) which provides a body-shape water- or tissue-equivalent environment.

Specification

Phantom diameter	100 mm
Phantom height	103 mm
Phantom weight	0.9 kg
Body material	Water-equivalent (CTwater), approx. 0 HU at (80 ... 140) kV[1]

Inserts

Air (central insert, Ø 30 mm)
ICRU Adipose (Ø 20 mm)
CTwater (Ø 20 mm)
ICRU Muscle (Ø 20 mm)
ICRU Spongious Bone (Ø 20 mm)
ICRU Mandible (Ø 20 mm)

[1]Accuracy ± 5 HU of specified values

Ordering Information

QRM-90110 Electron Density Phantom, D100

Options

QRM-20100 Thorax Phantom
QRM-20118 Abdomen Phantom
QRM-20115 Oval Body Phantom, Tissue
QRM-20116 Oval Body Phantom, CTwater
QRM-10141 Extension Ring CTwater, 160mm
QRM-10142 Extension Ring CTwater, 320mm

CTwater Slabs

A water-equivalent plastic that exhibits the physical X-ray and mass attenuation characteristics of liquid water

- Quality assurance measurements and monitor calibration procedures
- For high energy photon, electron, and proton dosimetry (MeV)
- Also ideally suited for the diagnostic energy range (approx. 0 HU at 80 KV to 140 kV tube voltage)
- Customizable: can be molded into arbitrary shapes

CTwater mimics the physical X-ray mass attenuation properties of liquid water regarding its physical density and electron density. It can be used for high-energy photon, electron, and proton fields in radiation oncology (MeV), which makes it suitable for the dosimetric evaluation of constancy tests in radiation therapy, e.g. depth dose measurements.
Besides therapeutic energies CTwater is ideally suited for clinical X-ray modalities due to its water-equivalency (0 ± 5 HU) within the full diagnostic energy range of 80 kV to 140 kV tube voltage.

The slabs exhibit long-term stability and can be produced in a large amount with a high degree of homogeneity and mechanical precision.

Custom chamber cavities and adapters for ionization chambers are available upon request.

Specification

Phantom dimension	300 mm x 300 mm
Phantom height	5 mm (QRM-90111), 10 mm (QRM-90112), 20 mm (QRM-90113)

Material

Body material	Water-equivalent (CTwater), approx. (0 ± 5) HU at (80 ... 140) kV
Homogeneity of the slabs	± 3 HU
Density (ρ)	1.03 g / cm^3

Ordering Information

QRM-90111 CTwater slab, 5 mm thick
QRM-90112 CTwater slab, 10 mm thick
QRM-90113 CTwater slab, 20 mm thick

Codes of Practice

1 Introduction

This chapter aims to briefly explain the physics and the assessment methods of image quality parameters for multiple QRM-phantoms dedicated to various X-ray applications. For a more detailed description we recommend relevant literature, e.g. (book) '*Computed Tomography – Fundamentals, System Technology, Image Quality, Applications – Willi A. Kalender, Publicis 2011*'

Although this chapter provides the reader with a concise overview for the evaluation of the X-ray system's imaging performance, it should be noted that **QRM phantoms are NOT registered as medical devices**. Hence, the procedures outlined in this chapter are recommended only for research and development purposes and do not replace relevant protocols and publications and shall not be used for the acceptance tests and constancy tests of X-ray imaging devices used for the diagnosis or treatment of patients.

Safety warnings and instructions
Please read these safety warnings and instructions carefully before use and keep them well for your future reference.

1. Do not place the phantoms in direct sunlight or near chemicals. Make sure that the environment does not experience abrupt changes in temperature or humidity.
2. Do not put the product on a cart, table, or desk, which is not stable, to avoid falling off.
3. Do not clean the phantom with solvents. Just use a mild soap and rinse with clear water.
4. Transportation is only recommended if a transport case is available.

2 CT Image Quality

Image quality parameters are of utmost importance for evaluating the performance of imaging systems and are affected by different factors. The physics and the assessment techniques of the common CT image quality checks defined in the literature, guidelines, and reports are briefly described below. The models name of the appropriate QRM phantoms for which these tests can be performed are indicated in each section.

1. Spatial Resolution and Modulation Transfer Function (MTF)

The MTF describes the capability of an imaging system to resolve fine structures, i.e. its ability to show small details. It is specifically defined for high-contrast structures. Basically, the measurements are carried out at high dose levels, such that noise in the image can be eliminated, allowing for low-noise assessments. Here, one has to evaluate spatial resolution in the axial plane and in the longitudinal direction (z-axis) as both quantities are affected by different quantities. The spatial resolution in the axial plane depends on the number of projections, reconstruction filters, pixel size, focal spot size, and detector size whereas the spatial resolution in the longitudinal direction depends on slice thickness, focal spot size and noise.

The spatial resolution can be measured either directly by visually determining the smallest resolvable pattern/structure, or indirectly by calculating the point spread function (PSF) and modulation transfer function (MTF). The PSF is a common metric used for the indirect measurement of spatial resolution. This two-dimensional (2D) mathematical function is the response of the imaging system to a point source input. While the PSF is defined in the spatial domain, the MTF is a way to quantify spatial resolution in the spatial frequency domain. Mathematically, the MTF is the Fourier Transform of the PSF and has the unit line pairs per cm (lp/cm). When resolving fine structures there are several blurring mechanisms (not discussed in detail here) which cause a loss of contrast in the image. Generally, the contrast reduces with decreasing structure size. The highest spatial resolution that can be achieved for a given system is often specified/indicated by the 10% value of the MTF, i.e. the spatial frequency, where the achieved contrast has dropped to 10% of the maximum value. This value serves as an objective quantity and can be used to compare the spatial resolution of different imaging modes as well as comparing the performance of different imaging systems.

For the acquisition of the spatial resolution using the PSF and MTF as described above, phantoms with thin wires are commonly used.
The spatial resolution along the longitudinal direction (z-axis) can be investigated using slice sensitivity profiles employing phantoms with thin high absorbing metal inserts.
Alternatively/Similarly, instead of using the PSF, the 3D MTF can also be calculated using the edge spread function (ESF) obtained from measurements of phantoms including sharp edges or spheres. Phantoms including such inserts hence allow to assess spatial resolution in all planes by evaluating the 3D MTF.

Visual spatial resolution evaluation with QRM Phantoms

- Use thin slices (approx. 1 mm slice thickness) and a suitable kernel, e.g. `standard` for regular scan protocols and `hi-res` for high-resolution scan protocols.
- Several line patterns shall be seen with distinguishable bright bars and dark spacing between the bars. Read out the corresponding spatial resolution (in lp/cm) of the smallest resolvable structure from the phantom datasheet.
- The smallest visible pattern determines the highest in-plane spatial resolution.

Example:
30 lp/cm corresponds to $\frac{1\ \text{cm}}{2 \cdot 30} = 0.016\ \text{cm}$

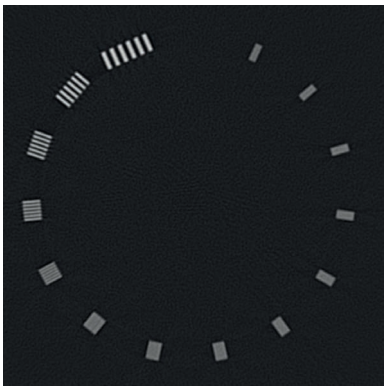


Figure 1: Cone-Beam Phantom CT Image (Test pattern section)

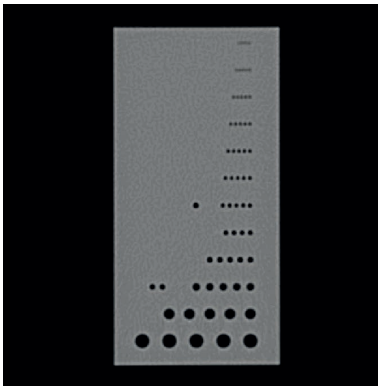


Figure 2: 3D Spatial-Resolution Phantom CT Image (Hole pattern section)

Suitable Phantoms
- QRM-10103 Cone-Beam Phantom, Expert
- QRM-10120 Cone-Beam Phantom, Basic
- QRM-10131 Dental CBCT QA Phantom, Expert
- QRM-10111 3D Spatial Resolution Phantom
- QRM-10101 3D Spatial Resolution Phantom, D100
- QRM-10140 High Contrast Resolution Phantom, D100

MTF evaluation with QRM Phantoms
- Use thin slices (approx. 1 mm slice thickness) and a suitable kernel (e.g., `standard` for regular scan protocols and `hi-res` for high-resolution scan protocols). Further, use the maximum available dose to reduce noise.
- The ESF or PSF should be measured to calculate the MTF of the imaging system. Typical values for describing the performance of scanners are 10% and 50% of the maximum value of the MFT.

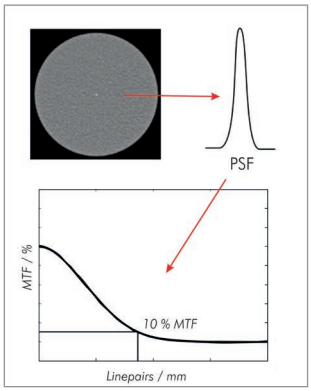


Figure 3: Wire Phantom CT Image - Resin, PSF and MTF

Suitable Phantoms
- QRM-10103 Cone-Beam Phantom, Expert
- QRM-10120 Cone-Beam Phantom, Basic
- QRM-10131 Dental CBCT QA Phantom, Expert
- QRM-10130 Dental CBCT QA Phantom, Basic
- QRM-10136 Breast CT QA Phantom, Expert
- QRM-10104 Wire Phantom, resin
- QRM-10105 Wire Phantom, D100
- QRM-10138 Wire Phantom, air
- QRM-10114 Slice Sensitivity Phantom

2. Low-Contrast Resolution and Contrast-to-Noise Ratio (CNR)

The low-contrast resolution describes how well an imaging system can differentiate adjacent tissues/materials that have similar X-ray attenuation. The capability to resolve low contrast features primarily depends on the noise level in the image. A high level of noise prevents two objects from being distinguishable resulting in poor contrast differentiation. The main X-ray-tissue interactions are mainly Photoelectric effect and Compton interactions, except for high-contrast structures such as bone. Primary photons lose their energy through scattering or absorption as they pass through tissue. Differences in image contrast are the result of atomic number, electron density, physical density, or differential attenuation of X-rays through tissues of different thicknesses. In imaging systems, windowing allows image contrasts to be visualized in grayscale. Low-contrast resolution is affected by different parameters such as tube current, tube voltage, beam energy, and contrast medium.

One important quantity to describe the low contrast detectability is the contrast-to-noise ratio (CNR). The CNR depends on the differences in the mean HU values, $CT\#_{\text{contrast insert}}$ and $CT\#_{\text{background}}$, and the background signal noise, $\sigma_{\text{background}}$:

$$\text{CNR} = \frac{CT\#_{\text{contrast insert}} - CT\#_{\text{background}}}{\sigma_{\text{background}}}$$

There are two implications of the CNR:
1. For features/structures of same size: the higher the CNR the lower the discernable contrast.
2. For a given/fixed contrast value of different sized features: the higher the CNR, the smaller the detectable structures.

The CNR can be assessed with phantoms containing several spherical (3D measurements) or cylindrical low contrast inserts (2D measurements) which provide different contrast values and insert diameters.

Evaluation of the low-contrast resolution with QRM Phantoms

We describe the assessment/evaluation of the low-contrast resolution here using the QRM Cone Beam Phantom (Low Contrast Section).
For the assessment of the CNRs of different contrast values provided in the phantom only the largest inserts (seen as circles/disks) should be considered. Smaller inserts should only be evaluated according to their visibility. Regions of Interest (ROIs) smaller than the diameter of the insert should be used to exclude cupping/edge effects from the analysis.

- Draw circular ROIs of appropriate size and place them within the large inserts.
- For reference, place similar ROIs in the proximity of the inserts, but at some distance from the phantom edge.
- Read out mean CT values within the ROIs and the signal noise (standard deviation of the fluctuating CT values) of the background and calculate the CNR.

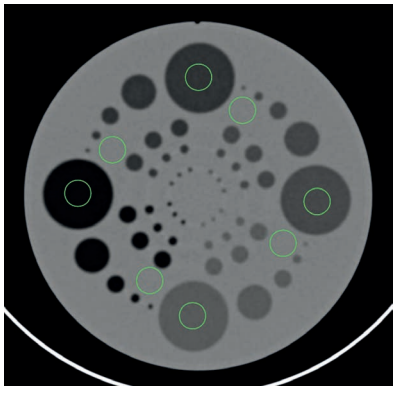


Figure 4: Cone Beam Phantom Low-Contrast section CT Image

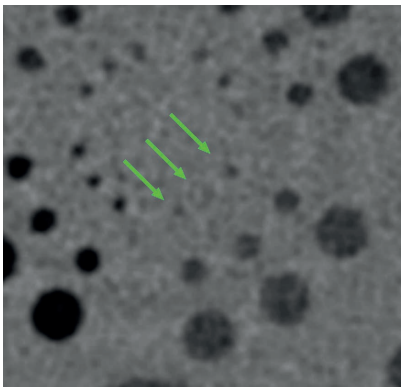


Figure 5: Detection of small low-contrast targets (arrows)

Suitable Phantoms

- QRM-10103 Cone-Beam Phantom, Expert
- QRM-10120 Cone-Beam Phantom, Basic
- QRM-10112 2D Low Contrast Phantom
- QRM-10100 2D Medium Contrast Phantom
- QRM-10109 3D Low Contrast Phantom (-10 HU)
- QRM-10110 3D Low Contrast Phantom (-20 HU)

3. CT Value Accuracy (Linearity)

After collecting/obtaining the projection data the 3D image matrix is calculated/reconstructed. The physical quantity affecting the intensity of the projection data and hence, creating the image contrast is the linear attenuation coefficient, $\mu_{material}$, of the irradiated material or patient. However, $\mu_{material}$ is an energy- dependent quantity and, hence, the intensity of the projection data depends not only on the material composition, but also on multiple other parameters as X-ray spectrum (i.e. tube voltage), filtration, detector configuration, beam hardening etc. Further, the image contrast is affected by the data processing, i.e. reconstruction kernel, pre-filtering etc. In order to ensure the comparability between different scanners and protocols in the clinical routine, CT values (grey values, CT#) are commonly quantified in Hounsfield Units (HU). The Hounsfield scale is defined by setting the grey value of water to 0 HU and the grey value of air to -1,000 HU, regardless of the used tube voltage or scan protocol. The CT value of an arbitrary material is calculated as follows:

$$CT\# = \frac{\mu_{material} - \mu_{water}}{\mu_{water}} \cdot 1000\ HU$$

The HU-scale is used in all clinical applications and guarantees comparable results regardless of tube voltage, filtration, CT manufacturer etc.

Typical CT values are -300 HU to 100 HU for soft tissues, 300 HU to 2000 HU and higher for compact bone, and 100 HU to 600 HU for iodinated contrast media.

The stability/constancy of the CT values should be monitored regularly as part of the quality assurance. Consecutively acquired values should not deviate more than ±4 HU of the mean value.

Homogeneous phantoms containing different materials (e.g. bone, water, air) are standard tools for this purpose. CT value linearity should be assessed separately for each protocol used in the clinical routine.

CT Value Accuracy (Linearity) evaluation with QRM Phantoms

Thick slices (approx. 5 mm slice thickness) and a soft kernel shall be used to reduce the image noise. In order to exclude cupping/edge effects (in particular in the highly absorbing bone insert) ROIs smaller than the inserts' diameter should be used to evaluate the HU values. Within this limit, the ROIs should be chosen as large as possible to average over many image pixels.

- Draw circular ROIs of appropriate size and place them in the scaling inserts
- Read out mean CT values within the ROIs and compare them to data acquired in prior quality assurance checks/ measurements.

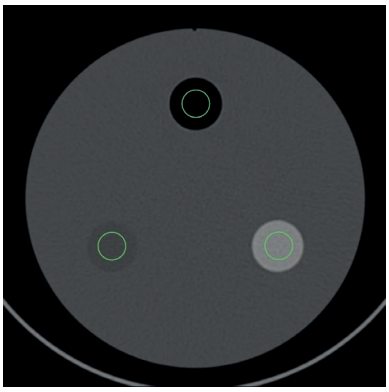


Figure 6: CT Image showing CT Value analysis

Suitable Phantoms

- QRM-10103 Cone-Beam Phantom, Expert
- QRM-10120 Cone-Beam Phantom, Basic
- QRM-10131 Dental CBCT QA Phantom, Expert
- QRM-10130 Dental CBCT QA Phantom, Basic
- QRM-10136 Breast CT QA Phantom, Expert

4. Signal-to-Noise Ratio (SNR)

In imaging systems, there are several sources of noise as, for example, thermal noise in the detector or scattered photons that do not pass straight through the tissue due to the Compton effect, but still contribute to the signal.

The Signal-to-Noise Ratio (SNR) is a good metric to quantify the image noise and hence, is particularly useful to specify/assess the system's performance. It can be calculated by comparing the mean signal amplitude, (*CT#*) (mean CT value), to the image noise, $\sigma_{background}$ (standard deviation of the fluctuating CT values) in a specific ROI:

$$SNR = \frac{(CT\#)}{\sigma_{background}}$$

The higher the SNR, the lower the noise in the image. The SNR is directly related to the (low) contrast separation: the higher the SNR, the better the low contrast separation (see section 2.2)
The SNR is affected by various parameters. Generally, the SNR is scales with the number of X-ray photons contributing to the image. Therefore, a high dose favors a high value of the SNR:

$$SNR \ \alpha \ \sqrt{\text{Radiation Dose}}$$

Further, high tube current (mAs), high tube voltage (kV), increased slice thickness or voxel size facilitate a high SNR while large patients or strong absorbing materials lead to a reduced SNR.

Also the reconstruction kernel in imaging systems affects the SNR and hence, the contrast separation. Bone filters provide a low SNR while soft tissue filters provide a high SNR. For this reason, smooth filters are used in soft tissue images, while sharp filters are used in imaging high-contrast structures such as bone.

SNR evaluation with QRM Phantoms
For an evaluation of the SNR uniform phantoms are used.
- Place the homogeneous section of the phantom at the isocenter and scan the phantom with the scan protocol for which the SNR should be evaluated using a slice thickness of at least 2 mm.
- Draw a circular ROI of sufficient size (e.g. 30 % of the phantom diameter) in the center of the phantom and examine the mean CT value and the noise level (standard deviation of CT values within the ROI).
- If necessary, repeat the measurement at several positions within the homogeneous phantom, with different ROIs or with different scan protocols, filters, reconstruction kernels etc.

Suitable Phantoms
QRM-10103 Cone-Beam Phantom, Expert
QRM-10120 Cone-Beam Phantom, Basic
QRM-10131 Dental CBCT QA Phantom, Expert
QRM-10130 Dental CBCT QA Phantom, Basic
QRM-10136 Breast CT QA Phantom, Expert

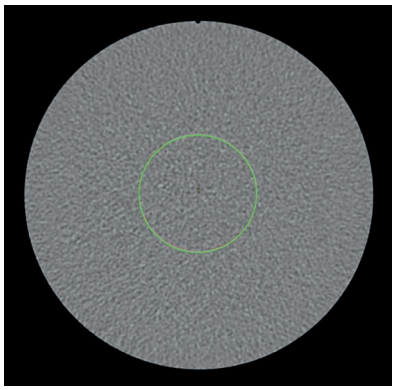


Figure 7: CT Image showing SNR analysis

5. CT Value Uniformity (Homogeneity)

Uniformity is an important image quality parameter that determines how uniform the CT values of a homogeneous test object are depicted in an image.Due to artifacts such as beam hardening, cupping artifacts or detector-specific issues that often arise in clinical practice, uniformity should be inspected regularly to ensure that the CT value deviation between the center and periphery of the image is not higher than the tolerances. The tolerance value is defined according to international and national guidelines, and the difference in the mean CT values between the center and the periphery of the image should not exceed ± 4 HU. The deviation from the baseline values should not exceed ± 2 HU.

CT Value Uniformity (Homogeneity) evaluation with QRM Phantoms

- Place the homogeneous phantom at the isocenter and scan the phantom with the largest dose (mAs) and most frequently used tube voltage. Use relative thick slices of at least 2 mm thickness.
- Insert several ROIs (central, top, right, bottom and left) of roughly 20 % of the phantom diameter in the axial image of the homogeneous phantom and examine the mean CT values to assess the homogeneity of the CT values within the image.
- Avoid placing the peripheral ROIs too close to the edge of the phantom.
- Evaluate how much the mean CT values of the peripheral ROIs deviate from the value at the center.
- If necessary, repeat the analysis using different ROI sizes and locations, as well as slice thicknesses, scan protocols and reconstruction kernels.

Suitable Phantoms

- QRM-10103 Cone-Beam Phantom, Expert
- QRM-10120 Cone-Beam Phantom, Basic
- QRM-10131 Dental CBCT QA Phantom, Expert
- QRM-10130 Dental CBCT QA Phantom, Basic
- QRM-10136 Breast CT QA Phantom, Expert

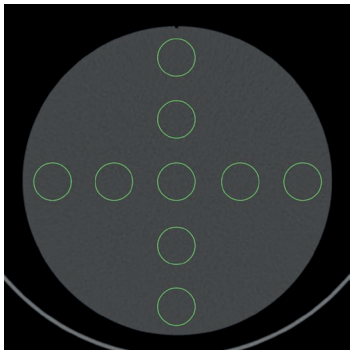


Figure 8: CT Image showing homogeneity analysis

6. Geometric Accuracy

In radiotherapy or interventional applications, treatments are based on the accuracy of the patient's anatomy obtained by CBCT, i.e. sensitively depend on the exact localization/spatial positions of the internal structures. The treatment isocenter and the imaging isocenter must match each other, and the reproducibility of the spatial positioning of movable internal structures should be checked regularly. Different parameters such as reconstruction algorithms and spatial resolution affect the geometric accuracy. While monthly geometric accuracy tests are recommended in Radiotherapy Units, annual controls are sufficient for dental and interventional CBCT.

Geometric accuracy evaluation with QRM Phantoms

- Use thin slices (approx. 1 mm thickness) and a suitable reconstruction kernel, e.g. a regularly/frequently used scan protocol and high-resolution kernel.
- Measure the dimensions of the holes at each position using a ruler or equivalent tool of your DICOM Viewer to determine a distortion of the hole matrix. An overestimation of hole size depends on scanner settings and beam hardening in the image. The holes may appear larger than they are. Measure the positions of the holes within the regular hole grid to uncover a distortion of the hole matrix in the periphery.

Suitable Phantoms

- QRM-10103 Cone-Beam Phantom, Expert
- QRM-10120 Cone-Beam Phantom, Basic

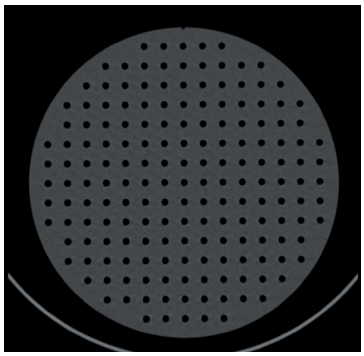


Figure 9: CT Image showing image distortion analysis

3 CT Dose Index (CTDI)

The Computed Tomography Dose Index ($CTDI_{100}$) indicates the air-kerma readings in mGy across a 100 mm long calibrated pencil-shaped ionization chamber in CT systems. The $CTDI_{100}$ is defined as the integral of the dose profile (z axis) along a line perpendicular to the tomographic plane (x-y plane).

$$CTDI_{100} = \frac{1}{N \cdot T} \int_{-50\ mm}^{+50\ mm} D(z)\, dz$$

D (z): dose profile along the axis perpendicular to the axial/scan plane (z-direction)
T: slice thickness
N: number of slices acquired per single axial rotation

Although the $CTDI_{100}$ does not represent the patient dose and does not yield information about the radiation attenuation within real tissue it is a important parameter for dose comparison between different CT systems and scan protocols. By default cylindrical PMMA phantoms (usually with a diameter of 32 cm/16 cm for the adult body/head section and 16 cm/10 cm for the pediatric body/head section) are used in clinical routine during the acceptance and constancy tests. However, for a more realistic investigation of the radiation dose , semi-anthropomorphic water-equivalent phantoms that exhibit the same x-ray attenuation properties as liquid water in for tube voltages of 80 kV to 140 kV can also be a useful tool for dose evaluation.

Since the chamber has a homogeneous response along its axis, it not only integrates over radiation within the slice, but also detects scattered radiation along its entire length. The weighted CTDI ($CTDI_{weight}$) more reflects the real absorption of x-rays in the examined body and is an established metric to quantify the dose. It is the weighted sum of the central and peripheral CTDI values:

$$CTDI_{100,weight} = \frac{1}{3} CTDI_{100,center} + \frac{2}{3} CTDI_{100,periphery}$$

where $CTDI_{100,c}$ is the CTDI measured in the center hole of the phantom and $CTDI_{100,p}$ is the average value of the four peripheral CTDIs.
Even though the CTDI characterizes the particular CT system it is not a direct measure of the real patient dose as it depends on scan range, patient size and anatomy etc.

Therefore, the dose-length-product (DLP) is commonly considered to estimate the patient dose resulting from a complete examination:

$$DLP = \Sigma_i\, CDTI_{100,weight,i} \cdot N_i \cdot N_{rot,i} \cdot T_i \cdot C_i$$

The summation with index i accounts for all scanning sequences of the examination. N_i indicates the number of simultaneously acquired slices, $N_{rot,i}$ is the number of sequential scans or spiral rotations and T_i is the collimation (slice thickness) in examination i. C_i is the mAs value of the i^{th} scan. Typically, the standard value of 100 mAs is used for the determination of the DLP.

The volumetric CTDI ($CTDI_{vol}$) is another important metric used for dose evaluations particularly for helical CT scans which takes the pitch factor into account. Each CT scan protocol indicates the $CTDI_{vol}$ as part of the scan report. It is an important indicator for comparing patient scans and protocols during clinical routine.
It is calculated from the ratio of weighted CTDI over pitch:

$$CTDI_{volume} = CTDI_{100,weight} / pitch$$

CTDI and DLP assessment with QRM Phantoms

- After placing the phantom on the couch, it should be positioned accurately at the isocenter by using the internal alignment lasers.
- Insert the 100 mm pencil-shaped ion chamber in the phantom (using the adapter) and connect it to the calibrated electrometer.
- Acquire the values first of from the central position and then from the peripheral positions (top, right, bottom, left).
- Scanning parameters (kVp, mAs, collimation, pitch etc.) are recorded for each scan protocol.
- During the measurement of one position, all other bore holes must be filled with plugs

Suitable Phantoms

- QRM-40100 CTDI CTwater Phantom
- QRM-40101 Oval CTDI CTwater Phantom
- QRM-40104 Thorax Dosimetry Phantom
- QRM-40105 Abdomen Dosimetry Phantom
- QRM-20120 Pediatric Thorax Phantom, newborn
- QRM-20137 Pediatric Thorax Phantom, 1 year
- QRM-20138 Pediatric Thorax Phantom, 3 years
- QRM-20121 Pediatric Thorax Phantom, 6 years
- QRM-20123 Pediatric Thorax Phantom, 12 years
- QRM-20139 Pediatric Thorax Phantom, 15 years
- QRM-20125 Pediatric Abdomen Phantom, newborn
- QRM-20140 Pediatric Abdomen Phantom, 1 year
- QRM-20141 Pediatric Abdomen Phantom, 3 years
- QRM-20142 Pediatric Abdomen Phantom, 6 years
- QRM-20143 Pediatric Abdomen Phantom, 12 years
- QRM-20144 Pediatric Abdomen Phantom, 15 years

4 Multi-Energy and Photon Counting CT

Multi-Energy CT (MECT)

The linear attenuation coefficient and, hence, the CT value depends on the material's effective atomic number, effective X-ray energy (poly-energetic spectrum) and mass density. Therefore, in conventional CT imaging materials with different atomic numbers might appear with similar CT values at a particular tube voltage making material differentiation difficult. As the linear attenuation coefficient depends on the X-ray energy, this limitation can be circumvented by measuring at different tube voltages, i.e., different (poly-energetic) spectra and the materials can be separated. This approach is called Dual- or Multi-energy imaging. The most common example is the separation of Calcium and Iodine, but recently also other materials and contrast media gain importance (e.g. Gd, Fe, etc.).

The basic principle behind dual- or multi-energy imaging is the energy-dependence of the linear attenuation coefficient: the dominant interactions between X-ray radiation and tissue occurring at the energies used in diagnostic imaging are Compton scattering and Photoelectric absorption. As the tube voltage, and hence, the X-ray energy increases, the cross-section of photoelectric effect decreases, while the Compton interaction gains importance.

In clinical practice, there are different technical approaches to multi-energy imaging invlolving photon counting detectors , dual-layer CT, kV-switching or dual-source CT. All these material-specific imaging techniques provide valuable information regarding the contribution, concentration, and chemical composition of the materials in specific tissues and enables separate visualization these materials.

Photon-Counting CT

Among all established approaches of Multi- or Dual-energy imaging, the new generation of CT scanners using photo-counting detectors is particularly promising.
X-ray detectors used in conventional CTs integrate over the energy of all radiation deposited in the detector, i.e. the signal comprises all photons absorbed in the detector. By contrast, X-rays absorbed in photon counting detectors are directly converted into electrical signals and hence, counted individually. Especially, it is possible to detect the energy of the individually detected photons as the amplitude of the electrical signal in the detector scales with the energy of the incident photon. This new approach offers multiple benefits with respect to conventional detectors.
Due to the way the new detectors are constructed, PC detectors exhibit smaller pixels compared to conventional detectors leading to enhanced spatial resolution. Further, as PC detectors are not susceptible to electronic noise, high contrast-to-noise ratio, low dose and reduced image artifacts can be achieved. The main advantage of PC technology is that the energy of the individual X-ray photons can be detected. Therefore, photons can be sorted according to their energy. Selecting appropriate energy thresholds possibly yields the separation of multiple contrast media or elements (e.g. Ca, I, Fe, Gd) with a single scan. Being challenging at the moment, this new technique paves the way to various new/future applications. For material decomposition, the CT values of different materials at low tube voltage (e.g. 80 kV) is plotted against the CT value at high tube voltage (e.g. 140 kV). With this method, materials can be differentiated from each other according to their position on the graph.
Modern dual- or multi-energy or PC post-processing protocols offer the possibility to create so-called virtual non-contrast images or iodine/calcium maps which automatically disentangle tissues rich in Iodine (or other contrast agents) or calcium. These images can be combined to color-maps with different colors indicating the presence of a specific element in the tissue (calcium, iodine or other contrast agents).

Multi-energy CT postprocessing and material decomposition with QRM Phantoms

- Position the phantom accurately at the isocenter by using the internal alignment lasers.
- Measure the phantom with standard scan protocols and evaluate different post-processing techniques and algorithms regarding the correct material separation, concentration etc.
- If necessary, repeat the measurement with varied positions of the test rods (possible for QRM-10150, QRM-10147 and QRM-10139).

Suitable Phantoms

- QRM-10150 Multi-Energy QA Phantom
- QRM-10147 Spectral CT Phantom II
- QRM-10139 Spectral CT Phantom
- QRM-10123 Dual Energy CT Phantom, V5
- QRM-10107 Dual Energy CT Phantom, V2

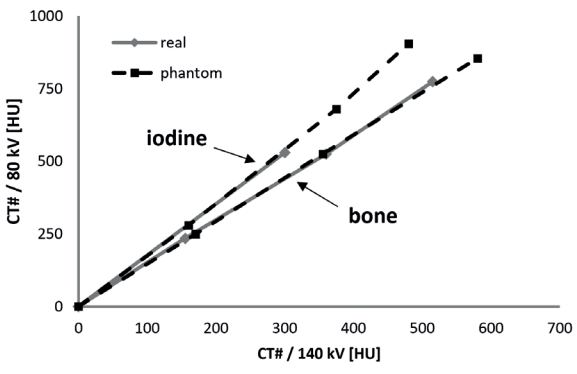


Figure 10: CT# of Iodine and CaHA-enriched material

5 CT Value Calibration in RT Planning Systems

CT Value calibration in Radiotherapy Treatment Planning Systems

In radiotherapy, it is crucial to deliver the prescribed dose to the target volume with high precision. Therefore, different algorithms are used in treatment planning systems (TPSs), which take elemental composition, stopping power, and electron density relative to water (ρ_e^w) into account when determining tumor and OAR (organs at risk) dose distribution. In order to perform pixel-by-pixel heterogeneity correction based on the estimated attenuation within the non-uniform tissue, an electron density map is generated corresponding to the CT values for all clinically used photon energies. Since the predominant tissue-photon interaction at typical X-ray energies in CT is Compton scattering and Photoelectric effect, the linear attenuation coefficient is considered to be proportional to the relative electron density of the tissues. The electron densities are calculated from the mass density and the elemental composition of each material. By scanning a phantom containing different tissue-equivalent materials with known electron densities on the tomography device, the CT values of each tissue-equivalent material can be determined and an electron density map (calibration curve) is created, which visualizes the relation between the relative electron densities and the corresponding CT values. Treatment planning systems use the linear fitting equation for heterogeneity corrections. The linear fitting equation is adapted to the CT models and acquisition parameters such as tube voltage, mAs, reconstruction algorithms, filters etc.

Suitable Phantoms

- QRM-90114 Comprehensive Electron Density Phantom
- QRM-90110 Electron Density Phantom, D100

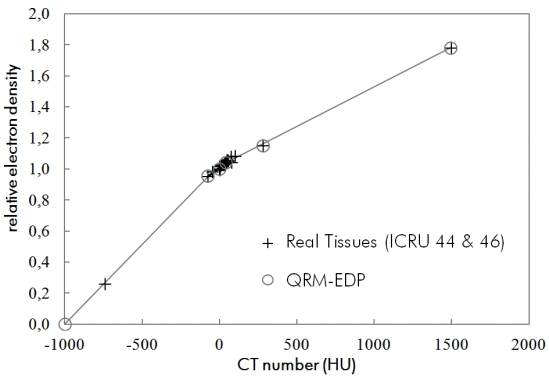


Figure 11: Relative Electron Density vs CT# (at 120 kV)

Electron Density Calibration Curve assessment with QRM Phantoms

- Although the tissue-equivalent electron density rods can be arranged in various ways depending on the research purpose, it is recommended to be place them according to the manufacturer's recommendation to minimize artifacts and achieve the best possible results.
- It is possible to compare results obtained in body geometry (phantom body and head insert) and using the head insert as stand-alone phantom.
- Place the phantom on the couch and insert the tissue-equivalent electron density rods according to the manufacturer's recommendation.
- Position the phantom accurately at the isocenter by using the internal alignment lasers.
- Acquire CT images within 3 different slices, one at centrally within the phantom and two slightly off-centered (approx. ± 1 cm). To have a good SNR, a 5+ mm slice thickness should be appropriate
- Place ROIs withing the tissue-equivalent inserts and evaluate the mean CT values. Use ROIs smaller than the inserts' diameter in order to exclude cupping/edge effects (in particular in the highly absorbing bone insert).
- Create a calibration curve using the measured CT values (average of three slices) and the corresponding electron density relative to water (ρ_e^w) provided by the manufacturer.

6 Bone Mineral Density

Osteoporosis is a condition that develops more rapidly in women after menopause than in men and increases fracture risk due to bone mineral loss and decrease in bone structure. Dual energy X-ray absorptiometry (DXA, DEXA) is the most often used method to measure bone mineral density. The method has gained acceptance for screening osteoporosis patients. DXA systems are widely used in hospitals and medical practices.
Quantitative CT (qCT) is beside DXA a standard method in bone densitometry. Due to its ability to acquire 3-dimensional images and its higher image quality, bone mineral density assessment is more accurate than DXA.

Calcium hydroxyapatite (CaHA) is the main component of bone. Because of its relatively high effective atomic number (Z_{eff}) and high mass density CaHA has a high linear attenuation coefficient compared to soft tissues. This can be exploited to measure the bone mineral density by methods such as dual energy X-ray absorptiometry (DXA) or quantitative CT (qCT).

Dual energy absorptiometry is a planar X-ray technique to assess bone mineral density. Considering the X-ray attenuation using two different poly-energetic spectra allows to separate the attenuation by bone from that of soft tissue.

While DXA gives information about the area bone mineral density (aBMD) in g CaHA/cm^2 , the volumetric density (vBMD) in g CaHA/cm^3 can be acquired with qCT. Further, as 3D cross-sectional images are obtained, this approach facilitates to evaluate the vBMD of cortical bone and trabecular bone separately.

In BMD examinations, there are specific criteria determined by the World Health Organization to assess the BMD which are the T score and the Z score. The T score is the standard deviation of the individual's BMD value to the average BMD of the young population of the same sex. This quantity serves for the diagnosis of osteoporosis: a value above -1 implicates a BMD in the normal range, a T score between -1 to -2.5 indicates osteopenia (low BMD) and a value below -2.5 implies osteoporosis. The Z score is the standard deviation relative to the average BMD of the same age group providing a comparison to the average population of the same age.

As the accuracy of the analysis, for both, DXA systems and CT systems, is very prone to beam hardening effects, amount of adipose tissue around the investigated area, the exact spectrum used, etc.
Hence, the actual value of the BMD can drastically vary between systems. In addition, different manufacturers use their own calibration methods which also lead to varying BMD values.
Therefore, it is crucial to calibrate the CT or DXA systems using phantoms containing well-defined BMDs.

Different body regions are commonly used for BMD analysis. Regions of highest interest are the lumbar spine, and the distal forearm. Other areas of interest are the Hip-region, the femoral neck and the distal legs (heel).

There are different phantoms available satisfying the requirements of DXA or qCT (or both) for the different body regions mentioned above. In qCT, one can create a calibration between CT values and BMD using specifically designed phantoms. DXA systems can be calibrated by phantoms specially designed for DXA applications. Furthermore, there are phantoms that are suitable for a cross-calibration between different DXA systems (e.g. for multi-center studies).

In addition to the assessment of Bone Mineral Density in female or male population, it is also possible to evaluate BMD of small animals using Micro-CT systems. For more information, please read the Micro-CT Section.

Bone Mineral Density assessment with QRM Phantoms in qCT

- Position the phantom accurately on the couch in the desired configuration.
- Acquire CT images in the region(s) of interest (e.g. in the different vertebrae of the ESP). To have a good SNR, use at least 5 mm slice thickness.
- Place several ROIs within the bone inserts (spongious/trabecular part) and measure the mean CT values. Importantly, use ROIs smaller than the inserts' diameter in order to exclude edge effects.
- Create a calibration curve (linear fit) using the measured CT values and the corresponding electron vBMD values provided by the manufacturer.
- This calibration curve can be used to determine the vBMD value of any bone under investigation.

Figure 12: Cross-calibration example (ESP with BDC Phantom)

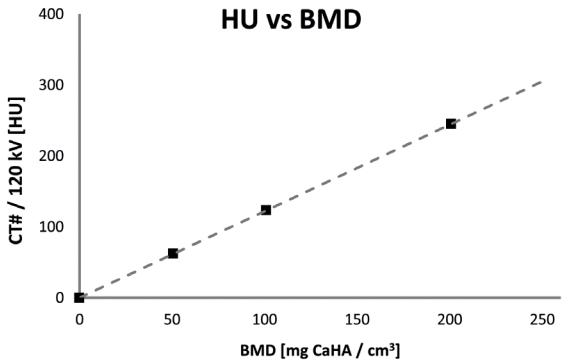


Figure 13: Example for BMD calibration curve

Bone Mineral Density assessment with QRM Phantoms in DXA

- Position the phantom accurately on the couch in the desired configuration.
- Acquire the aBMD using a standard examination.
- Compare the value of the a BMD to the one provided by the phantom manufacturer

Suitable Phantoms for DXA and qCT

- QRM-50100: European Spine Phantom (ESP)

Suitable Phantoms for DXA

- QRM-50100 European Spine Phantom (ESP)
- QRM-50110 DXA Spine QA Phantom, 3 HA
- QRM-50146 DXA Femur Phantom
- QRM-50139 JIS Forearm Phantom
- QRM-50143 JIS Heel Phantom
- QRM-50140 JIS Lumbar Spine Phantom
- QRM-50144 JIS Uniform Lumbar Phantom

Suitable Phantoms for qCT

- QRM-50100 European Spine Phantom (ESP)
- QRM-50111 European Forearm Phantom (EFP)
- QRM-50112 Forearm Phantom (BMF)
- QRM-50113 HIP Calibration Phantom, V2
- QRM-50131 HIP-QC120 Phantom
- QRM-50121 Spine-QC120 Phantom
- QRM-50137 Knee-QC Phantom
- QRM-50115 Bone Density Calibration Phantom, 3 H200
- QRM-50118 Bone Density Calibration Phantom, 3 H300
- QRM-50120 Bone Density Calibration Phantom, 3 H400
- QRM-50116 Bone Density Calibration Phantom, 3 H500
- QRM-50117 Bone Density Calibration Phantom, 3 H600
- QRM-50119 Bone Density Calibration Phantom, 3 H700
- QRM-50124 Bone Density Calibration Phantom, 6 H200
- QRM-50125 Bone Density Calibration Phantom, 6 H300
- QRM-50129 Bone Density Calibration Phantom, 6 H400
- QRM-50126 Bone Density Calibration Phantom, 6 H500
- QRM-50127 Bone Density Calibration Phantom, 6 H600
- QRM-50128 Bone Density Calibration Phantom, 6 H700

7 Pre-clinical Imaging (Micro-CT)

Micro-CT enables non-destructive material testing (NDT) at industrial sites and visualization and analysis of the internal structures of small animals (mouse, rat, etc.) for preclinical research purposes. Depending on the desired application, there are various systems offering a wide range of possible sample size and resolution. Nowadays spatial resolution in the sub-micrometer range can be reached.

In clinical CT scanners the gantry with X-ray tube and detector rotates around the patient. In micro CT, there are also other setups that can be found. E.g. the sample can be directly rotated around its axis (z-axis) between a fixed X-ray tube and detector (mostly for industrial applications). By varying the distances between sample, detector and X-ray tube the magnification can be adjusted. While rotating the sample, multiple projections at different angles are obtained and reconstructed in order to get a 3D image of the sample.

Compared to clinical CT, the X-ray beam originates from a very small focal spot (microfocus) enabling the superior spatial resolution.

Micro-CT systems are usually no medical devices and are not calibrated to the Hounsfield scale. There are not strictly pre-defined and calibrated scan protocols as in clinical systems, but rather various scan geometries as the user can adjust multiple settings (tube voltage, tube current, focal spot, distance between detector, sample and X-ray tube, acquisition time per projection, number of projections, etc.) in order to get the best imaging result. Unlike in clinical devices, there are no prescribed daily, weekly or monthly standard quality assurance test procedures. Especially, due to the specific scan geometry (Cone-beam) and detector type (usually flat-panel detectors are used), Micro-CTs are very prone to image artifacts.

Therefore, QA test procedures are essential to ensure constant quality and comparability of results obtained at a specific system or at several systems.
In principle, the image quality parameters/metrics and calibration procedures recommended for Micro-CT systems are the same as for clinical CT devices and can be assessed using high-tech phantoms specially developed for Micro-CT.
There are various phantoms available addressing different tasks: spatial resolution (directly by line patterns or indirectly by evaluation of the MTF), low-contrast resolution (CNR), signal-to-noise ratio (SNR), uniformity, grey value accuracy (linearity), geometric accuracy, in-vivo or in-vitro bone mineral density calibration and dose evaluation (CTDI and DLP).

Assessment with QRM Phantoms
The assessment methods explained above in the clinical CT part of this document can be applied to Micro-CT phantoms as well. Therefore, please read the corresponding section for clinical CT for more details of these different measurement tasks. Instead of quantifying the CT values in Hounsfield units, use the grey value scale of your Micro-CT.

Suitable Phantoms for Micro-CT
Spatial resolution:
- QRM-70109 Micro-CT Slice Sensitivity Phantom
- QRM-70113 Micro-CT Bar Pattern Phantom, air
- QRM-70114 Micro-CT Bar Pattern Phantom, resin
- QRM-70119 Micro-CT Bar Pattern Phantom, NANO
- QRM-70100 Micro-CT Wire Phantom air, D20, 10 micron
- QRM-70101 Micro-CT Wire Phantom air, D20, 25 micron
- QRM-70102 Micro-CT Wire Phantom air, D32, 10 micron
- QRM-70103 Micro-CT Wire Phantom air, D32, 25 micron
- QRM-70117 Micro-CT Wire Phantom air, D20, 3 micron
- QRM-70118 Micro-CT Wire Phantom air, D32, 3 micron
- QRM-70130 Micro-CT Wire Phantom resin, D32, 25 micron
- QRM-70131 Micro-CT Wire Phantom resin, D32, 10 micron
- QRM-70133 Micro-CT Wire Phantom resin, D20, 25 micron

Grey value accuracy (linearity):
- QRM-70105 Micro-CT Contrast Scale Phantom

Low-contrast resolution:
- QRM-70108 Micro-CT Low Contrast Phantom, V1
- QRM-70124 Micro-CT Low Contrast Phantom, V2

Signal-to-noise ratio, Uniformity (homogeneity):
- QRM-70110 Micro-CT Water Phantom, D60
- QRM-70111 Micro-CT Water Phantom, D32
- QRM-70112 Micro-CT Water Phantom, D20

Geometric accuracy (distortion) and post-processing techniques:
- QRM-70104 Micro-CT Multi Disk Phantom (Defrise)
- QRM-70137 Micro-CT Mouse Phantom

Bone mineral density calibration:
- QRM-70107 Micro-CT HA Phantom D32
- QRM-70129 Micro-CT HA Phantom D25
- QRM-70126 Micro-CT HA Phantom D20
- QRM-70127 Micro-CT HA Phantom D10
- QRM-70128 Micro-CT HA Phantom D4.5
- QRM-70134 Micro-CT HA set of 5 single rods

Dose phantoms (CTDI and DLP):
- QRM-70106 Micro-CT Dose Phantom

Product Index

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PTW is a global market leader for dosimetry and quality control solutions in radiation medicine, serving the needs of medical radiation experts in more than 160 countries worldwide. Starting with the famous Hammer dosemeter in 1922, the German manufacturer is the pioneer in medical radiation measurement, known for its unparalleled quality and precision.

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