# METROTOM 800

## CT scanner (CT)


## Operating Instructions

**(Translation of the original operating instructions)**

ZEISS

## Read this first!

– Please read these Operating Instructions before starting up the CT scanner.

– For your own safety, please keep all relevant accompanying documents always ready at hand.



### Contact

Carl Zeiss

Unternehmensbereich

Industrielle Messtechnik GmbH

D-73446 Oberkochen

METROTOM 800
Operating Instructions
2011-05-02
61211-8030202

# Table of contents

## Chapter 9 Maintenance and care



## Chapter 10 Shutdown and disposal

# Preface

## Information about these Operating Instructions

The CT scanner (CT) METROTOM 800 is described in these Operating Instructions. The Operating Instructions contain important information regarding safe and proper use of the CT scanner. These Operating Instructions address operators and users of the CT scanner.

# Configuration of safety instructions

Safety instructions indicate a personal health hazard. We distinguish three different levels: Danger, warning and caution. All three safety instructions are marked by the same warning symbol. The designation of the safety instruction is shown beside the symbol. The safety instructions used are described below.

## Configuration of a safety instruction

A safety instruction may have the following components:

- Warning symbol and designation of the safety instruction (signal word): Danger, warning or caution.
- Source and course of the danger
- Consequences for the user due to non-observance of the safety instruction
- Required measures to be taken by the user to avoid possible consequences
- A measure may cause an intermediate result.
- At the end of the measure, a final result may be caused.

## Personal health hazard

**⚠ DANGER**

**A »danger« indicates an imminent risk to life and limb.**
Non-observance of this safety instruction when the described risk occurs causes death or serious injuries.
*Example*: Electric shock due to high electric voltage.

**⚠ WARNING**

**A »warning« indicates a possible risk to life and limb.**
Non-observance of this safety instruction when the described risk occurs may cause death or serious injuries.
*Example*: Risk of severe crushing of the body caused by heavy loads.

**⚠ CAUTION**

**A »caution« indicates a personal health hazard.**
Non-observance of this safety instruction when the described risk occurs may cause slight to moderate injuries.
*Example*: Risk of minor crushing of the limbs caused by small loads.

## Risk of material damage

If there is no personal health hazard, but the CT system or components may be damaged, then the following note is given.

**This symbol refers to possible damage to the CT system.**
Non-observance of this safety instruction when the event occurs may cause damage to the CT or one of its components.
*Example*: Collision between the workpiece and the X-ray tube.

# Marking elements

The texts may be displayed differently in this document. Examples and the meaning of the representation type are described below:

| Example | Meaning |
|---|---|
| *not* | Words to be emphasized are represented in *italics*.<br>The italicized print is sometimes used to mark a subheading, e.g. *Type of measurement:* |
| *Main switch* | Any reference to operator's controls in the text is highlighted typographically. |
| **Tolerance** field | Designation of subdomains in software windows. |
| **Cancel** | Marking of buttons |
| RETURN | Keys of the keyboard are represented as small capitals. |
| "InstallShield Wizard completed" | Software messages |
| **File → Open** | Representation of menu items |
| `Code` | Source code |
| *…\Calypso\opt\om\protform* | File and directories |
| **CALYPSO** | Product name |
| **ZEISS** | Company name |
| **CAUTION! The measuring table must be clean.** | Safety instruction embedded in the text. |
| **[1]** | Representation of position numbers in texts |

# Chapter 1

# Introduction

**This chapter contains:**

# General specifications

## Standard equipment

The standard version of the CT scanner METROTOM 800 comprises the following components:

- CT scanner (CT)
- Control unit
- User computer
- Evaluation computer
- Software, e.g. CALYPSO
- Documentation
- Qualification test piece
- Filter

## CE marking

### EC declaration of conformity as defined by the Machinery Directive 2006/42/EC Annex IIA

We hereby declare that by its design and construction and version we placed on the market, the machinery named below complies with the requirements set out in the EC Directive 2006/42/EC and in the additional EC directives listed below. Should modifications be made on the machinery which have not been agreed by us, this declaration will no longer be valid.

| Designation of the machinery: | CT scanner |
|---|---|
| Machine type: | METROTOM 800 |
| Additional EC directives: | EMC directive (2004/108/EC) |
| Harmonized standards applied, in particular: | – EN 60204-1<br>– EN 61326-1 Annex 2, class A<br>– EN 61010-1<br>– EN ISO 12100-1/-2 |
| National standards: | – DIN 54113-1/-2 |

The product carries the CE marking on its type plate.


# Standards and regulations

The CT is designed, manufactured and tested according to the following standards and regulations:

## Regulations

– BGV A1 (VBG 1)

  Accident prevention regulations - principles of prevention

– BGV A3 (VBG 4)

  Accident prevention regulations - electrical systems and equipment

## Standards

– DIN/VDE 0100

  Erection of power installations, with rated voltages up to 1000 V

– EN 61010 part 1

  Safety requirements for electrical equipment for measurement, control and laboratory use

– EN 60204 part 1

  Safety of machinery. Electrical equipment of machines

– EN ISO 12100, part 1

  Safety of machinery - Basic terminology, methodology

– EN ISO 12100, part 2

  Safety of machinery - Technical principals

– EN 61326

  EMC – interference immunity; annex A, interference emission, class A

– CAN/CSA-C22.2 No. 61010-1-04

  Safety requirements for Electrical Equipment for measurement, control and laboratory use.

– UL 61010-1, Second Edition:

  Standard for Electrical Equipment for Laboratory Use.

– DIN 54113-1

Non-destructive testing – Radiation protection rules for the technical application of X-ray equipment up to 1 MV - part 1: General technical safety requirements

– DIN 54113-2

  Non-destructive testing – Radiation protection rules for the technical application of X-ray equipment up to 1 MV - part 2: General technical safety requirements and testing for the manufacture, installation and operation

# License agreement

| | |
|---|---|
| 1 | »License Agreement For Open Source Computer Vision Library<br>Copyright (C) 2000-2008, Intel Corporation, all rights reserved.<br>Copyright (C) 2008-2009, Willow Garage Inc., all rights reserved.<br>Third party copyrights are property of their respective owners.<br>Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met: Redistribution of source code must retain the above copyright notice, this list of conditions and the following disclaimer.<br>Redistribution in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.<br>The name of the copyright holders may not be used to endorse or promote products derived from this software without specific prior written permission.<br>This software is provided by the copyright holders and contributors “as is” and any express or implied warranties, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose are disclaimed. In no event shall the Intel Corporation or contributors be liable for any direct, indirect, incidental, special, exemplary, or consequential damages (including, but not limited to, procurement of substitute goods or services; loss of use, data, or profits; or business interruption) however caused and on any theory of liability, whether in contract, strict liability, or tort (including negligence or otherwise) arising in any way out of the use of this software, even if advised of the possibility of such damage.« |
| 2 | METROTOM OS uses the FreeImage open source image library. See http://freeimage.sourceforge.net for details.<br>FreeImage is used under the 'FreeImage Public License' (FIPL), version 1.0. |

# Warranty

## Notes

- The specifications and statements in the German Operating Instructions are prevalent and binding for translations into other languages.
- All rights pertaining to changes in the CT scanner and its options, the software packages and the pertaining documents reserved.
- All rights reserved, especially in cases of granting a patent or registering a utility model.

The warranty does not cover the following:

- incidentals
- wearing parts.

## Exclusion of warranty

The manufacturer cannot be held liable.....

- for actions contrary to the instructions given in this manual,
- if the CT scanner version delivered by us was changed,
- if maintenance work is not carried out by personnel specially trained at ZEISS,
- if measures for care are not taken by the operator or user according to the specified measures,
- if original spare parts are not used for maintenance and repair work,
- if the necessary maintenance work and measures for care are not carried out according to the technical documentation.

Any information regarding maintenance work and measures for care, incidentals and wearing parts are specified in separate publications.

Chapter 2

# Safety

**This chapter contains:**

# Intended use

The CT scanner (CT) is exclusively intended for the nondestructive testing of objects that are not alive. The check is carried out by means of X-ray radiation.

Any other use or any use other than the intended use is considered as improper use.

The CT is built in accordance with state of the art standards and recognized safety rules. Nevertheless, its use may constitute a risk to life and limb of the user or third parties. Furthermore, damage to the CT system and other material property may be caused.

The CT may only be operated if it is in perfect condition. It is required that the CT is serviced and maintained correctly. Any alterations to the CT which affect the safety must be eliminated immediately.

Proper use includes the strict observance of the Operating Instructions.

## Reasonably foreseeable misuse

These Operating Instructions must not be infringed.

**⚠ WARNING**

**X-ray radiation.**

Life-threatening radiation with fatal consequences.

a) Never measure living objects.

**NOTICE**

Safe operation during the service life of the system is only guaranteed if the CT scanner is operated according to these Operating Instructions.

## Warranty

Carl Zeiss cannot be held liable for damage to the CT and other material property as well as for bodily injury if these result from infringements of these Operating Instructions.

# Safe operation of the CT system

## Information about this chapter

The points to be observed to guarantee safe operation of the CT scanner (CT) are mentioned in the following.

– Read this section carefully before starting the operation of the CT.

– Please observe all relevant information to guarantee safe operation.

## General conditions

### Important manuals

You must read the following manuals to guarantee safe operation of the CT system:

– complete documentation of the CT system, e.g. Operating Instructions

– accident prevention regulations applicable in the country of destination

– recognized technical rules for safe and professional working.

### Contractual provisions

Installation, connection to the power supply, inspection and start-up must be carried out according to the stipulated conditions.

### Approval of Carl Zeiss

In cases in which no agreements have been concluded, you must obtain prior approval from the company Carl Zeiss, e.g. when relocating the CT.

## Information on exposure to radiation

### X-ray ordinance

The METROTOM CT scanner fulfills the conditions of annex 2, paragraph 3 of the German X-ray ordinance (RöV); thus, it complies with the properties of a fully protected device. This means: It is not necessary to monitor the outside area of the radiation protection enclosure. Working time on the METROTOM does not need to be limited.

According to the German X-ray ordinance, the local dose rate must not exceed 1 µSv/h at a distance of 0.1 m from the surface of the radiation protection enclosure. With the METROTOM, it is ensured that this limiting value is not exceeded if the distance is 0.05 m.

The X-ray ordinance is only applicable in Germany. In other countries, other regulations apply.

### Comparison values of exposure to radiation

| Type of exposure | Equivalent dose | Remark |
|---|---|---|
| METROTOM (outside area) | 1 mSv/a | 2000 hours exposure duration |
| Thoracic exposure | approx. 0.1 mSv per radiograph | |
| CT screening | 5 mSv per screening | Several screenings are generally needed. |
| Deep X-ray therapy | 1 Sv per irradiation | Several irradiations are generally needed. |
| Exposure to radiation of aircrew | 3 mSv/a (world, averaged)<br>6 mSv/a (northern hemisphere) | 1000 hours exposure duration |
| Natural exposure to radiation | 2.5 mSv/a | Germany |
| Civilizatory exposure to radiation | 2.5 mSv/a | Germany |

# Requirements for the operator

## Requirements for the operation of a CT system

Special conditions apply to the operation of a CT system; these must be complied with.

### Germany

The following specifications refer to the operation of X-ray devices in the Federal Republic of Germany. In other countries, corresponding regulations apply which must be observed by the operator.

**NOTICE**

According to § 3 of the German X-ray ordinance (RöV), operation of the METROTOM is subject to licensing.

The following measures must be taken by the operator to obtain an operating license:

- After installation, the METROTOM must be checked by an independent expert for the technical inspection of X-ray devices.
- A radiation protection officer must be called.
- An application for authorization must be filed at the supervisory authority in good time before starting operation. The application for authorization includes ...

- ... the result of the review by experts
- … data relating to the radiation protection officer - personal data, proof of technical qualification, order document, etc.
- ... data relating to the radiation protection association - personal data of the radiation protection supervisor.

In connection with the licensing notice, the supervisory authority is allowed to issue additional requirements for operation.

**Five years**

According to §18 of the German X-ray ordinance (RöV), the METROTOM must be subjected again to a review by experts after a maximum period of five years (recurrent tests).

Usually, the responsible supervisory authority in the individual states is the Trade Supervisory Office, the Occupational Safety and Health Administration or the regional board.

### Other countries

In other countries, the national regulations regarding X-ray protection must be observed.

## Requirements for working with the CT system

The operator must ensure the following:

- The installation site requirements must be met.
- The user has been properly instructed regarding handling and operation of the CT.
- The operator must complete these Operating Instructions with regard to the existing national accident prevention and environmental protection regulations.
- The user must receive operating instructions for working with the CT which are based on the Operating Instructions. The operating instructions must be suitable for all local and operating conditions and available in the language spoken by the operating personnel. The operating instructions must always be available within easy reach of the CT.
- The user must know and observe the safety instructions.
- Maintenance work and work on electrical equipment must be carried out only by competent specialists.
- The Operating Instructions must be read and used by every person entrusted with work on the system.

# Defining a competent specialist

A competent specialist is a person who reliably performs the required work and who is able to recognize and avoid possible risks.

The following conditions apply for performing a task:

- The competent specialist has been authorized by the person responsible for the safety of the device to perform the required tasks.
- The competent specialist must have relevant training and experience.
- The competent specialist must have been instructed in the use of this device.
- The competent specialist must be familiar with the relevant standards, regulations, accident prevention regulations and present operating conditions.

**Work to be carried out by competent specialists**

- Installation of the CT system
- Maintenance work on the CT system
- Work on the electrical equipment, e.g. control unit
- Preparation of the measurement

## Requirements for safe use

In order to ensure safe operation of the CT scanner (CT), certain requirements must be met.

Observe the following:

- Observe the generally recognized accident prevention regulations and safety instructions.
- Operate the CT only with the protective devices provided for that purpose.
  - Do not remove any covers, protective equipment or warning signs.
- Use only power cords and connectors which are in perfect condition.
- The connection must be a permanent connection or a plug connection according to EN 60309.
- A perfect protective ground connection is required.
- Observe the maximum permissible workpiece weight.

**No warranty claims**

The manufacturer of the machine cannot be held liable for any damage caused by unauthorized interventions in the X-ray system. In case of unauthorized manipulations, all warranty claims against the manufacturer and supplier as well as the validity of the EC declaration of conformity are void.

**Documentation**

Correct operation of the CT is essential for a safe measuring run. It is assumed that you are familiar with the documents included in the scope of delivery.

– Ensure that the Operating Instructions for the CT are always available within easy reach of the CT.
– Ensure that the report of the review by experts is always available within easy reach of the CT.

## Danger areas of the CT

| Danger area | Danger | Measure |
|---|---|---|
| Positioning system | – Risk of crushing during travel movements in X, Y, Z.<br>– Risk of crushing during lifting and lowering movements | No parts of the body must be inside the radiation protection enclosure during travel movements.<br>– Do not reach head and hands into the inside during travel movements.<br>– Observe the applicable national accident prevention regulations.<br>– During visual checks, keep a sufficient distance.<br>– During maintenance work, disconnect the CT from the power supply and secure against switch-on. |
| rotary table | Risk of injury during rotary movements | See »Positioning system« |
| Control cabinet | Voltage - risk of death | The CT must not be operated while the control cabinet is open. |

## Basic safety instructions

### X-ray beams

**⚠ WARNING**

**Risk of death by X-ray radiation in the radiation protection enclosure. X-ray radiation is generated in the X-ray tube.**
Irreparable health damage with fatal consequences.

a) Operate the CT only with all safety devices mounted.
b) Switch off the X-ray tube before opening the loading door.
c) Do not perform any program modifications and do not install your own software on the computers.
The functioning of the computers and the CT may be disturbed.
d) Never step into the interior of the radiation protection enclosure.

### Electric voltage in the control cabinet

**⚠ WARNING**

**Voltage - risk of death. Electric voltage is applied to the control unit.**

There is a risk of electric shocks.

Any work on the control unit must be carried out only by an electrical engineer. The cover of the control unit may only be removed if the CT is out of operation. The following measures must be taken:

a) Switch the drives and the control unit off.

b) Remove the power plug.

### Structural alterations

**⚠ WARNING**

**Risk of death by X-ray radiation due to structural alterations.**

Alterations cause malfunctions and can present life-threatening consequences. Furthermore, the operating license may become void due to structural alterations.

a) Never dismantle or alter the CT.

b) Never dismantle or alter any components of the CT.

### Beryllium

**⚠ WARNING**

**Risk of diseases with fatal consequences due to inhaling released beryllium particles.**

Beryllium particles deposit in the respiratory system and may cause cancer.

▹ There is a beryllium plate between the outlet window of the X-ray tube and the collimator plate. The surface of this plate must not be damaged under any circumstances.

a) Never unscrew the collimator plate.

### Smoke, smells and noises

**⚠ WARNING**

**Risk of death due to possible damage to the CT system caused by smoke, unusual smells and unusual noises.**

It is extremely dangerous to continue operation of the CT system.

a) Immediately switch off the CT system.

b) Call a ZEISS service engineer.

### Foreign substances

**⚠ WARNING**

**Risk of death due to electric shocks and fire caused by foreign substances in the radiation protection enclosure or in components of the CT system.**

Foreign substances may lead to malfunctions and serious damage to the CT thus causing unforeseeable risks for the user.

a) Never operate the CT if a foreign substance or a liquid has penetrated into one of its components.

b) Call a ZEISS service engineer.

### Damage to cables

**⚠ WARNING**

**Risk of death due to electric shock and fire caused by damaged cables.**

Live cables may cause electric shocks and burning when touched. They may also cause fires.

a) Always handle power cables and other cables carefully.

b) Never put any objects onto the cables.

c) Never step on any cables.

d) Do not bend the cables.

e) If cables are damaged, you must call a ZEISS service engineer.

### Behavior in case of fire

**⚠ WARNING**

**Risk of death due to unforeseeable events caused by fires in the proximity of the CT system.**

A safe operation is not guaranteed in case of fire outbreaks.

a) Immediately switch off the CT system completely.

b) Call a ZEISS service engineer.

### Loading door

**⚠ CAUTION**

**Risk of crushing when closing the loading door**
Body, arms, hands and fingers might get crushed.

a) Make sure before closing the loading door of the radiation protection enclosure that nobody can reach into the door opening or lean against the opening towards the interior of the radiation protection enclosure.

## General measures of precaution

### Temperature in the control cabinet

**Extremely increased temperatures in the control cabinet may lead to malfunctions.**
In an extreme case, a fire may be caused.

a) Make sure that the required environmental conditions are complied with. ➢ *Ambient conditions [⇨ 4-3]*

b) Make sure that sufficient fresh air is supplied for the fan.

### Temperature of the workpiece

**Problems if there are large temperature differences between workpiece and X-ray chamber.**
Never check workpieces which do not have the temperature of the interior of the radiation protection enclosure. *Ambient conditions [ 4-3]*

a) Measure the temperature of the workpiece.

### Cleanliness in the X-ray chamber

**The interior space of the radiation protection enclosure must be clean and dust-free.**
The following must be observed:

a) Do not leave the loading door open.

b) Open the loading door only for setting up the workpiece and cleaning.

c) Set up only clean and dust-free workpieces on the rotary table.

d) Clean the workpieces outside the radiation protection enclosure.

# Safety of the CT system

## Safety symbols on the CT system

The following symbols are attached to the CT scanner (CT) and/or the control unit.

| | |
|---|---|
|  | Danger symbol for electric voltage:<br>This symbol indicates a risk to life and limb. |
|  | Danger symbol:<br>This symbol indicates a danger to people and the CT as well as to its components. |
|  | Danger symbol for X-ray radiation.<br>X-ray radiation is dangerous to health. Text beside the symbol: *„Do Not Insert Any Part of the Body When System is Energized X-Ray Hazard."*<br>Close the door of the radiation protection enclosure before switching the X-ray tube on. |

**NOTICE**

Any work on the control must be carried out only by an electrical engineer.

## Safety devices

### Safety circuits

Two independent safety circuits are used in the CT system to avoid exposure to radiation. It is only possible to switch on the X-ray radiation when the loading door is completely closed. However, utmost care is needed when working with X-ray radiation.

- Observe all safety instructions.

### EMERGENCY STOP buttons

The CT is equipped with two EMERGENCY STOP buttons, one on the radiation protection enclosure and one on the control cabinet. Pressing the EMERGENCY STOP button initiates the following measures:

– The X-ray tube is switched off.
– The release of all positioning movements is blocked.
– All drives are switched off.

**High load of the CT components when pressing EMERGENCY STOP buttons**

The CT components are subject to increased wear.

a) Press the EMERGENCY STOP button only in cases of emergency.
b) Switch the X-ray tube off using the operating software.

**No warranty claim**

In case of damage due to frequent and unnecessary activation of the EMERGENCY STOP buttons, all warranty claims are void.

**NOTICE**

The EMERGENCY STOP button is locked once it has been pressed. It can be unlocked by turning it slightly.

More information on the measures to be taken after an EMERGENCY STOP is given in other sections. ➢ *See [⇨ 8-4]*

### Drives OFF

The positioning movements of the positioning system are monitored. If the forces exceed a certain value, the drives are switched off. Voltage is still applied to the electric components.

# Chapter 3

# Description

**This chapter contains:**

# Structure

## Views and main components

### Views

*Radiation protection enclosure, front*

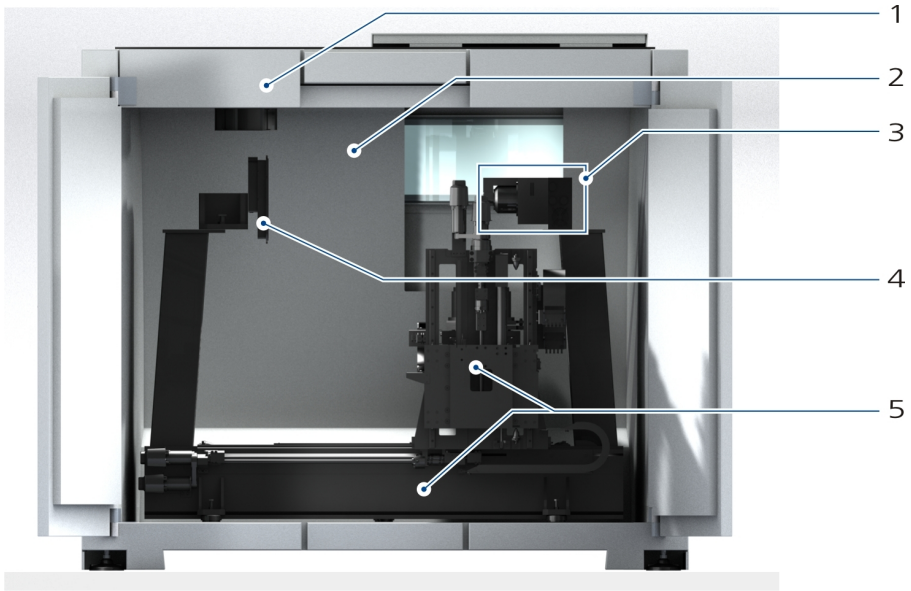
The radiation protection enclosure is made of special polymer concrete. This material absorbs X-rays. The parts mounted to the radiation protection enclosure are lead-coated. Example: Loading door and doors on the rear.

*Radiation protection enclosure, rear*

**NOTICE**

The doors at the rear may only be opened by a ZEISS service engineer.

## Main components




*Main components, open rear of the METROTOM 800*

1 Radiation protection enclosure
2 X-ray chamber with components, e.g. X-ray system, positioning system
3 X-ray system

4 Detector
5 Positioning system

In addition:

– Control cabinet
– Computers (user computer and evaluation computer)

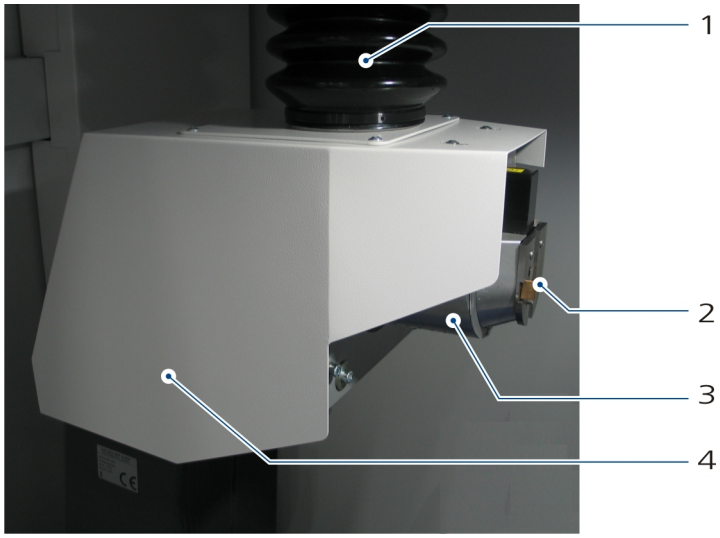
## Loading door

The radiation protection enclosure is equipped with a loading door with a leaded window. The loading door must be opened and closed manually.


1 Loading door with a leaded window
2 Handle for manual opening and closing of the loading door

# Components and function

## X-ray tube




*X-ray tube*

1 Hose for heat dissipation
2 Collimator plate with filter holder
3 X-ray tube (consisting of electron source and target)
4 High voltage generator

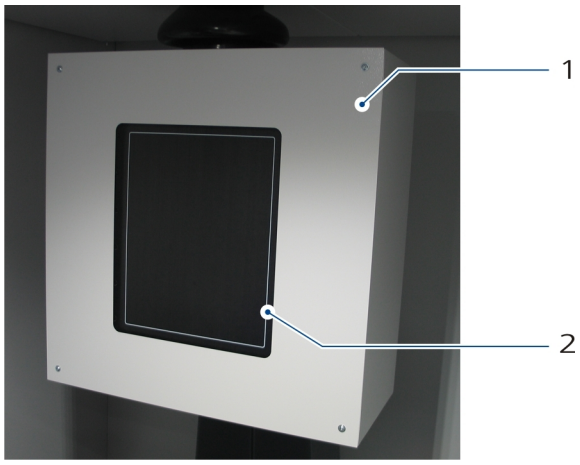
An electron beam is produced in the X-ray tube with high voltage. This beam is highly focused and hits a target element. The contact point of the electrons is called »focal spot«; in the CT system, it represents the X-ray source.

**NOTICE**

The focal spot is also called »focus«. ➤ *See [⇨ Annex 43]*

The radiation emerges in the form of a conical beam through the collimator diaphragm towards the X-ray detector.

## X-ray detector




*Detector*

1 Housing of the X-ray detector
2 Marking of the active image region

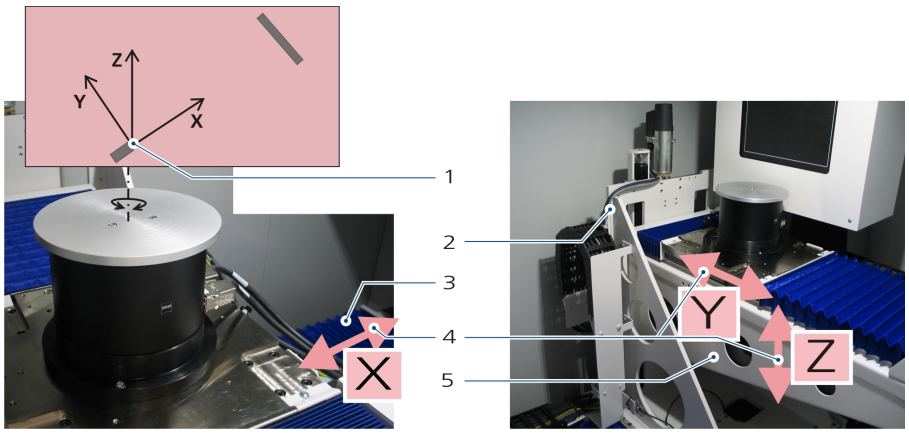
In the X-ray detector, the X-ray beams are converted into visible light in a sensitive layer. This light is again converted into electric charge by the photodiodes located behind it.

**Gray scale value**

The charge is converted into a voltage signal which corresponds to a gray scale value on the monitor of the user computer. The gray scale value can be set, among other things, by means of the detector gain and the integration time.

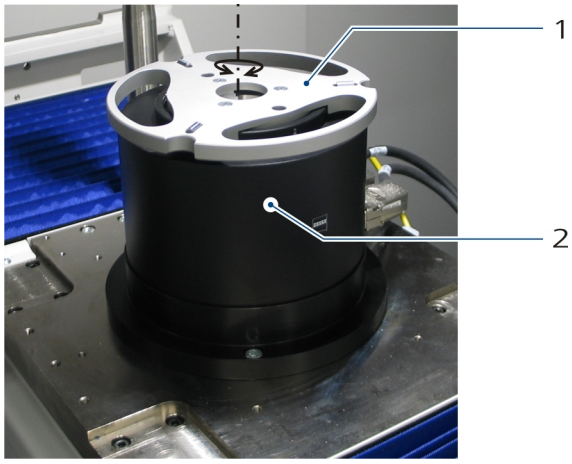
## Positioning system

The positioning system consists of several components: X guide beam, Y slide, Z carrier and a rotary table.




*Positioning system, travel movements*

1 Coordinate system; origin near the X-ray tube
2 Z carrier
3 Bellows cover on X guide beam
4 Travel movements in X, Y, and Z direction
5 Y slide




*rotary table*

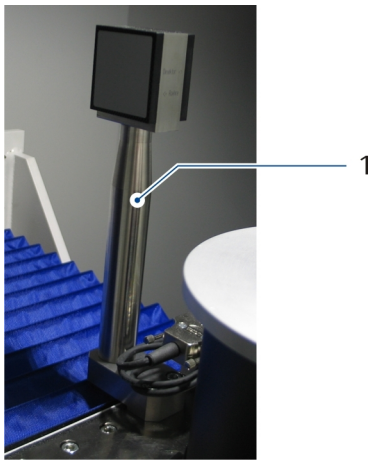
1 Mounting plate for workpiece pallet
2 rotary table

All four components can be moved. The X, Y, and Z axes are the travel axes; the fourth axis is the rotary table axis.

The magnification of the workpiece to be imaged is determined by the position of the Z carrier on the X guide beam. The workpiece is rotated by the rotary table.

# Further components

## Test piece for focal spot control




*(1) Test piece for focal spot control*

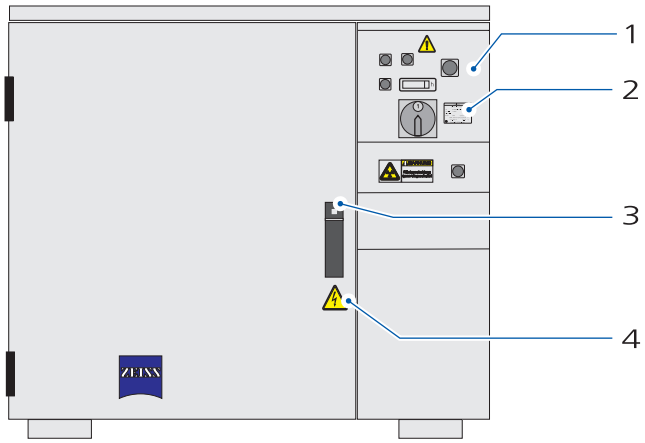
The test piece for focal spot control is firmly mounted on the Y slide. It is used for geometric qualification and CT measurements. ➢*Info [⇨ 7-32]*

# Control unit

## Control cabinet

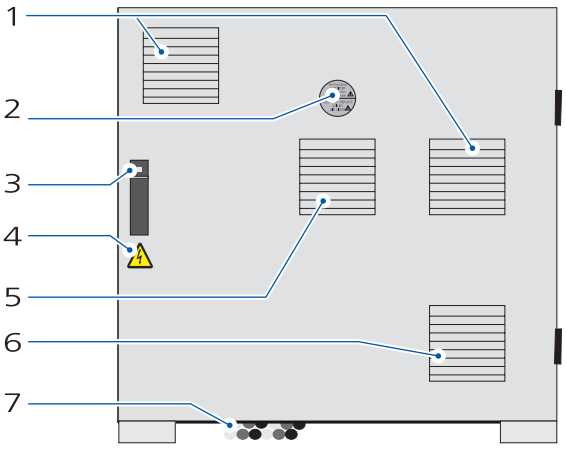
The CT is equipped with a MCC 800 control cabinet. It contains a 32 bit control unit C99. The housing of the control cabinet has protection class IP54.

### MCC 800




*Control cabinet MCC800, front*

1 Operator's controls
2 Type plate for control cabinet
3 Door latch
4 Warning symbol for electric voltage: The control cabinet must be opened only by an electrical engineer.



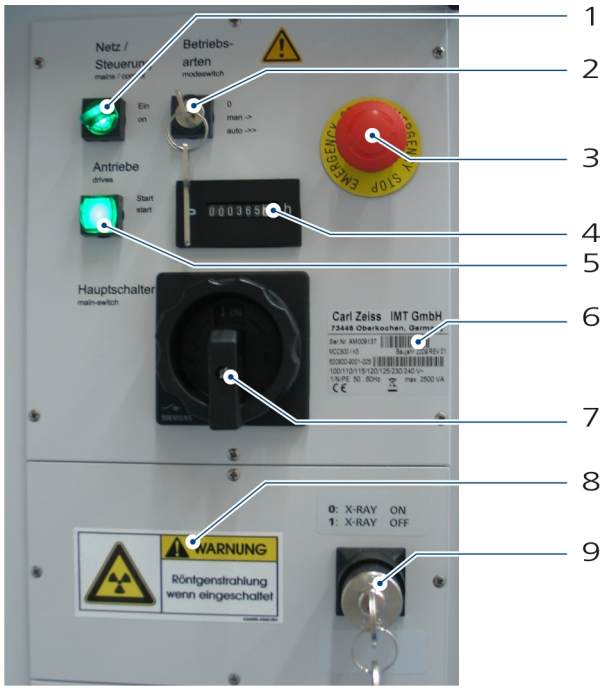

*Control cabinet MCC800, rear*

1 Air filter
2 Warning label: Replace or clean dirty air filter!

3 Door latch
4 Warning symbol for electric voltage: The control cabinet must be opened only by an electrical engineer.
5 Fan and air filter; air outlet
6 Fan and air filter; air intake
7 Power supply of the control cabinet and cables leading to the CT.

**NOTICE**
ZEISS USB sticks (backup or boot sticks) may only be used for ZEISS control units and computers by ZEISS service technicians. We do not assume any warranty and liability for damages due to other use.

## Operator's controls on the MCC800 control cabinet

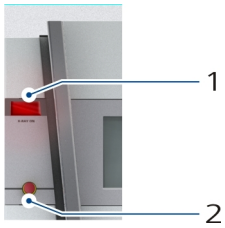



*Control cabinet MCC800 - operator's controls*

1 Rotary switch for control unit; with indicator lamp
2 Key switch for operating mode selection
3 EMERGENCY STOP button; push-and-turn switch
4 Working-hour meter
5 Push-button for drives; with indicator lamp
6 Type plate
7 Main switch for power supply
8 Warning sign for X-ray radiation
9 Key switch for X-ray radiation

| Operator's control | | Function |
|---|---|---|
| *Main switch* |  | When the main switch is turned *ON*, the power supply is connected. |
| *Rotary switch* for the control unit | | The rotary switch is used to switch the control on. If it is in the *ON* position, the control unit is switched on. The integrated indicator lamp lights up. |
| *Push button* for drives | | The push-button is used to switch the drives on. When the drives are switched on, the integrated indicator lamp lights up. |
| *Key switch* for operating mode selection | | The key switch is used to determine the operating mode in which the measurements are to be carried out.<br>– 0: No travel movement possible.<br>– MAN: Manual mode – Set-up mode.<br>– AUTO: Automatic mode – Series measurement mode. |
| *Key switch* for X-ray tube | | The key switch is used to switch the X-ray tube on and off. |
| *EMERGENCY STOP button* |  | The EMERGENCY STOP button is used to switch off the X-ray radiation and to stop all dangerous movements. .<br>It engages when pressed. The *EMERGENCY STOP button* must be released before reactivating the X-ray radiation and the drives. Release the button by turning it counterclockwise. Afterward, the drives can be switched on again. For further information ➢ *EMERGENCY STOP [⇨ 2-11]* |
| Working-hour meter | | The working-hour meter counts the number of hours during which the drives remain activated. |

# Operator's controls on the radiation protection enclosure




*Operator's controls on the radiation protection enclosure*

1 Warning lamp for X-ray radiation
2 EMERGENCY STOP button

| Operator's control | Function |
|---|---|
| *Warning lamp* for X-ray radiation | A warning lamp for X-ray radiation is located at the top left, next to the loading door.<br>The warning lamp is lit when the X-ray tube is on. X-ray beams are then exiting from the X-ray tube in the radiation protection enclosure. |
| *EMERGENCY STOP button* | The EMERGENCY STOP button is a push-button. When you press the button, the X-ray tube is switched off. All travel movements of the positioning system are stopped. For more information see ➤*page [⇨ 2-11]*. |

# Chapter 4

# Technical data

**This chapter contains:**

# CT scanner

## General data

### CT with radiation protection enclosure

| Dimensions | | | |
|---|---|---|---|
| | Width | [mm] | 2200 |
| | Depth | [mm] | 1310 |
| | Height | [mm] | 1960 |
| | A minimum distance must be kept on all sides around the radiation protection enclosure.<br>Laterally: 800 mm, at the rear: 900 mm | | |
| **Measuring range**<br>Vertical installation of the detector (standard) | X-Y plane, diameter | [mm] | 170 |
| | Z | [mm] | 190 |
| **Measuring range**<br>Horizontal installation of the detector | X-Y plane, diameter | [mm] | 200 |
| | Z | [mm] | 140 |
| **Positioning system** | Travel directions | [-] | ±X, ±Y, ±Z |
| | X travel range | [mm] | 700 |
| | Y travel range | [mm] | 270 |
| | Z travel range | [mm] | 270 |
| **Weight** | Radiation protection enclosure, complete (without control cabinet) | [kg] | 5750 |
| **Noise level of the CT** | | [dBA] | <70 |

### Control cabinet

| Dimensions | | | |
|---|---|---|---|
| | Depth | [mm] | 800 |
| | Width | [mm] | 800 |
| | Height | [mm] | 800 |
| | A minimum distance must be kept on all sides around the control cabinet. 800 mm. | | |

### rotary table

| | | | |
|---|---|---|---|
| **Design** | | | Surface-mounted version |
| **Operation position** | | | Vertical |
| **Dimensions** | Faceplate, diameter | [mm] | 170 |
| **Loading capacity** | Workpiece weight, max. | [kg] | 4<br>(incl. workpiece pallet) |

## Characteristic values

| | |
|---|---|
| Overvoltage category | III |
| Pollution degree | 2 |
| Protection class | 1 |

## Connection data

### Electric data

| | |
|---|---|
| Line voltage | 100/110/115/120/125/230/240 V~ (±10 %) |
| Type of current | 1/N/PE |
| Frequency | 50 to 60 Hz (± 3.5 %) |
| Power consumption | max. 2500 VA |
| Fuse | C 25A |

## Ambient conditions

The following conditions must be fulfilled to guarantee perfect operation of the CT scanner.

| | |
|---|---|
| Ambient temperature for operational readiness | +15 °C to +35 °C |
| Relative humidity | 40 % to 70 % |
| Room temperature for measuring operation | 20 ±2 °C |

# X-ray system

## X-ray tube

| | | |
|---|---|---|
| Voltage | [kV] | 20 - 130 |
| Current | [µA] | 1- 300 |
| Target power, max. | [W] | 39 |
| Target material | [-] | Tungsten |
| Focal spot size, min. | [µm] | 5 |

## X-ray detector

| | | |
|---|---|---|
| Distance: tube - detector | [mm] | 800 |
| Geometric magnification (2D), max. | [-] | 45 |
| Geometric magnification (3D), max. | [-] | 40<br>For workpieces with 4 mm diameter |
| Resolution | [-] | Upright installation position: 1536 × 1920 pixels<br>Transverse installation position: 1920 × 1536 pixels |
| Pixel size | [µm] | 127 × 127 |

# Chapter 5

# Transport and installation

**This chapter contains:**

# Notes

## Separate document

**NOTICE**

You received the “Installation Instructions” brochure prior to the delivery of the CT system. This document informs you about all measures to be taken for transport and installation. In the following, we will refer to some of the most important points contained in this document.

# Transport

## To be observed on delivery

The CT scanner is delivered disassembled on transport pallets. The individual parts are wrapped in insulated packaging. For overseas transport, the individual parts are packed in shipping containers.

### Requirements regarding the fork-lift truck

A fork-lift truck with sufficient carrying capacity has to be used for transport. The fork-lift truck must be suitable for the weight of the individual transport containers. In order to avoid tilting of the load, the forks must be completely underneath the transport pallets or shipping containers and the fork width must be variable. You will find the weight and dimensions of the individual parts in the “Installation Instructions” brochure.

**NOTICE**

The packing material or the shipping containers must not be damaged. The packaging material may only be removed at the installation site by a ZEISS service engineer.

**Ambient temperature +5°C to +40°C**

The CT scanner and its components must remain in their packaging and be stored in a covered area until the machine is installed. The ambient temperature at the storage area must be between +5°C and +40°C.

## Transport conditions

The transport route from the storage area to the installation site must be selected carefully. It might be necessary to prepare it in order for it to meet the requirements.

**Prerequisites for transport**

Observe the following regarding transport:

- Weight: Is the bearing capacity of the floor along the routes suitable for the weight of the shipping containers and the fork-lift truck?
- Dimensions: Are the height and width of the doorways and routes sufficient for the transport containers and the fork-lift truck?
- Fork-lift truck: Does the fork-lift truck comply with the requirements?

# Installation

## Selecting the installation site

The installation site must meet the following requirements. The following questions must be clarified:

- Is the room height sufficient?
- Is enough space available?
- Is the floor suitable for the weight of the CT and the fork-lift truck?
- How strong are the vibrations at the installation site?

  Disturbing vibrations may, for example, be caused by machines in adjacent rooms or buildings.
- Does the installation site comply with all of the environmental conditions required for perfect operation of the CT?
- Is the installation site free from coarse dirt particles, such as casting sand and metal chips?
- Are there problems with the power supply?

For more information, please refer to the "Installation Instructions" brochure.

## Prerequisites for installation

The following preparations have to be made prior to the installation of the CT by ZEISS service engineers:

- Provision of steel plates.
- Installation of the power supply.
- Adaptation of the CT to room temperature.

You will find the data required for preparation in the "Installation Instructions" brochure.

### Adaptation to room temperature (48 hours)

When installing the CT, the temperature of all CT parts must be stabilized at a minimum temperature of 15°C.

- Store all parts of the CMM in a place having an ambient temperature of at least 15°C at least two days prior to installation.

# Chapter 6

# Start-up

**This chapter contains:**

# Preparation

## Notes

The preparation includes activities that are not necessary to be carried out on a daily or weekly basis. One exception to this is the visual check. The visual check should be part of your daily measuring operation routine.

## Initial start-up

Initial start-up is carried out by a ZEISS service engineer. However, you must familiarize yourself with the preparations required for start-up as well as know and observe the corresponding safety instructions.

– Please also observe the information in chapter »Safety«.

## Connecting the power supply

The power supply must be close to the installation site in order to be able to make the power supply connection to the CT. This must be done before installing the CT.

– Please observe the electric data.

**NOTICE**

For more information on the electrical power supply, please refer to the "Installation Instructions" brochure.

## Visual check and check list

The visual check must be part of the routine work to be carried out during the daily measuring operation. Before switching the CT on, make sure by means of a visual check that the measuring system components do not show any visible damage.

### In case of damage, ...

Start-up of the CT is not allowed in case of damage to the CT.

**1** In this case, protect the CT against switching on.

- Turn off the main switch and lock it with a padlock.
- Turn the key switch for operating mode setting to the OFF position and withdraw the key.

**2** Inform a ZEISS service engineer.

### Housing covers

The CT may only be operated if all CT housing covers are mounted and all doors are closed.

– Mount all housing covers before taking further measures.

### Cable for power supply

The cable must be in perfect condition. It must not be bent nor damaged.

– Ensure that no heavy objects are lying on the cable.

# What you should know!

## Notes

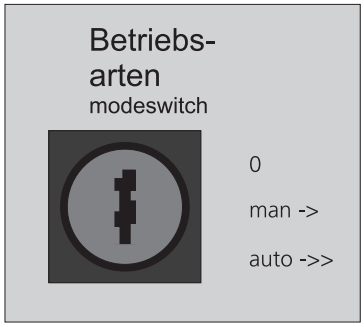
### EMERGENCY STOP buttons

**NOTICE**
The EMERGENCY STOP buttons on the radiation protection enclosure and on the control cabinet must be unlocked.

## Operating modes

### Operating modes for the measuring run

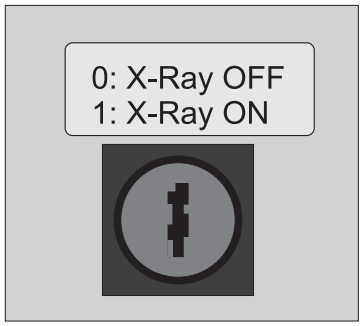
Select the operating mode with the key switch.




| | |
|---|---|
| 0 | The positioning system cannot be moved. |
| MAN | The positioning system moves at reduced speed. |
| AUTO | The positioning system moves at maximum speed. |

### Operating modes for the X-ray tube

There is a separate key switch on the control cabinet for the X-ray tube.




| | |
|---|---|
| 0 (OFF) | The CT system is out of operation. |
| 1 (ON) | The X-ray tube is ready for operation.<br>The tube must be powered up first to enable workpiece radiation. |

## Start-up sequence

Proceed in the following order:

1. Make the settings on the control cabinet.
2. Prepare the CT system on the user computer.

# Starting the CMM

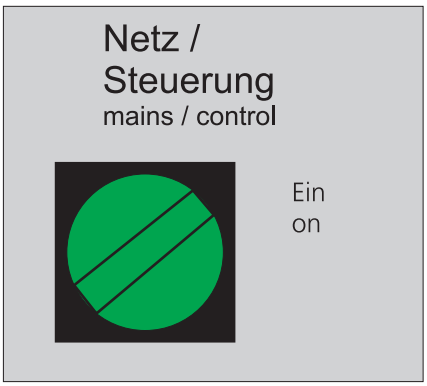
## Settings on the control cabinet

### Cold start

When starting up the CT system for the first time or if the CT system has been switched off for a longer period of time, you must proceed as follows.

**1** Connect the power supply.


- Turn the main switch clockwise to position «1».

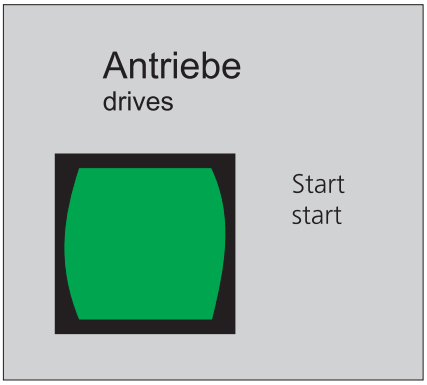



**2** Switch on the control unit.

- Turn the switch to «ON».
- Wait for about 20 seconds until the booting process is completed.

**3** Switch on the drives.

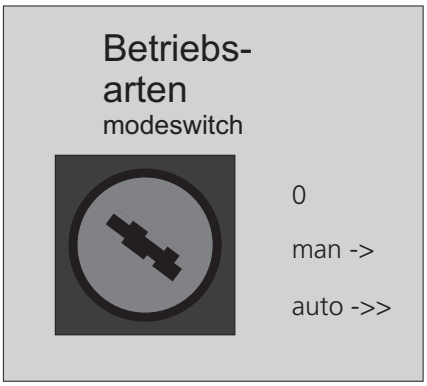
- Press the button.




The integrated lamp lights up to confirm that the drives are switched on.

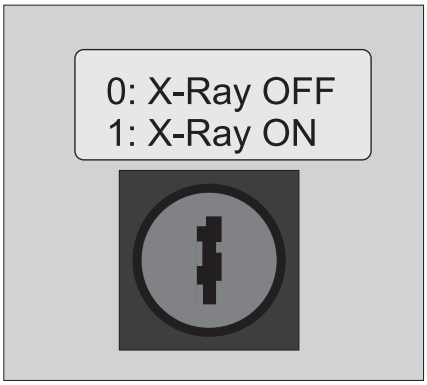
**4** Select the operating mode.

- Turn the key switch to AUTO.




**5** Switch on the X-ray tube (X-Ray).

- Turn the key switch to position «1».




**NOTICE**
Afterwards, you must continue the preparations on the user computer.

# Preparing the CT system on the user computer

## «ct» user account

After powering up the user computer, the user «ct» is logged in automatically. The password is also «ct». This user account has restricted rights under Windows. The user cannot do any modifications on the operating system. The «Administrator» user account, which normally has no password, has the right to do so.

### Define a password for «Administrator».

For reasons of safety, a password should be defined for the user «Administrator».

1 Log off the user «ct» and log in as administrator.

2 Select the »User accounts« category in the Control Panel.

The «User accounts» window appears.

3 Select the Administrator account.

4 Select Create password.

5 Enter a new password and repeat the password.

6 Click Create password.

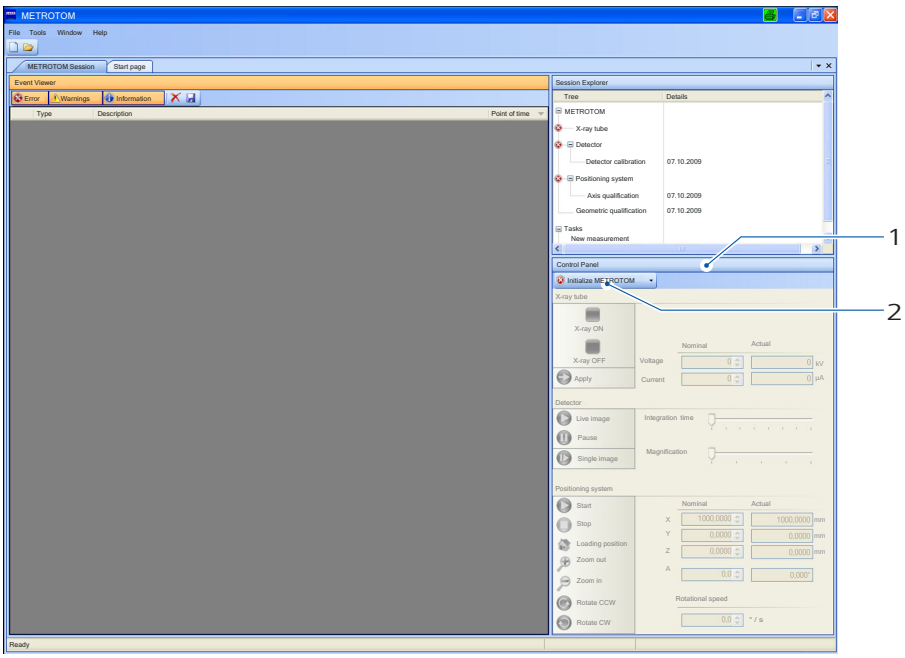
## Initialization of all CT components

### Starting the user software

There is a desktop shortcut for starting the user software (logo with the text METROTOM OS).

– Afterwards, you must continue the preparations on the user computer.

Once the user software has been started, the User Desk is displayed. An initialization must be carried out before you can work in the User Desk.




*User Desk before initialization*

1 Control Panel
2 Button for initialization

At the beginning, all CT components must be initialized. These include:

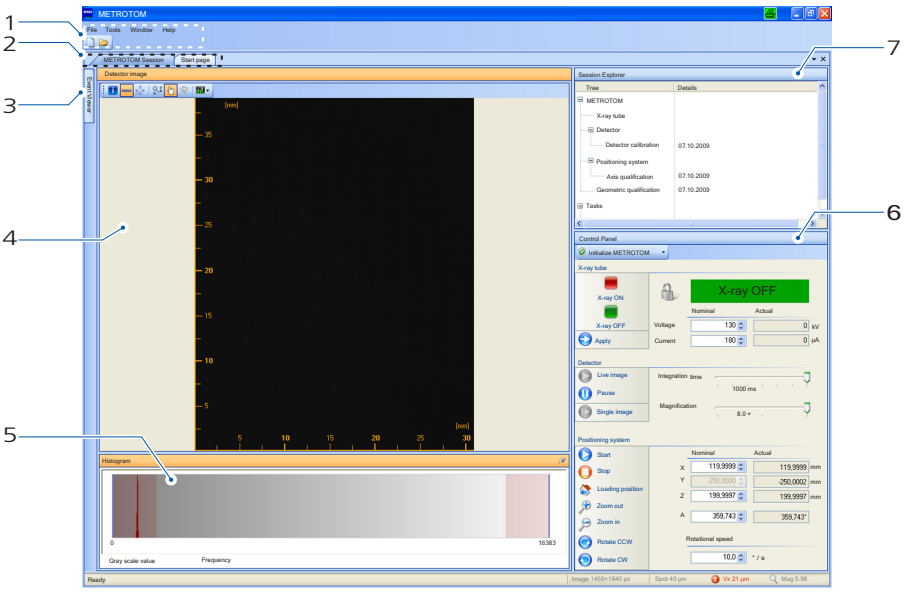
– X-ray tube
– Detector
– Positioning system

## Starting initialization

– For initializing the CT components, click **Initialize METROTOM** in the »Control Panel« window.

  The initialization then runs automatically.

After initialization, the detector image is displayed in the window. The histogram window is displayed below the display window.




*User Desk after initialization*

1 Menu bar and toolbar
2 Tabs; higher level
3 Button for displaying the Event Viewer
4 Display window
5 Histogram window
6 Control Panel
7 Session Explorer

**NOTICE**

The initialization can be repeated during the measuring run. Single CT components can also be initialized.

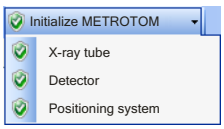
### Abort during initialization

If the initialization has not been performed successfully, the following message will be displayed in the Event Viewer. See ➢ *Event Viewer [⇨ Annex 14]*

Furthermore, you can look for the causes of the initialization failure in the Inspector windows of the »Session Explorer«. See ➢ *Session Explorer [⇨ Annex 13]*

## Initialization of single CT components

For initializing a certain CT component, click the arrow next to the edge of the **Initialize METROTOM** button. A selection window opens and you can select the CT component to be initialized.




### Initialization of the X-ray tube


1 Click the arrow next to the **Initialize METROTOM** button.

A selection field opens.

2 Select **X-ray tube**.

The initialization of the X-ray tube then runs automatically.

3 Warm-up, if required. ➢ *Warm-up [⇨ 7-5]*

The warm-up is always performed until the maximum voltage (130 kV) is reached.

### Initialization of the detector


1 Click the arrow next to the **Initialize METROTOM** button.

A selection field opens.

2 Select **Detector**.

The initialization of the detector then runs automatically.

### Initialization of the positioning system


1 Click the arrow next to the **Initialize METROTOM** button.

A selection field opens.

2 Select Positioning system.

The initialization of the positioning system then runs automatically.

**See also**

- ➢ *Settings for the X-ray tube [⇨ 7-2]*

## Messages during initialization

The initialization processes are logged in the Event Viewer. Errors and warnings can be output for each component.

If an error is output for a certain component, the corresponding component cannot be operated. In case of warnings, however, the corresponding component can still be operated. You can make the Event Viewer appear by using a button. See ➢ *Event Viewer [⇨ Annex 14]*

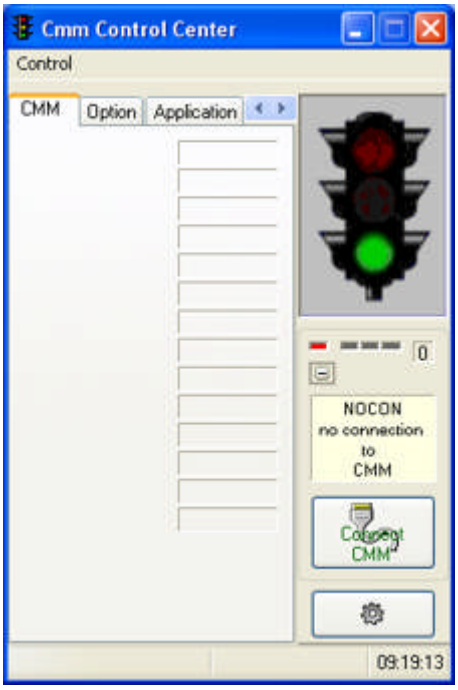
– Observe the measures specified in the ➢ *Messages in the Event Viewer [⇨ Annex 23]*

In some cases, you will have to contact the ZEISS Service.

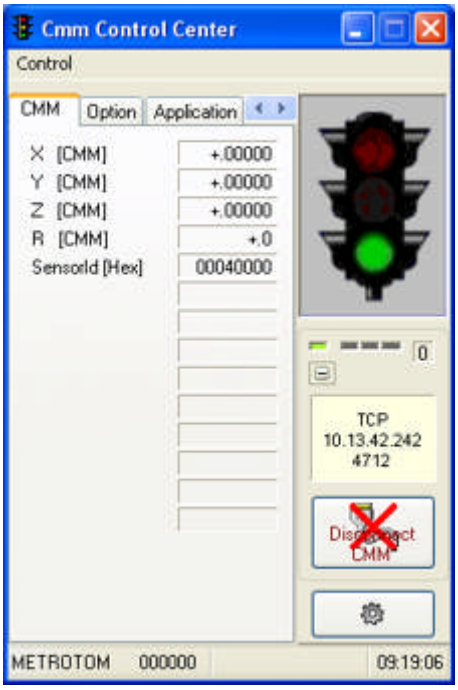
## CMM Control Center

When starting METROTOM OS, the CMM Control Center is started as well. This is indicated in the task bar by the icon shown here. A simple click on the icon opens the window shown below.

During initialization of the positioning system, the CMM Control Center automatically establishes a connection to the control unit. This is a prerequisite for operating the METROTOM. In case of problems with the CMM Control Center, these will be displayed in the Event Viewer.




*CMM Control Center; no connection*




*CMM Control Center; connected*

**See also**

- ➢ *Meldungen in Ereignisanzeige und Meldungsfenstern [⇨ Annex 23]*

# Calibration and qualification

## Detector calibration

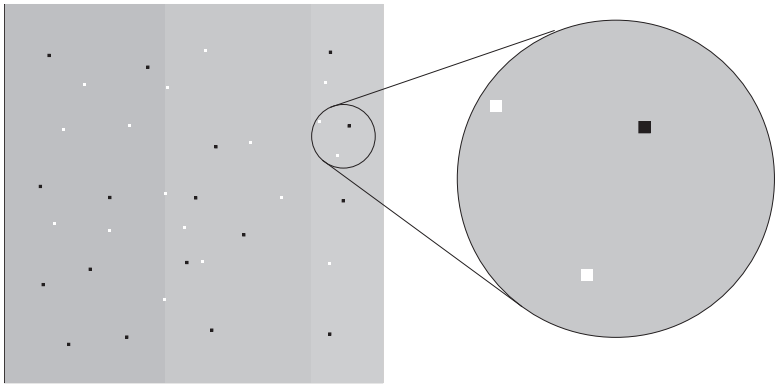
### What you should know!

The detector calibration homogenizes the active detector field. A check is made as to see whether there are any »bad pixels«. Monthly detector calibration is recommended. For this purpose, a measuring run is integrated in the user software.

#### Binning mode

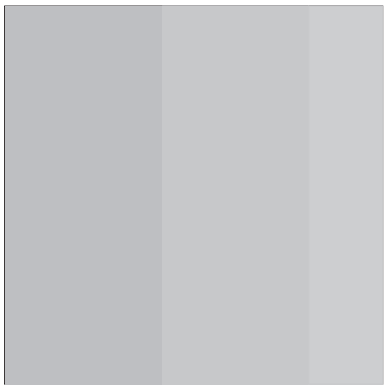
The detector calibration is always carried out in the 1×1 binning mode. If a different binning mode has been selected prior to starting the detector calibration, the 1×1 binning mode will automatically be selected. After the qualification, the original binning mode is automatically restored.

#### Consequences of detector calibration



*Before detector calibration*

Different gray scale values and bad pixels, bright and dark pixels.



*After detector calibration*

The bad pixels are corrected and considered in the reconstruction data. Stripes are visible in the image after the detector calibration. They origi-

nate from the readout electronics of the detector and they are corrected during the reconstruction but not in the preview.

## Procedure for detector calibration

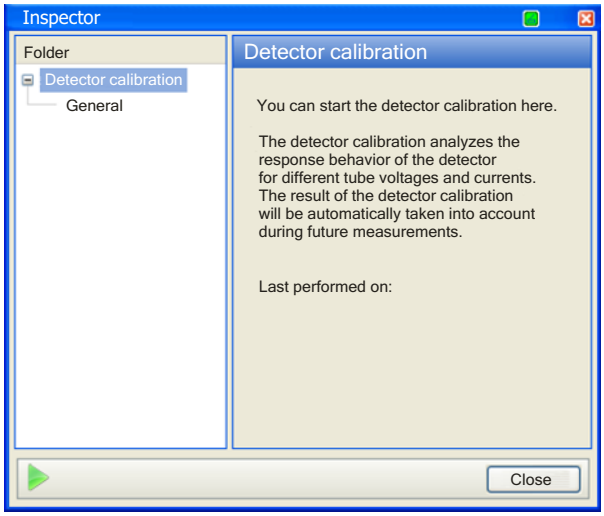
Proceed as follows:

1 Make sure that no filter is used on the X-ray tube.

2 Close the loading door.

3 Double-click **Detector calibration** in the Session Explorer.

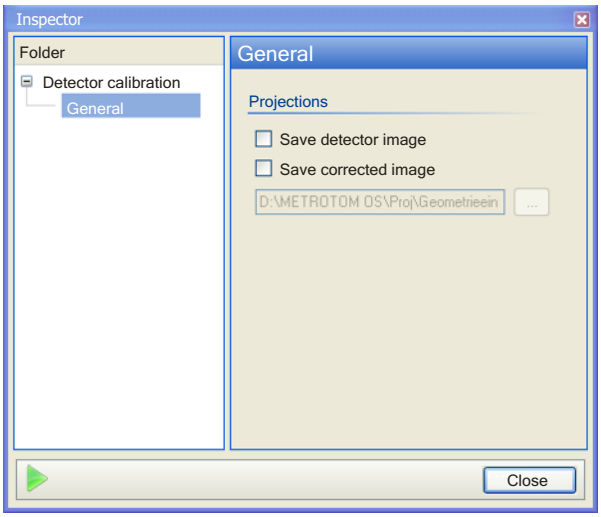
The following window appears:




4 Define under **General** if the calibration images are to be saved.

The saved images may be useful for service operations.

- Select the type of images to be saved: detector images, corrected images or both.
- Select the directory for saving the images.



**5** Click the button shown here to start the calibration.

Once the calibration has been started, homogenization of the detector field begins. This process will take about 25 minutes.

# Geometric qualification

## What you should know!

The qualification function is used to check and align the CT scanner. It should be carried out every week: or more frequently if inaccurate measurements occur at shorter intervals. In the case of interventions in the CT system, you must first carry out a geometric qualification.

A special qualification test piece and a mounting stand are available for the qualification. A measuring run is integrated in the user software.

### Effect on axis qualification

An axis qualification should be performed after a geometric qualification, because the results of the geometric qualification are included in the axis qualification.

### Binning mode

Geometric qualification is performed in the 2×2 binning mode. If a different binning mode has been selected prior to starting the geometric qualification, the correct mode will automatically be activated. After the qualification, the original binning mode is automatically restored. See ➢ *Binning [⇨ Annex 39]*.

### Prerequisites

The preconditions that have to be satisfied before you can start performing the geometric qualification are as follows:

– The entire CT system has reached the working temperature.

– The loading door is closed.

– All components of the CT systems must have been running for minimum two hours.

– A warm-up of the X-ray tube has been performed.

**NOTICE**

No filters must be used. Remove any existing filters prior to starting the qualification.

### Storing the qualification test piece

For storing, observe the following:

– Handle the qualification test piece with care.

– Do not remove the protective housing in any case.

– Do not store it in areas with high humidity.
– Avoid direct exposure to solar radiation.

### Checking the qualification test piece

It is possible to have the qualification test piece checked by ZEISS.

## Procedure for geometric qualification

Proceed in the following order for qualification:

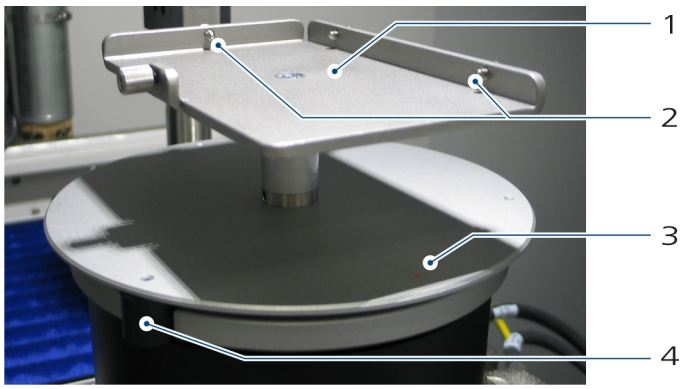
**1** Make sure that no filter is used on the X-ray tube.

**2** Move to the loading position.

**3** Open the loading door.

**4** Place the stand for the qualification test piece on the rotary table plate.

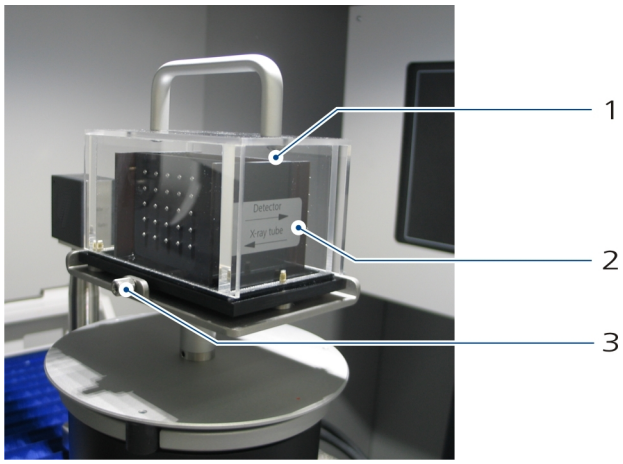
The red mark on the stand must coincide with the red mark on the rotary table.




*Deposit plate for geometric qualification test piece*

1 Deposit plate for qualification test piece
2 Stop for qualification test piece
3 Red mark for correct alignment; there is another red mark on the rotary table
4 Rubber buffer for fixing on the rotary table

**5** Place the qualification test piece on the stand.




*Qualification test piece*

1 Qualification test piece for geometric qualification
2 Label for correct alignment
3 Thumbscrew for fastening the qualification test piece

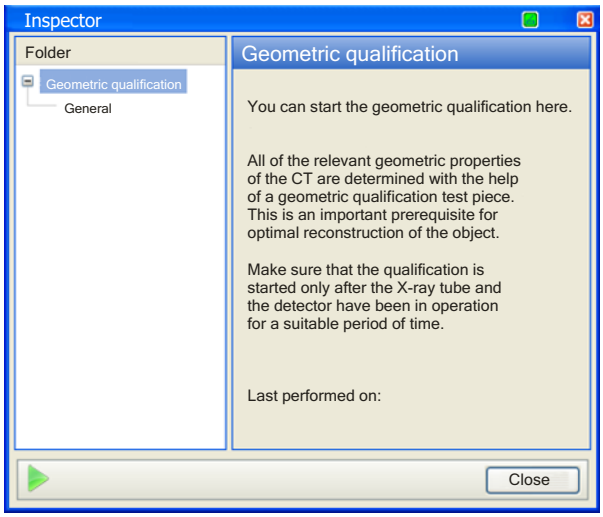
- Pay attention to the label for correct alignment.
- Slightly push to the rear right against the limit stops.

**6** Fasten the qualification test piece by means of the thumbscrew.

**7** Close the loading door.

**8** Double-click **Geometric qualification** in the Session Explorer.

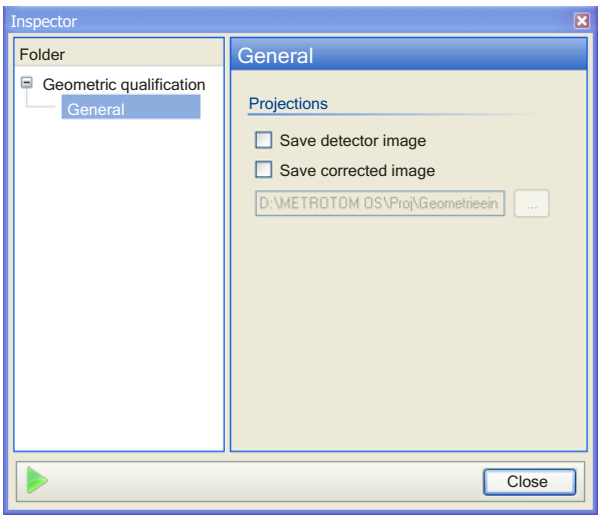
The following window appears:




**9** Define under **General** if the calibration images are to be saved.

The saved images may be useful for service operations.

- Select the type of images to be saved: detector images, corrected images or both.
- Select the directory for saving the images.




**10** Click the button shown here to start the qualification.

The qualification run is performed automatically and takes about five minutes.

**11** Move to the loading position.

**12** Open the loading door.

**13** Loosen the upper thumbscrew and remove the qualification test piece from the stand and deposit it in a safe place.

**14** Remove the stand from the rotary table plate and store it in a safe place.

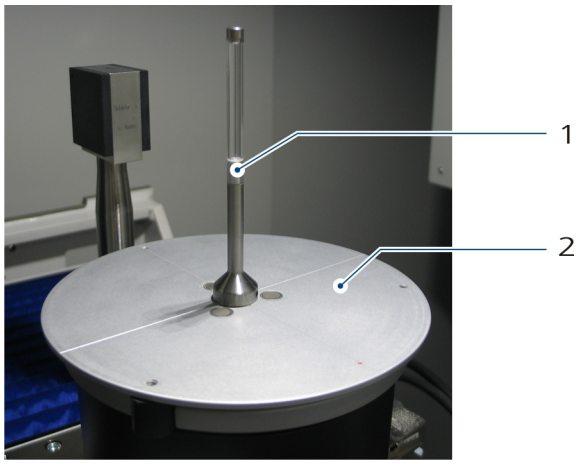
# Axis qualification

## What you should know!

An axis qualification should always be performed after a geometric qualification, because the results of the geometric qualification are included in the axis qualification. The axis qualification can be carried out regardless of the geometric qualification.

### Axis qualification intervals

The rotary table axis is qualified during the axis qualification. The rotary table axis must be qualified every week. For this purpose, a measuring run is integrated in the user software. Furthermore, a qualification test piece is required.

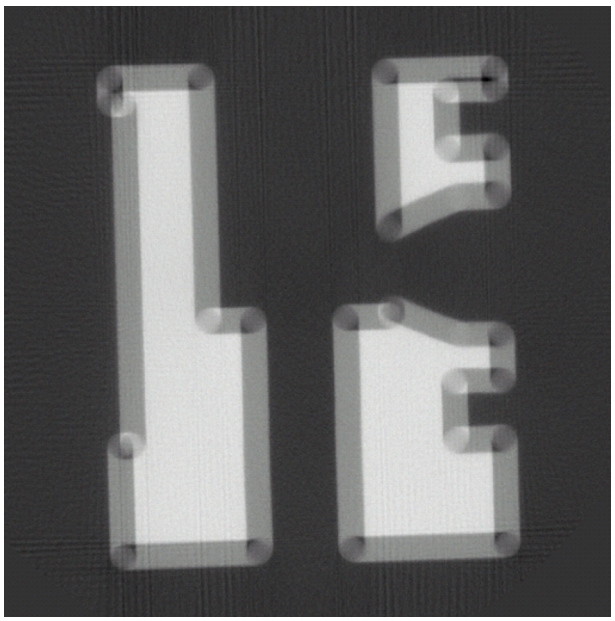



*Qualification test piece for axis qualification*

1 Qualification test piece
2 Rotary table plate

## Axis qualification in the case of a double edge

If the contour of the workpiece shows a double edge in the reconstruction, then you must carry out an axis qualification. See illustration.



*Reconstruction with double edge*

## Binning mode

Unlike the geometric qualification, the axis qualification is always carried out in the 1×1 binning mode. If a different binning mode has been selected prior to starting the axis qualification, the 1×1 binning mode will automatically be selected. After the qualification, the original binning mode is automatically restored.

## Procedure for axis qualification

Proceed as follows:

1 Make sure that no filter is used on the X-ray tube.

2 Move to the loading position.

3 Open the loading door.

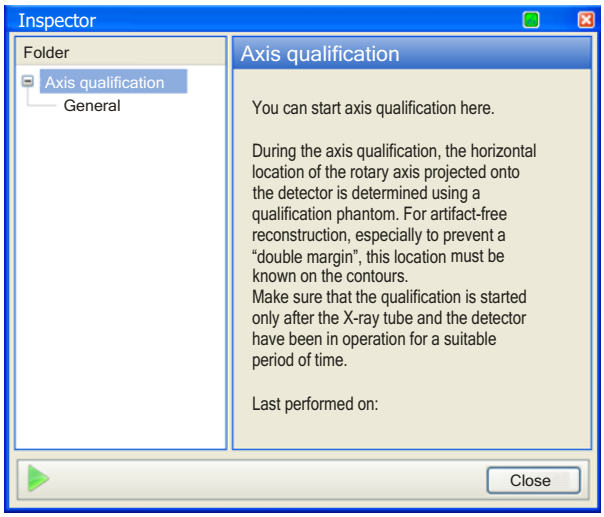
4 Place the workpiece pallet with screwed-in qualification test piece on the rotary table.

- Pay attention to the red mark for correct alignment.

5 Close the loading door.

6 Double-click **Axis qualification** in the Session Explorer.

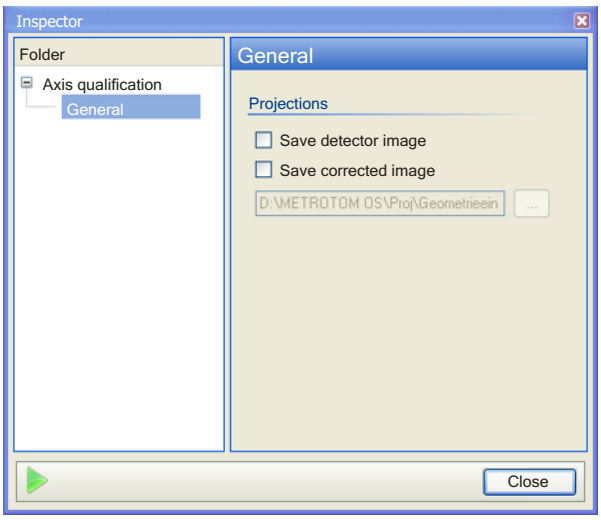
The following window appears:




7 Define under **General** if the calibration images are to be saved.

The saved images may be useful for service operations.

- Select the type of images to be saved: detector images, corrected images or both.
- Select the directory for saving the images.




**8** Click the button shown here to start the qualification.

Once the qualification run has been started, the rotating axis is qualified over the entire X travel range.

**NOTICE! Risk of collision after qualification. The Y slide is near the X-ray tube when the qualification is completed.**

**9** Move to the loading position.

**10** Open the loading door.

**11** Remove the qualification test piece from the rotary table and store it in a safe place.

# Start-up checklist

## Control cabinet

- Has the CT system been switched on in the correct order? ➤ *See [⇨ 6-4].*
- Have the settings on the control cabinet been made? ➤ *See [⇨ 6-5].*
  - Is the power supply connected?
  - Control cabinet switched on?
  - Drives switched on?
  - Operating mode selected?
  - X-ray tube switched on?

## User software

- User software started?
- Initialization carried out? ➤ *See [⇨ 6-8]*
- Initialization of all CT components. ➤ *See [⇨ 6-7]*

## Qualification and calibration

- Have you calibrated the detector? ➤ *See [⇨ 6-13]*

  Calibrate the detector once a month.
- Have you qualified the geometry? ➤ *See [⇨ 6-15]*

  Qualify the geometry once a week.
- Have you qualified the axis? ➤ *See [⇨ 6-19]*

  Qualify the axis once a week.

# Chapter 7

# Measuring operation

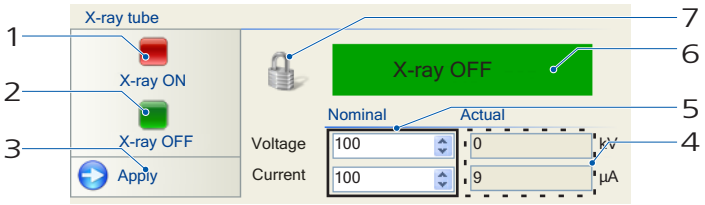
**This chapter contains:**

# Settings of CT components

## Settings for the X-ray tube

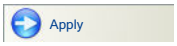
### GUI widgets in the »Control Panel« window

The GUI widgets for the X-ray tube are to be found in the »Control Panel« window. Further setting options can be opened via the Session Explorer. ➢ *See [⇨ 7-4]*




*GUI widgets in the »Control Panel«*

1 Button for X-ray radiation ON
2 Button for X-ray radiation OFF
3 Button for applying the nominal values
4 Display fields for actual voltage [KV] and current value [µA]
5 Input fields for nominal voltage [KV] and current value [µA]
6 Text field for indication of the X-ray tube status
7 Icon for display of additional status information

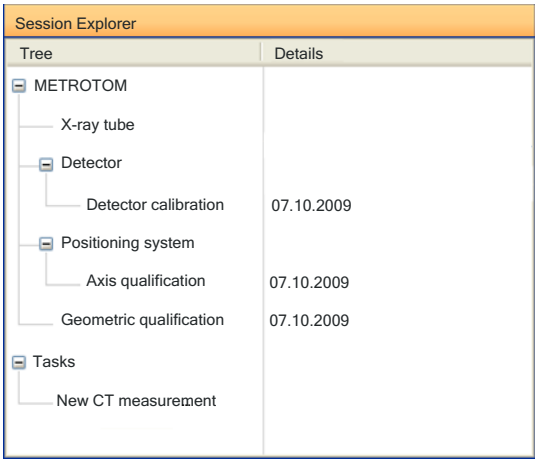
| Text / Icon | | Description | Measure |
|---|---|---|---|
|   | 1 | Switches the X-ray tube on. | |
|   | 2 | Button with two functions:<br>– Switches the X-ray tube off.<br>– Cancels the following processes:<br>– Initialization<br>– Warm-up | |
|   | 3 | Applies the nominal current and voltage values.<br>Alternatively, you can accept the values by pressing the Enter key. | |
| Voltage / Actual | 4 | Actual value of the tube voltage. | |

| Text / Icon | | Description | Measure |
|---|---|---|---|
| Current / Actual | 4 | Actual value of the tube current. | |
| Voltage / Nominal | 5 | Field to enter the nominal value of the tube voltage.<br>Value range: 20 to 130 kV<br>The entry can be applied using Enter (keyboard) or **Apply**. | The voltage value and the current intensity depend on several factors.<br>– Select the suitable filter. ➤ *See [⇨ 7-18]*<br>– Select voltage and current. ➤ *See [⇨ 7-20]* |
| Current / Nominal | 5 | Field to enter the nominal value of the tube current.<br>Value range: 0 to 300 µA<br>The entry can be applied using Enter (keyboard) or **Apply**. | ➤ »Voltage / Nominal«. |
| Initialization running...<br>X-ray OFF<br>X-ray ON | 6 | Status of the X-ray tube | |
|  | 7 | X-ray radiation OFF, loading door closed | |
|  | 7 | X-ray radiation OFF, loading door open | |
|  | 7 | There are the following options: Initialization, warm-up or overload reset is in process. | |
|  | 7 | X-ray radiation ON | |

| Text / Icon | | Description | Measure |
|---|---|---|---|
|  | 7 | Warning:<br>The X-ray tube can be switched on but the user should gather information about the problem and take suitable measures. | – Check the Event Viewer regarding the existing problem. ➤*See [⇨ Annex 14]*<br>– Take measures if necessary. |
|  | 7 | Error:<br>The X-ray tube cannot be switched on. | – Check the Event Viewer regarding the existing problem. ➤*See [⇨ Annex 14]*<br>– Take measures if necessary. |

## Other possible settings

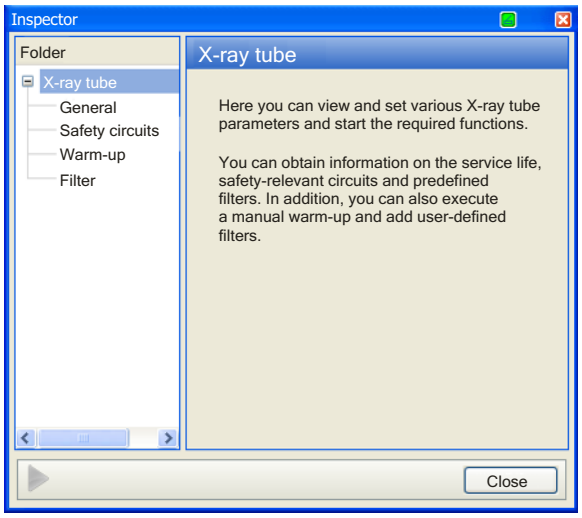
In the Session Explorer, you can open an Inspector window under »X-ray tube«.




*Session Explorer*

**1** Double-click X-ray tube.

The following window opens:




*Inspector for X-ray tube*

**NOTICE**

The settings in the Inspector window are described in the annex. ➢ *See [⇨ Annex 29]*

## Please observe any additional information

There are some procedures with regard to the X-ray tube that you can or must perform yourself if required. In the following, you will find information about the procedures and particularities of the X-ray tube.

### Automatic warm-up

After more than eight hours after the last warm-up, a warm-up is automatically started in the following cases:

– During initialization of the X-ray tube

– When the X-ray tube is switched on.

The warm-up duration depends on the time during which the X-ray tube was off:

| X-ray radiation OFF | Duration of the warm-up |
|---|---|
| Eight hours up to one month | 15 minutes |
| One month up to three months | 40 minutes |
| More than three months | 120 minutes |

### Manual warm-up

If problems with the X-ray tube occur, the warm-up should be started manually.

**1** In the Session Explorer, double-click X-ray tube.

The »X-ray tube« Inspector window opens.

**2** Select Warm-up.

3 Click Start. ➤ *See [⇨ Annex 31]*

**Ionization effects**

During a warm-up, the voltage in the X-ray tube is increased in small steps; the voltage is also called acceleration voltage. By increasing the voltage slowly, the ionization effects in the cathode chamber are decreased; ionization effects are caused by impurities in the X-ray tube.

### Adjustment of nominal and actual values

In case of change in current or voltage in the **X-ray ON** status, the program checks if the actual value corresponds to the nominal value. If the values are different, a warning will be displayed in the Event Viewer.

### Focal spot mode

The X-ray tube can be operated in three different focal spot modes: Small, middle and large. The modes refer to the X-ray power.

Example: In the »Small« mode, the maximum X-ray power is 8 W. The focal spot can have two sizes in this mode: 5 µm with an X-ray power of up to 4 W and 8 µm in the range from 4 to 8 W.

| Mode | Power | Focal spot size |
|---|---|---|
| Small | Up to 8 W | – 8 µm in the range from 4 to 8 W<br>– 5 µm in the range up to 4 W |
| Middle | Up to 16 W | 20 µm |
| Large | Up to maximum power | 40 µm |

The mode changes automatically if the X-ray power changes as a result of a change in voltage or current. Thus you can always use the smallest possible focal spot size. If the X-ray tube is on, it will automatically be switched off for a short time to enable mode switching and will then be switched on again.

### Overload

In rare cases, it may occur that the X-ray tube switches off automatically due to overload. To avoid any permanent damage to the X-ray tube, a process for safe restart will be activated in this case. The process consists of the following steps:

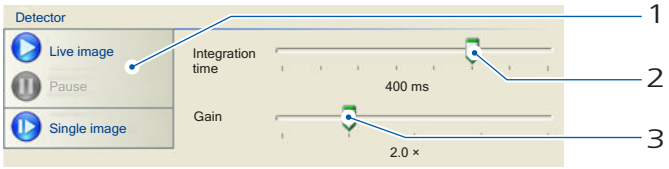
– Reset of the overload protection
– Waiting time of 100 seconds
– Execution of a quick warm-up.

Duration: 100 seconds. If another overload occurs during the quick warm-up, the process will be canceled and the X-ray tube remains in error status. In this case, you will have to contact the ZEISS Service.

# Settings for the detector

## GUI widgets in the »Control Panel« window

The GUI widgets for the detector are to be found in the »Control Panel« window. Further setting options can be opened via the Session Explorer. ➢ *See [⇨ 7-8]*




*Operator's controls for the detector*

1 Buttons for displaying the detector image
2 Slider for integration time [ms], with indication of the value
3 Slider for gain factor of the photodiodes, with indication of the value

| Text / Icon | Description |
|---|---|
|  | Request of live images.<br>Images are continuously requested and displayed in the display window. |
|  | Pause in the continuous live image request. |
|  | Request of a single image. The displayed image corresponds to a status at a certain point in time. |

### Gain setting

The detector settings allow you to set the gain of the photodiodes by means of a factor. The gain has an effect on the image signal and the image blurring. If you increase the gain, the image signal and the image blurring increase proportionally. Thus, the image becomes brighter and noisy. This measure does not influence the measuring time.

### Selecting the integration time

The integration time corresponds to the exposure time of analog cameras. If you increase the integration time, more photons are used for the image measurement. Thus, the image signal is improved without increasing the image blurring. Furthermore, the images become brighter. The measuring time increases also with increasing integration time.

If you create a brighter image, it is possible to reduce the power of the X-ray tube and thus the focal spot. The focal spot for the full projection of the workpiece must always be smaller than the natural voxel size.

When setting up a workpiece, it is useful to see the detector image. To do so, you must set an appropriate integration time.

– Set the integration time to 500 ms.

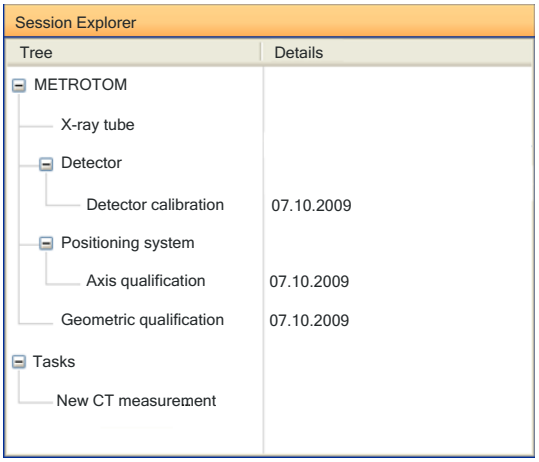
  With 130 kV, 8 W (61 µA), 500 ms and maximum gain, you can achieve a good utilization of the detector dynamics. You may have to change the integration time again later when adapting the focal spot size.

### Relation between gain, integration time and brightness of the image

The absolute brightness of an image in gray scale values is proportional to the product of integration time and gain.

## Other possible settings

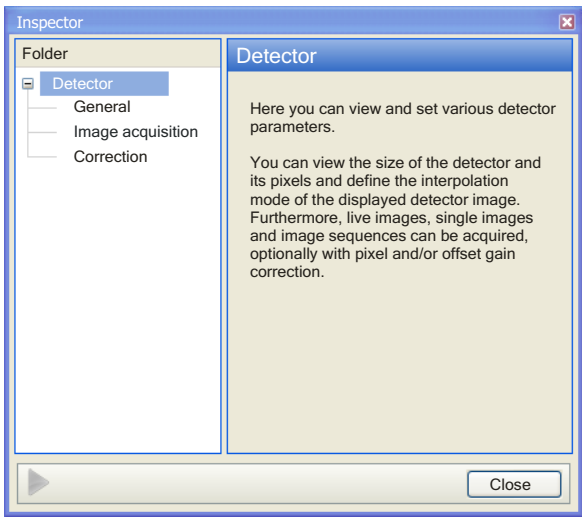
In the Session Explorer, you can open an Inspector window under »Detector«.




*Session Explorer*

**1** Double-click Detector.

  The following window opens:




*Inspector for detector*

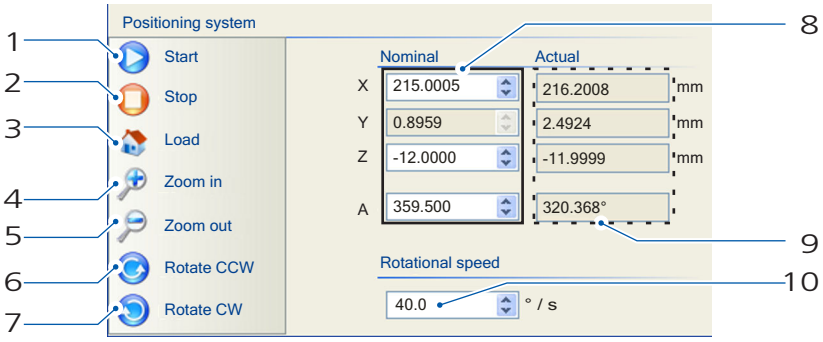
**NOTICE**

The settings in the Inspector window are described in the annex. ➢ *See [⇨ Annex 32]*

# Settings for the positioning system

## GUI widgets in the »Control Panel« window

The GUI widgets for the positioning system are to be found in the »Control Panel« window. Further setting options can be opened via the Session Explorer. ➢ *See [⇨ 7-11]*




*Control panel for positioning system*

1 Start of the positioning movement to the desired position, based on the entered nominal values
2 Cancelation of the positioning movement
3 Approaching the loading position
4 Positioning movement in negative X direction in predefined steps
5 Positioning movement in positive X direction in predefined steps
6 Rotating the rotary table counterclockwise

7 Rotating the rotary table clockwise
8 Input fields to enter the nominal position of the rotary table axis
9 Display fields for the actual position of the rotary table axis
10 Input fields to enter the rotational speed of the rotary table for a manual rotation

**NOTICE**

Risk of collision due to positioning movement in the X axis! The workpiece or the workpiece holder may collide with the X-ray tube or the detector and cause damage.

Observe the value range when entering the nominal values. See

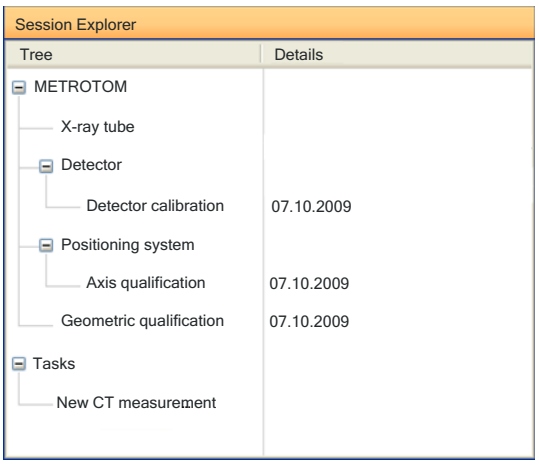
Make sure that the entered nominal value does not cause any collision.

| | Text | | Description |
|---|---|---|---|
|  | Start | 1 | Start of the positioning movement to the desired position, based on the nominal values entered. |
|  | Stop | 2 | Cancelation of the positioning movement |
|  | Load | 3 | Movement to the loading position |
|  | Zoom in | 4 | The rotary table moves in predefined steps in the negative X direction; movement to the X-ray tube.<br>Each click on the button zooms in the workpiece by 10% in the detector image. |
|  | Zoom out | 5 | The rotary table moves in predefined steps in the positive X direction; movement to the detector.<br>Each click on the button zooms out the workpiece by 10% in the detector image. |
|  | Rotate CCW | 6 | The rotary table turns counterclockwise |
|  | Rotate CW | 7 | The rotary table turns clockwise |
| | X (nom) | 8 | Field to enter the nominal value of the X coordinate |
| | Y (nom) | 8 | Field to enter the nominal value of the Y coordinate |
| | Z (nom) | 8 | Field to enter the nominal value of the Z coordinate |
| | A (nom) | 8 | Field to enter the nominal value of the rotary table angle |
| | X (act) | 9 | Display field for the actual value of the X coordinate |
| | Y (act) | 9 | Display field for the actual value of the Y coordinate |
| | Z (act) | 9 | Display field for the actual value of the Z coordinate |

| Text | | Description |
|---|---|---|
| A (act) | 9 | Display field for the actual value of the rotary table angle |
| Rotational speed | 10 | The rotational speed is indicated in degrees per second<br>This only applies to rotation using the two buttons **Rotate CCW** and **Rotate CW**. |

## Other possible settings

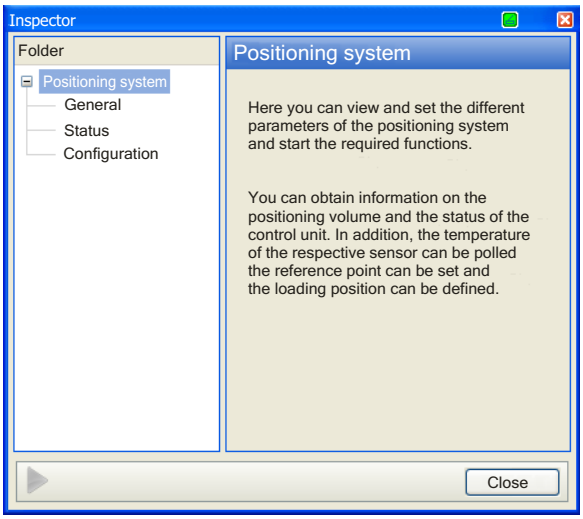
In the Session Explorer, you can open an Inspector window under »Positioning system«.




*Session Explorer*

**1** Double-click Positioning system.

The following window opens:




*Inspector for the positioning system*

**NOTICE**

The settings in the Inspector window are described in the annex. ➤ *See [⇨ Annex 37]*

# Setting up the workpiece

## Sequence

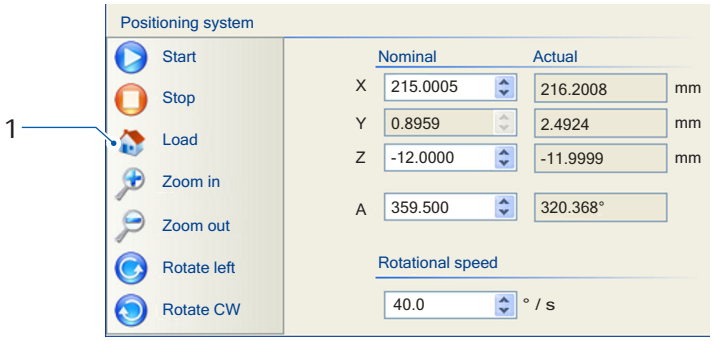
1. Move to the loading position. ➤*See [⇨ 7-12]*

   Positioning movements via the positioning system are only possible if the loading door is closed.

2. Open the loading door.
3. Set up the workpiece.
   - Observe the instructions.
   - Observe the criteria ➤*See [⇨ 7-13]*
4. Select and insert the filter. ➤*See [⇨ 7-18]*
5. Close the loading door.
6. Select voltage and current. ➤*See [⇨ 7-20]*

## Moving to the loading position

The User Desk of the user software contains a button for movement to the loading position.




*Moving to the loading position*

**1** Click the **Load** button **[1]**.

The rotary table moves to the loading position.

**NOTICE**

You can set the coordinate values for the loading position in the Inspector for the positioning system under »Configuration«. ➤*See [⇨ Annex 39]*

# Criteria for set-up

## Notes

### Clamping

**NOTICE**

Workpieces must be clamped, i.e. ensure that they do not bounce and change their position. No magnetic materials may be used for clamping. Magnets have an effect on the electron optics in the X-ray tube. The magnets in the workpiece pallet are shielded and do not exert an effect.

### Holding block

It must be possible to move the workpiece close to the X-ray tube to ensure that even small parts can be imaged on the detector with maximum magnification. Therefore, the following applies: the smaller the workpiece, the smaller the holding block. If the holding block is too large, collision with the X-ray tube may be caused.

In the case of similar parts (serial parts) to be measured frequently, it is recommended to create special holding blocks, e.g. a polystyrene holding block in which the contour of the workpiece to be measured has been milled or burned out. Advantages:

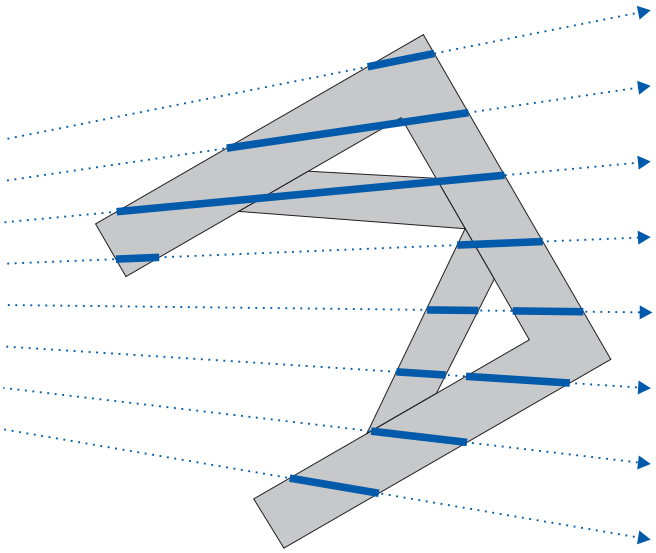
– Increased repeatability of measurements.

– The settings of previous measurements can be loaded.

The burning out of a polystyrene block leads to a compression of the material which may have a negative effect on the measurement. This is the case, for example, if compressed polystyrene in the vicinity of a surface to be measured appears to indicate a wrong surface. Therefore, cutting out the Styrofoam is to be preferred in most cases.

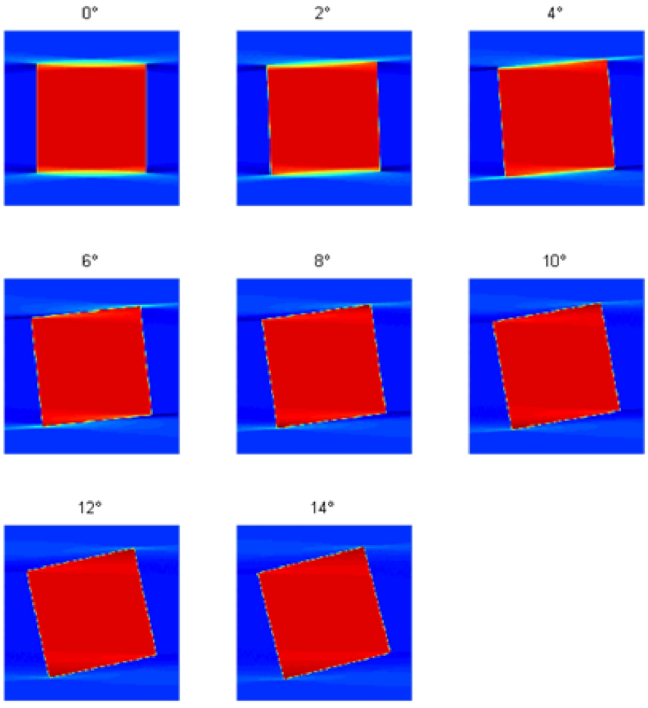
## Maximum values for cumulative wall thicknesses

The total of all wall thicknesses to be penetrated by radiation represents a criterion for the usability of the projections for the reconstruction of a workpiece. The following illustration shows the different possible lengths of the irradiation distance. By modifying the alignment of the workpiece, the maximum distance to be penetrated by radiation can be reduced.



*Cumulative wall thickness*

The workpiece should principally be aligned to ensure that the maximum distance to be penetrated by radiation is reduced. At the same time, select the alignment to ensure that the workpiece surfaces to be measured are inclined at least 10° to the rotating axis. In this way, disturbing artifacts on the surfaces are avoided. The following images show the influence an alignment of the part has on the quality of the result and the sharpness of the reconstructed edges.




*Tilting effect of workpieces*

The alignment is *one* influencing variable. However, the material of the workpiece is very important. Furthermore, the objective of the CT meas-

urement is also important: Do you only want to carry out a go-and-no-go check for the workpiece or do you want to measure its geometric features by means of CT data?

## Arrangement

Proceed as follows for arranging the workpiece:

**1** Arrange the workpiece in the center of the rotary table.

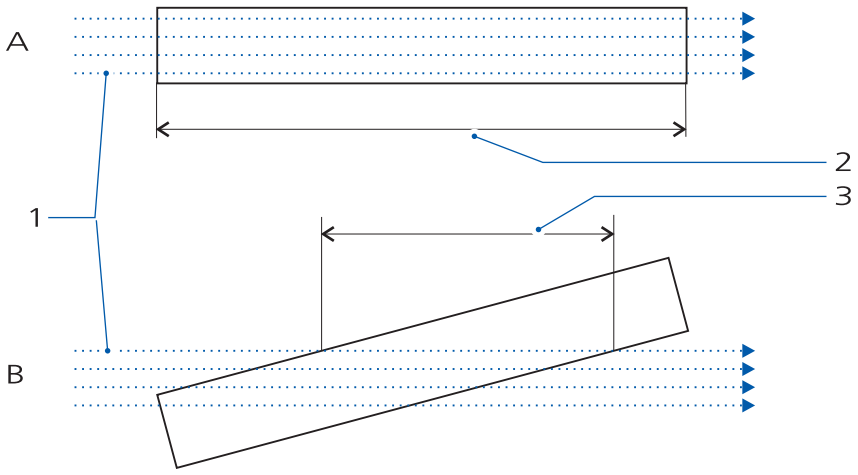
It is thus guaranteed that the workpiece is in the center of the cone beam. This is required to ensure that the workpiece is completely shown on the detector in all angular positions of the rotary table. Eccentric arrangement of the workpiece is also possible. In this case, you must select a reduced magnification to ensure that the workpiece is completely visible in all projections.

**2** Arrange slim long parts in upright (vertical) position.

The surfaces to be measured should be inclined at least 10° to the rotating axis.

**3** Arrange larger workpieces in an inclined position.

This reduces the radiation length.




*Radiation distance*

A Horizontal position of the workpiece

B Inclined position of the workpiece

1 X-ray beams

2 Long distance; penetration by radiation of the complete length of the workpiece

3 Short distance

## Holder and clamping

### Adapt the form and the material of the holder to the workpiece.

**Polystyrene**

Polystyrene is an ideal material for clamping. Main advantage: Little absorption of the X-ray radiation.

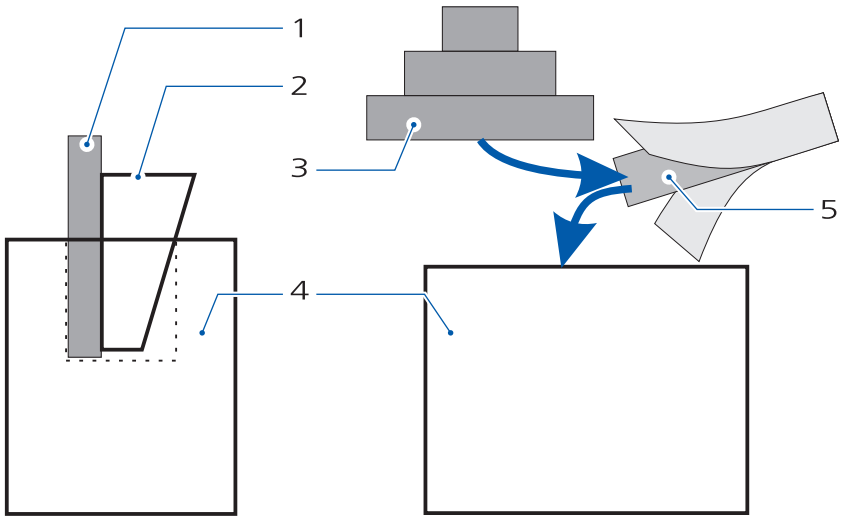
The polystyrene used should have the following characteristics: bright, solid, brittle and not shapeable.

**NOTICE**

Polystyrene is compressed under the weight of the workpiece. This property has a negative influence on the accuracy of the measurement. Therefore, you should fasten the workpiece in the polystyrene block and let it rest for at least one hour prior to the measurement. Afterwards you must handle the polystyrene block with care. Avoid any deformation.

Furthermore, you must also consider the high thermal expansion of polystyrene. In case of unfavorable shape and size of the polystyrene block, even the heat of the hand may cause a workpiece movement by several micrometers. It is therefore important that the polystyrene block has the same temperature as the X-ray chamber.

### Fasten the workpiece by means of double-sided adhesive tape.




*Holding block and fixing aids*

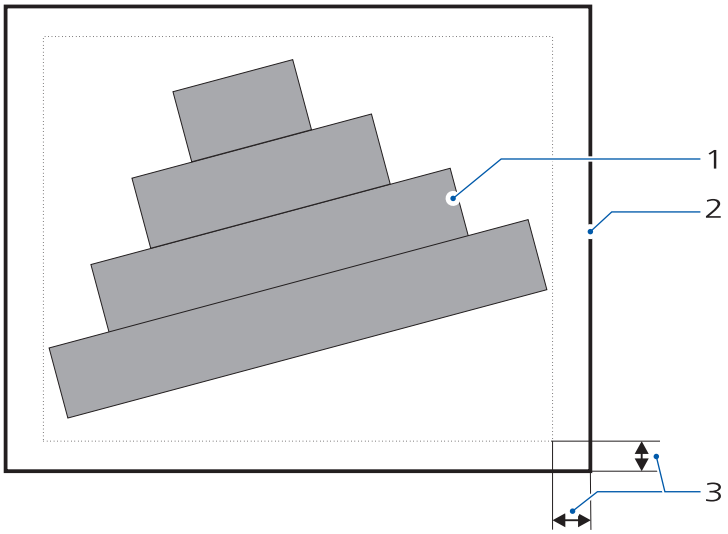
1 Slim long workpiece
2 Wedge made of polystyrene for clamping the workpiece
3 Compact workpiece
4 Holding block made of polystyrene with or without internal recess; cylindrical or rectangular
5 Clamping the workpiece by means of double-sided adhesive tape

**NOTICE**
In the ideal case, the outer workpiece surfaces to be measured should not rest against the holding block. The adjacent polystyrene can falsify the measured value, e.g. if compressed polystyrene appears to indicate wrong surface points. However, the workpiece must be in a stable position. Consequently, you must check whether the workpiece surfaces to be measured should be uncovered.

## Projection

Make sure that the workpiece is always shown as large as possible on the detector. This ensures the smallest possible voxel size for subsequent evaluation. Select the distance between the X-ray source and the workpiece in such a way that there is a free space of at least 20 pixels from the detector edge during all projections of the workpiece.

**NOTICE**
The projection surface may be enlarged by rotating the workpiece. This must be taken into account.




*Magnification without distortion of the workpiece*

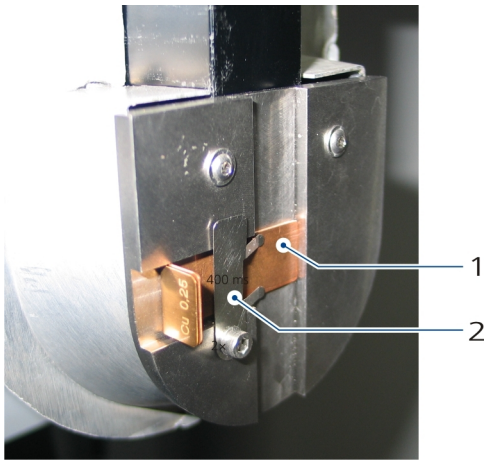
1 Projected workpiece
2 Detector
3 Minimum distance from the detector edge: 20 pixels; the number of pixels is shown on the User Desk.

# Selecting the filter

## Purpose of a filter

Filters are used to reduce artifacts in the volume model and thus increase the measuring accuracy. However, filters reduce the radiation intensity and the filter thickness must therefore be adapted to the workpiece.

### Attaching the filter




*Filter at the outlet of the X-ray tube*

1 Filter
2 Filter holder

## Filter material

Copper or aluminum is used as filter material on the METROTOM 800 . There are no general rules regarding the filter thickness. The required thickness depends on the material of the workpiece and the cumulative wall thickness to be penetrated by radiation.

**Reference values for filter selection:**

| Workpiece material | Voltage | Filter material | Filter thickness |
|---|---|---|---|
| Plastic | from 60 kV | Cu, Al | Cu: min. 0.25 mm<br>AL: 1 to 2 mm |
| Light metal | from 90 kV | Cu | depending on cumulative wall thickness |

### Attenuation of X-rays

X-rays are attenuated by the following parameters:

- Density of the workpiece and ordinal number (atomic number Z)
  - The higher the density, the higher the attenuation.
  - The higher the ordinal number, the higher the attenuation.
- Wall thickness

  The thicker the workpiece and the cumulative wall thickness, the higher the attenuation.
- Voltage

  The lower the voltage, the higher the attenuation.
- Filter

  The thicker the filter, the higher the attenuation.

**NOTICE**

The more the X-ray radiation is attenuated by a workpiece, the higher is the beam hardening.

### Beam hardening

Beam hardening is the shifting of the X-ray spectrum towards a higher average photon energy. It results from an irregular attenuation of the X-ray radiation: Low-energy X-ray radiation is more absorbed than high-energy radiation. Beam hardening causes undesired artifacts and should therefore be minimized.

Principle:

- A workpiece with low attenuation of the X-ray radiation causes little beam hardening.
- Filters are used to reduce beam hardening.

  The thicker a filter, the better the effect. Any thickness of the filters, however, is not possible, as the detector must still be sufficiently modulated. The parameters are integration time and gain.

## Defining and selecting the filter in the software

Before you carry out a new measurement, you will have to select the inserted filter in the Inspector for CT measurement. The »Prefilter« pull-down window is provided for this purpose. ➢ *See [⇨ 7-34]*

Some filters are predefined. You can also define your own filters. To do so, open the Inspector for the X-ray tube. You can create customized filters under »Filter«. ➢ *See [⇨ Annex 32]*

**NOTICE**

Focal spot control can only be performed correctly for predefined filters.

# Selecting voltage and current

## Voltage

In an X-ray process, voltage and penetration are directly related. With increasing voltage, the penetration capability will also increase.

The voltage, the target material and the prefilters used define the X-ray spectrum for acquisition of the workpiece. An increase in voltage produces a high-energy spectrum. The attenuation in the workpiece is reduced.

If the gray scale value is too low in some areas of the workpiece, you should increase the voltage. Read the gray scale values in the histogram. ➢ *See [⇨ 7-29]*

## Current

The magnification of the workpiece defines the voxel size and thus the maximum focal spot size. The focal spot size defines the tube power. The voltage required varies according to the workpiece material and the workpiece thickness, thus defining the necessary current. If the actual current value indicated in the Control Panel is too high, the required current can be reduced by the following measures:

– Increasing the integration time

  You can set a maximum integration time of one second.

– Increasing the gain

  The noise is increased by increasing the gain. This impairs the measuring accuracy.

**NOTICE**

The relations between focal spot size and power are described elsewhere in detail. ➢ *See [⇨ 7-25]*

# Checklist

## Setting up the workpiece

– Criteria for the workpiece considered?
– Cumulative wall thickness?
– Arrangement?
– Workpiece arranged in central position?
– Clamping?
– Projection?
– Largest possible display of the workpiece selected?
– Workpiece tilted?

- Correct filter selected?
- Settings for voltage and current determined?

# Setting up the measurement

## General procedure

### Preliminary measures

Before continuing, please settle the following questions:

– Have you set up the workpiece on the rotary table?

– Have you selected a filter and attached it to the X-ray tube?

  A filter is not always required.

After you carried out these measurements, you can continue with setting up the measurement.

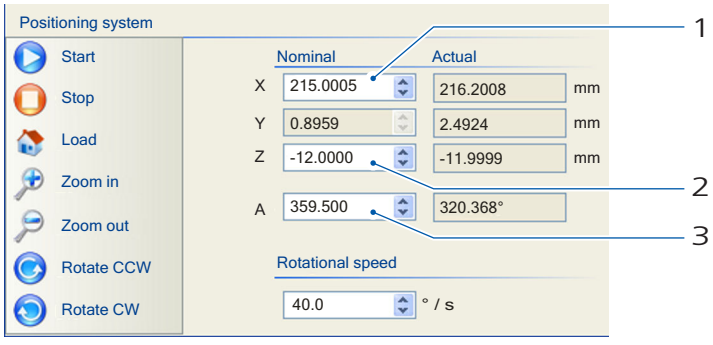
### Further measures

1. Close the loading door.
2. Move the Y slide into an appropriate X position.
3. Switch the X-ray tube on.
4. Determine the maximum focal spot size and the required power.
5. Optimize the histogram distribution.

   The current, voltage, integration time and gain parameters of the detector are used for this.
6. Load a new measurement.
7. Set the reconstruction area.
8. Make the settings in the Inspector for CT measurement.
9. Start the measurement.

## Setting the position

The Control Panel is located at the right bottom of the User Desk. You can enter values for the position of the Y slide and the rotary table under »Positioning system«. The best Y position is approached automatically, because it was determined via the axis qualification.




*Setting the position*

1 Nominal value for the X position
2 Nominal value for the height of the rotary table (optional)
3 Nominal value for the rotation angle of the rotary table axis.

**NOTICE**

Risk of collision due to positioning movement in the X axis! The workpiece or the workpiece holder may collide with the X-ray tube and may cause damage.

Observe the value range when entering the nominal values. See

Make sure that the entered nominal value does not cause any collision.

### Procedure

**1** Enter the nominal values

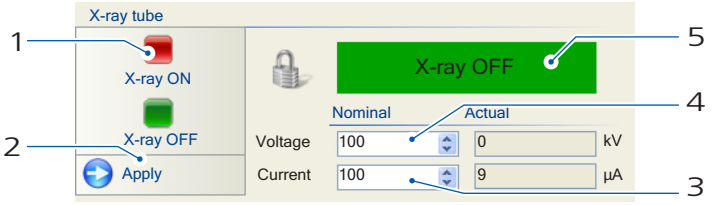
**2** Click the button shown here.

Move the Y slide and the rotary table to the desired position.

## Switching the X-ray tube on

Prior to switching on the X-ray tube, initialization must have been completed and the workpiece must have been aligned.

The next step is to prepare the measurement. The X-ray tube remains switched off; a green rectangle labeled **X-ray OFF** is shown at the top right of the Control Panel.

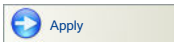



*Control Panel: X-ray tube OFF*

1 Switches the X-ray tube on.
2 Applies the values set for voltage and current
3 Input field for current [µA]
4 Input field for voltage [kV]
5 Status of the X-ray tube

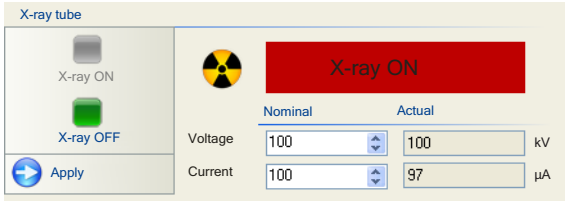
### Procedure

**1** Set the values for voltage and current. ➢ *Info [⇨ 7-20]*




**2** Click **Apply**.


**3** Then click the **X-ray ON** button.




After switching on the X-ray tube, a red rectangle with the text **X-ray ON** appears on the Control Panel.

The symbol to the left of the red rectangle changes:

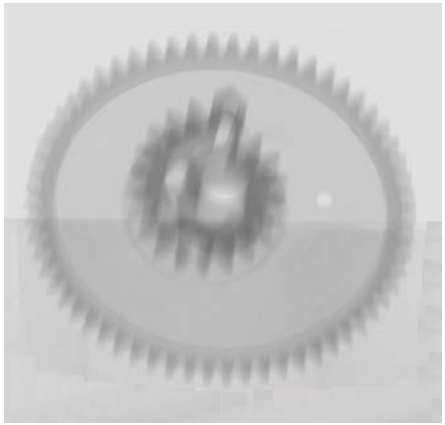
The symbol remains visible while you set the nominal values.

The symbol appears when the nominal values are reached.

Once the X-ray tube has been switched on and the detector runs in the Live Image mode, the projected image of the workpiece is displayed in the preview.

# Adapting the preview

## Display window



*Preview*

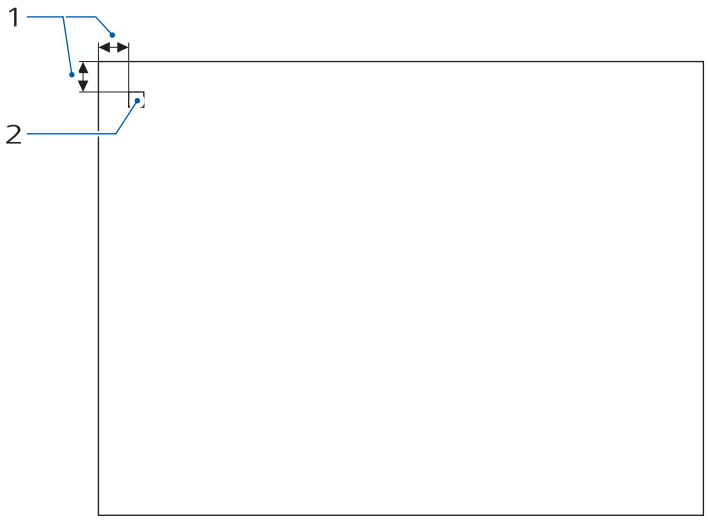
Make sure that the image of the projected workpiece fills the window optimally. Just a clearance of approximately 20 pixels should be left along the edge.

**NOTICE**

Furthermore, it is important to make sure that the workpiece is not projected into the reference area throughout the entire measurement.

### Reference area

The reference area is located in the upper left area of the detector. This sensor is required for image correction. ➢ *See [⇨ 7-33]*




*Reference area of the detector*

1 Distance from the left corner: 40 pixels in horizontal and vertical direction

2 Reference area: 20×20 pixels

# Determining the focal spot size

## Relation between natural voxel size and focal spot size

For an optimum resolution, the natural voxel size and the focal spot size must be aligned. Both sizes are displayed in the status bar. The magnification is also indicated there.


| | |
|---|---|
| Spot | Focal spot size |
| Vx | Natural voxel size |
| Mag | Magnification |

The focal spot size depends on the energy which hits the target and is required for the alignment involving the detector resolution and image blurring.

| | |
|---|---|
| Information about focus and focal spot | ➢ *See [⇨ Annex 43]* |
| Information about blurring | ➢ *See [⇨ Annex 45]* |

**NOTICE**

The focal spot size should not be greater than the natural voxel size resulting from the Y slide position and the detector resolution. Only then is it possible to guarantee the maximum resolution. ➢ *See characteristic curve [⇨ 7-27]*

The voxel size, the focal spot size and the magnification are influenced by the following factors:

– Position of the positioning system
– Voltage and current
– Binning mode

The natural voxel size is influenced by the position of the positioning system and the binning mode. The focal spot size is influenced by the current and the voltage. The magnification is influenced by the position of the positioning system.

| Influencing factors | Position of the positioning system | Voltage and current | Binning mode |
|---|---|---|---|
| Natural voxel size | × | | × |
| Focal spot size | | × | |
| Magnification | × | | |

In some cases, it may be difficult to adapt all parameters as they influence each other.

– A filled histogram defines a well-modulated detector (Histogram condition).
– If it is not possible to meet the condition »Focal spot smaller or equal to voxel size«, it is preferable, in moderation, to work with a lower tube current than with a greater voxel size.

### Parameters for X-ray tube and detector

The illumination of the detector and the ratio between natural voxel size and focal spot size is important.

If the ratio between the natural voxel size and the focal spot size is not optimal, the value for the natural voxel size is displayed in red with a red exclamation mark.

In this case, one of the following measures can be taken:

– Reduce the power of the X-ray tube. This means: Reduce either voltage or current.
– Position the workpiece at a larger distance to the X-ray tube.

### Approximate value for the focal spot size

The relations are as follows:

– The tube power defines the focal spot size. See table below.
– Die X position defines the voxel size.
– The focal spot should have the same size as the voxel. It may be smaller but not greater than the voxel.

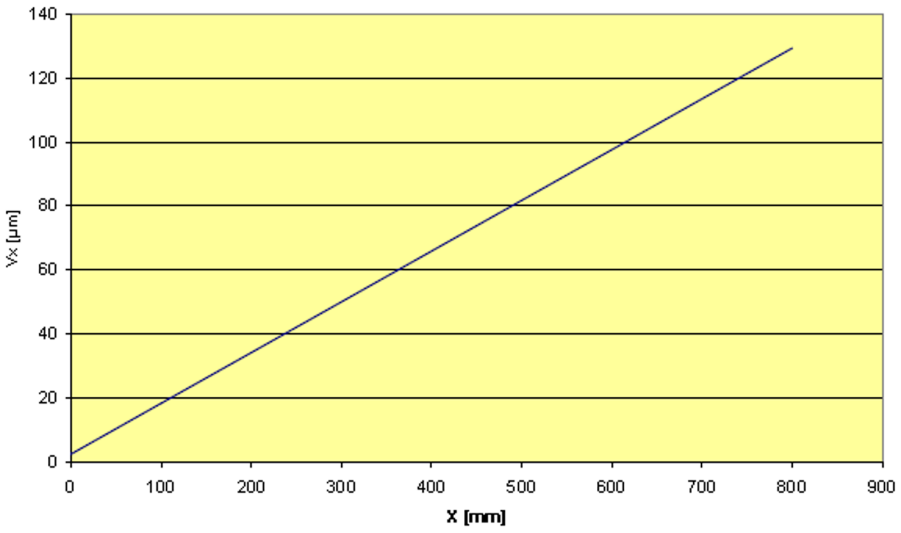
The X-ray tube operates in different modes: Small, middle and large. The »Small« mode is divided into two parts.

**Influence of the focal spot modes**

| | | Focal spot mode | | | |
|---|---|---|---|---|---|
| | | Small | | Middle | Large |
| Tube power | [W] | 4 | 8 | 16 | 39 |
| Focal spot size | [µm] | 5 | 8 | 20 | 40 |
| X position | [mm] | 16,5 | 35,4 | 111 | 237 |
| | | The given values apply to the mode 1×1. With larger modes, you will have to move to another X position without changing the magnification. | | | |

## Characteristic curve

The diagram below shows the natural voxel size as a function of the X position. The maximum focal spot size can be determined based on the defined X position by means of the diagram. It must not be greater than the natural voxel size.




*Characteristic curve for voxel size*

| | |
|---|---|
| Vx | Natural voxel size |
| X | Distance: collimator plate - workpiece |

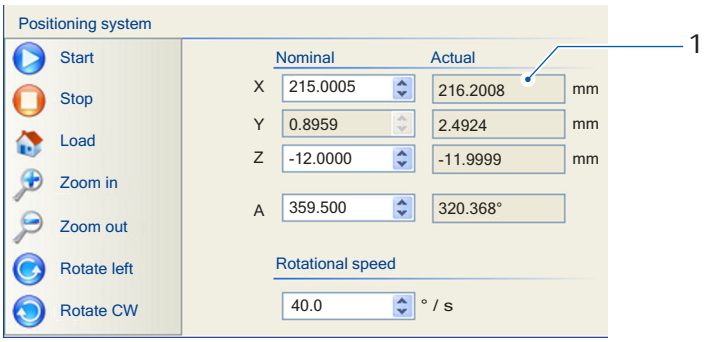
### See also

- ➢ *Vorgehensweise [⇨ 7-28]*

## Procedure

1 Align the workpiece and select the X position such to use as much of the detector surface as possible.

2 Read the X position in the user software.




*X position of the Y slide (1)*

3 On the basis of the X position, determine the natural voxel size and thus the maximum focal spot size. See the diagram.

4 Determine the maximum focal spot size by means of the diagram.

5 Determine the power on the basis of the focal spot size.

*Example*: The X position is 200 mm. The diagram indicates a voxel size of about 34 µm.
According to the X-ray modes, the focal spot size can be 20 or 40 µm. The lower value is decisive. Consequently, the power for the middle X-ray mode must be selected. This is 16 W. See ➢ *»Focal spot mode« table [⇨ 7-27]*

6 Set voltage and current.

The voltage is predefined to a large extent by the workpiece material and the cumulative wall thickness. Fine adjustment is made by setting the current and the detector parameters. While doing this, you should watch the detector image and the histogram. ➢ *See [⇨ 7-24]*

7 Adjust the focal spot size.

If the displayed focal spot size exceeds the natural voxel size at the detector, you can reduce the focal spot size by increasing the integration time and reducing the current. The result of this iterative process should be a completed histogram and a focal spot size which is smaller than the natural voxel size.

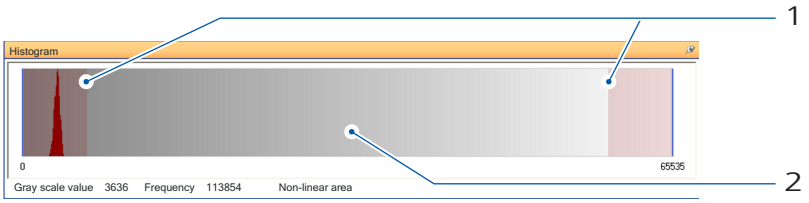
**NOTICE**

If, in spite of all parameter modifications, the focal spot size is still greater than the voxel size, moderately reduce the tube current, even if the histogram is no longer completely filled then. Only when less than half of the histogram is filled, you should try to increase the X position or the binning mode.

# Adapting the gray scale values

## Requirements

The gray scale value distribution for the workpiece should be within the linear range of the detector and fill this range ideally. This range is located between the red shaded areas. The limits of the linear range correspond to 10 and 90% of the gray scale values. If the gray scale values lie between these limits, the detector resolution is optimally used. »Linear« means that the radiation intensity and the gray scale value are linearly proportional to each other. Only approximate linearity is given. This is why the images are corrected. ➢ *Page [⇨ 7-33]*




*Histogram with linearity limits*

1 Linearity limits
2 Linear range

The histogram is influenced by the following factors:

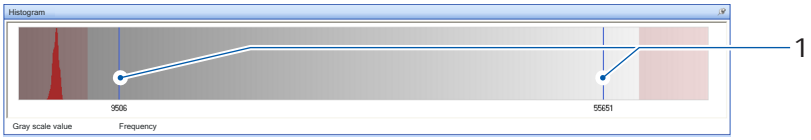
– Integration time
– Gain
– Performance of the tube. The voltage and the current can be modified.

  Normally, the voltage is determined by the workpiece material which means that you must primarily vary the current intensity.

## Brightness and contrast

The brightness and the contrast of the detector image change when you move the vertical blue lines on the left and right edge of the histogram.

This setting does not influence the CT measurement. It is only for the representation on the screen.



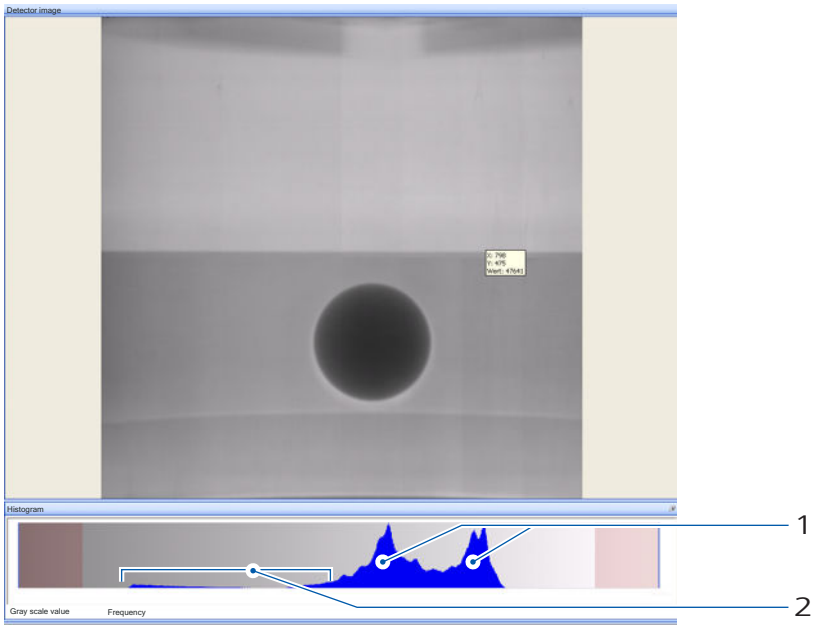

*Histogram; modifying brightness and contrast*

1 Bar for adjusting the brightness and contrast

## Relationship between histogram and CT measurement

In general, a very high and a very low contrast have a negative effect on the result of the CT measurement. A high contrast usually leads to undesirable artifacts in the reconstruction, a low contrast leads to a noisy reconstruction.

The following illustration shows an example of a good contrast behavior. The contrast between the object and the background is sufficient and the object is bright enough to allow sufficient penetration by radiation.

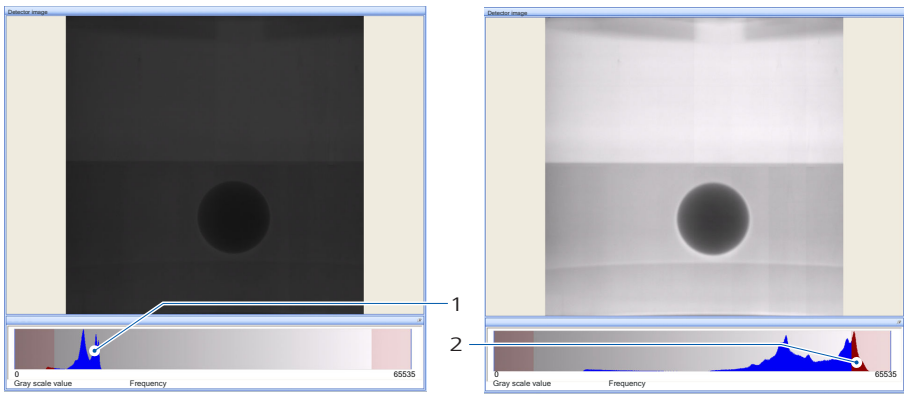



*Favorable gray scale value distribution*

1 Gray scale values of the background
2 Gray scale values of the workpiece

The gray scale values of the background and the workpiece should be as far apart as possible in the histogram. If this is not the case, a weak measuring signal is received which leads to a noisy reconstruction. See the illustration below (1).

In addition, the gray scale value distribution should be within the range of 10 to 90% of the histogram. This corresponds to gray scale values between 1640 and 14740. Outside this range, no sufficient linearity of the detector is given. See the illustration below (2).




*Unfavorable gray scale value distribution*

1 The background and the workpiece in the histogram lie close together. This means: The measuring signal is weak. This leads to a noisy reconstruction.

2 The gray scale values for the object and the background are far apart but the measurement of the background already takes place in the nonlinear range of the detector.

# Carrying out a measurement

## Focal spot control

### What is the purpose of the focal spot control?

#### Shifting of the focal spot

It is not guaranteed that the focal spot will always remain at the same position under different operating conditions. It may be shifted by some dozen micrometers, with the consequence of undesired artifacts and wrong scaling in the reconstruction.

Causes of the focal spot shifting:

– Thermal expansion of the X-ray tube

– Mechanical impact on the tube

– Parameters of the X-ray tube

The focal spot position determined during geometric qualification is exactly valid only at this moment and will need to be corrected for future CT measurements via the focal spot control.

The focal spot control does not need to be performed for each CT measurement. We recommend to use the focal spot control in the following cases:

– in case of high magnification, where the focal point shifting is in the order of several voxels and may cause visible artifacts in the reconstruction.

– in case of geometric measurements on a reconstruction, as only the focal spot control can guarantee the reproducibility.

#### Result of the focal spot control

Repeated measurements of the same workpiece without correction will result in slight deviations of the measured dimensions. These deviations can be eliminated almost completely in the reconstruction by using the focal spot control and the derived correction values. This will significantly improve the reproducibility of CT measurements.

### Performing the focal spot control

#### Test piece

A test piece is required for the focal spot control. The test piece is firmly mounted to the Y carrier of the positioning system and remains permanently in this position. ➢ *See [⇨ 3-8]*

#### Functional principle

The focal spot control consists of the following steps:

– Acquisition of an image of the test piece
– Evaluation of the image
– Calculation of the corrected focal spot position

### When is focal spot control performed?

Focal spot control takes place during the following measurements:

– Geometric qualification
– CT measurement

For geometric qualification, focal spot control is activated by default. It can be deactivated in the expert mode. CT measurements can be carried out with or without focal spot control.

### Conditions

The following conditions must be met in order to perform focal spot control during the CT measurement:

– A geometric qualification must have already been carried out with activated focal spot control.
– If a filter is used on the collimator and if this filter is selected when creating a CT measurement, a correction file must be available for the filter.

If these conditions are not met, an error message will be output and the process will be canceled.

## Correction for calculated images

For improving the results, the scanned images are corrected during the measuring run.

### Homogenization of the radiation intensity

Prior to the measurement, the radiation intensity of the scanned images is standardized by scanning one offset image and one or more gain images. The procedure is as follows:

– The workpiece moves out of the beam path.
– The X-ray tube switches off automatically.
– An offset image is scanned to determine the response characteristics of the detector without radiation.
– The X-ray tube switches on and the default values for voltage and current are set automatically.
– One or more gain images are captured.

### Correction of the radiation intensity

The radiation intensity may vary during the measuring run. This can result in darker or brighter images as compared to the previous images. This effect can be compensated mathematically.

### Correction by means of dynamic gray scale value determination

**Reference area**

For the correction, a reference area is defined at the detector inside of which the radiation intensity is constant during the entire measuring run. The mean radiation intensity for each image is determined based on this reference area and then the whole image is scaled. The dynamic gray scale value determination is activated in the Inspector for CT measurement under »Image correction«.

The reference area is preset. It is a rectangle of 20x20 pixels. This area is located in the upper left corner of the detector. The upper left corner of the area starts with the position X = Y = 40 pixels. ➢ *See [⇨ 7-25]*

**NOTICE**

No workpiece must be projected onto the reference area at any time during the measurement. The intensity correction is active by default.

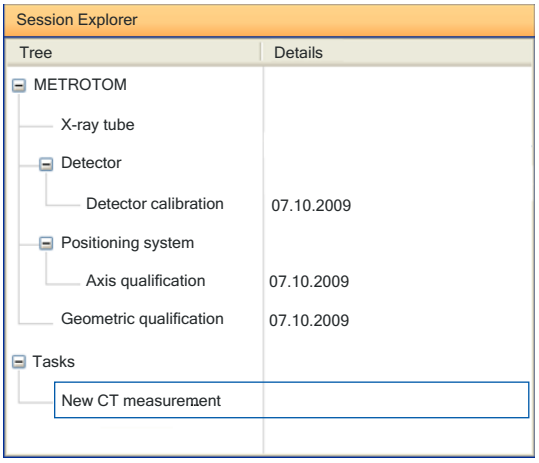
### Correction by means of static gray scale value determination

If the projection of a workpiece in the reference area cannot be guaranteed, the correction must be carried out statically. For this purpose, you must enter a value for the gray scale value. The static gray scale value is defined in the Inspector for CT measurement under »Image correction«.

## Creating a new measurement

Once you have made the settings for the positioning system, the X-ray tube and the detector, you can carry out the measurement.

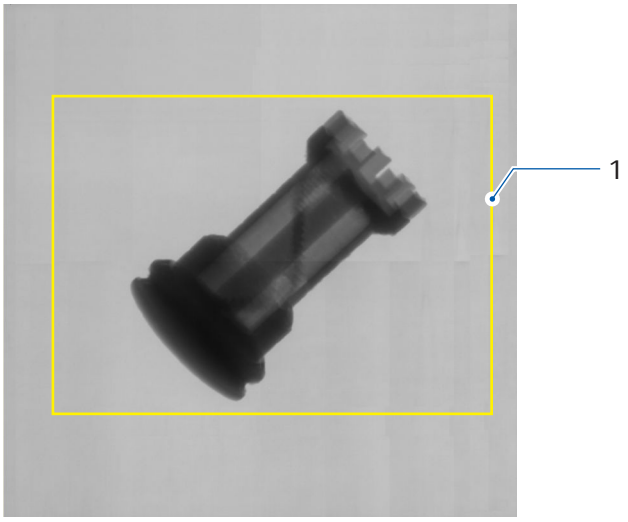
**1** Double-click **New CT measurement** in the Session Explorer.




The Inspector window for »CT measurement« opens. ➤*See [⇨ 7-36]*

In addition to that, a yellow frame for the reconstruction area is displayed in the window. The reconstruction area serves for limiting the data volume. Only the cuboid-shaped volume area defined by the frame is reconstructed.

The button for defining the reconstruction area becomes active in the toolbar of the detector image. ➤*See [⇨ Annex 16]*




*Detector image with reconstruction area*

1 Reconstruction frame

**2** Set the reconstruction area.

- Click the button shown here and adapt the frame to the workpiece.

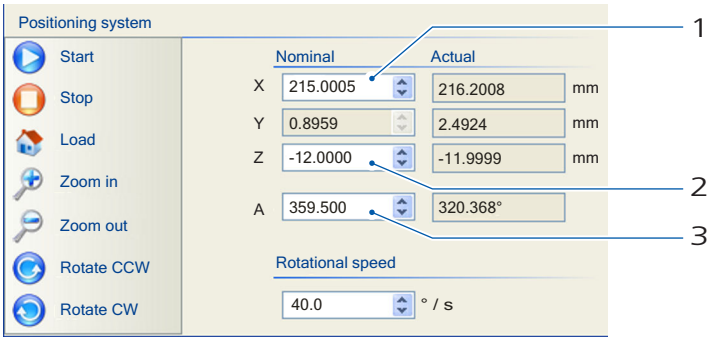
The reconstruction area should not include the reference area as the reference area is required for the image correction. If the reference area is part of the reconstruction area, make sure that the workpiece never moves through the reference area. ➤*Reference area [⇨ 7-25]*

The workpiece must be set up on the rotary table in such a way that all projected images of the workpiece are located inside the reconstruction

area when a 360° rotation is performed. Therefore, you should check whether the reconstruction area is large enough and the workpiece is set up correctly prior to the measurement.

**3** Check the reconstruction area.

- Turn the rotary table to the 0° position.
- Enter the nominal value »0« for »A«.
- Confirm by pressing Enter (keyboard) or click **Start**.




*Control Panel: Setting the position*

1 Nominal value for the X axis
2 Nominal value for the Z axis
3 Nominal value for the rotation angle of the rotary table

**4** Click one of the buttons shown here and observe the reconstruction area.

The rotary table moves to the desired position.

**NOTICE**

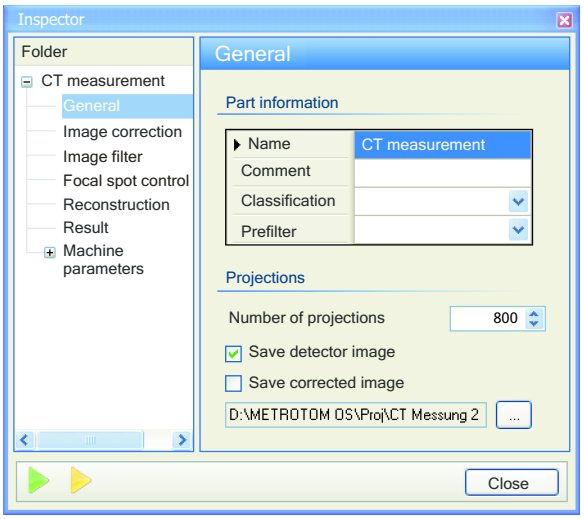
You can proceed if the projections of the workpiece are always located within the reconstruction area throughout the entire rotation.

If, however, one or more projections are outside the reconstruction area, you must redefine the reconstruction area and repeat the measurement.

## Making settings

**1** Enter specific information on the measurement in the Inspector window.

- First enter the information under **General**.

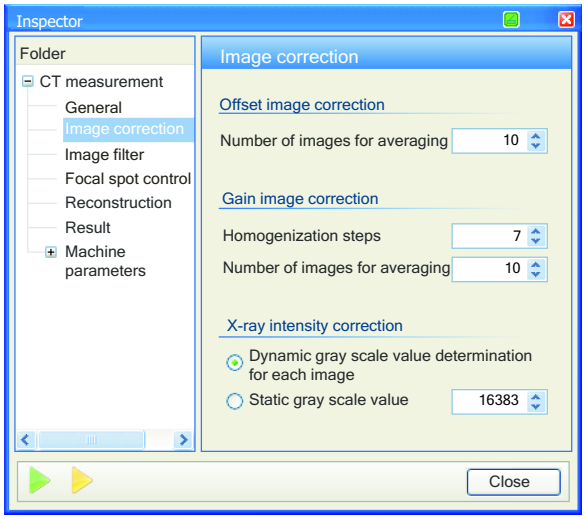



*CT measurement inspector; general*

**Detailed information about »General« in the CT measurement inspector**

| Text | Description |
|---|---|
| **Component information** | |
| Name | Name of the measurement for later identification. Default: CT measurement |
| Comment | Comment on the measurement. |
| Classification | Assignment of the measurement to a previously defined or new group, e.g. name of the customer. |
| Prefilter | Selection of the filter used on the collimator. ➢ *See [⇨ 7-18]*<br>The selection comprises all filters defined in the Inspector for the X-ray tube. ➢ *See [⇨ Annex 32]*<br>Correction files exist for the predefined filters. These are needed for the focal spot control. If you define your own filters, contact the ZEISS service to make sure that the necessary correction file is provided.<br>If no correction file exists for a certain filter, the measurement cannot be performed with focal spot control. ➢ *Info [⇨ 7-32]* |
| **Projections** | |
| No. of projections | Number of projections for one measurement.<br>Value range: 5 to 10000<br>Default: 800 |
| Save detector image | Projections are saved without correction.<br>The images are saved in a selected folder. You may select the folder and the file type under **Tools** → **Settings**. ➢ *See [⇨ Annex 8]* |
| Save corrected image | Projections are corrected and saved.<br>The images are saved in a selected folder. You may select the folder and the file type under **Tools** → **Settings**. ➢ *See [⇨ Annex 8]* |
| Projection path | Path in which the corrected and uncorrected projections are saved.<br>Default: defined folder for the projections + »\« + name of the measurement + current date and time |

**2** Switch to **Image correction**.



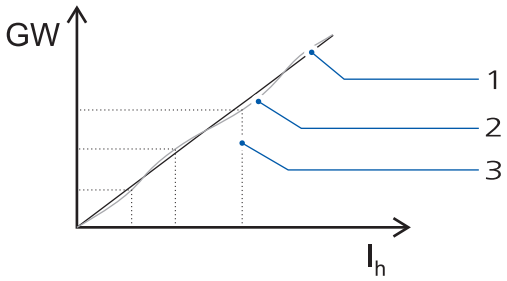

*CT measurement inspector; image correction*

The settings in this window allow you to improve the quality of the scanned images. All images are corrected mathematically before they are transferred to the reconstruction. To do so, one or more offset images and one or more gain images are scanned. Both the offset images and the gain images are averaged. As the scanned images are used for the correction of the images, you should scan several images. Image blurring is minimized by the averaging.

The procedure is as follows:

- The workpiece moves out of the beam path.
- The X-ray tube switches off automatically.
- An offset image is scanned to determine the response characteristics of the detector without radiation.
- The X-ray tube switches on and the default values for voltage and current are set automatically.
- One or more gain images are captured.

**Detailed information about »Image correction« in the CT measurement inspector**

| Text | Description |
|---|---|
| **Offset image correction** | |
| Number of images for averaging | Number of scanned offset images. The averaged image is used for the correction.<br>Default: 10 |
| **Gain image correction** | |
| Homogenization steps | Number of homogenization steps. A homogenization step corresponds to a mathematical node.<br>The ratio between the gray scale value for the radiation intensity of the detector is not exactly linear. Effect: If the gain image correction is carried out with only one homogenization step and specific radiation intensity, circular artifacts may be caused in the reconstructed volume. This effect can be corrected mathematically by using gain images with different radiation intensities. |
| | The more homogenization steps used, the more nodes are available for the nonlinear correction curve of the detector shown below. However, by increasing the number of homogenization steps, the measuring time is also increased.<br>Default: 7 |
| |  <br>GW Gray scale value<br>$I_h$ Homogenized radiation intensity<br>1 Ideal linear relation<br>2 Possible differing course<br>3 Homogenization step (node) |
| Number of images for averaging | Number of images scanned per homogenization step.<br>Default: 10 |
| **X-ray intensity correction** | The radiation intensity may vary during the measuring run. This can result in darker or brighter images as compared to the previous images. This effect can be compensated mathematically. |
| Dynamic gray scale value determination for each image | The variations in intensity in the detector image are permanently corrected by the dynamic gray scale value determination. For this purpose, a reference area is defined in the upper left area of the detector. |

| Text | Description |
|---|---|
| | Make sure that no workpiece is projected within the reference area throughout the entire measurement. ➢ *Reference area [⇨ 7-24]*<br>For the correction, a reference area is defined at the detector inside of which the radiation intensity is constant during the entire measuring run. The mean radiation intensity for each image is determined based on this reference area and then the whole image is scaled. |
| | The reference area is preset. It is a rectangle of 20x20 pixels. This area is located in the upper left corner of the detector. The upper left corner of the area starts with the position X = Y = 40 pixels.<br>No workpiece must be projected onto the reference area at any time during the measurement. The intensity correction is active by default. |
| Static gray scale value | If the projection of a workpiece in the reference area cannot be guaranteed, the correction must be carried out statically. For this purpose, you must enter a value for the gray scale value: Gain image less offset image.<br>Example:<br>Gray scale value of the offset image: 3000<br>Gray scale value of the gain image: 10000<br>➛ 10000- 3000 = 7000<br>The corresponding gray scale value can be seen in the »Pixel information« of the display window. ➢ *See [⇨ Annex 16]* |

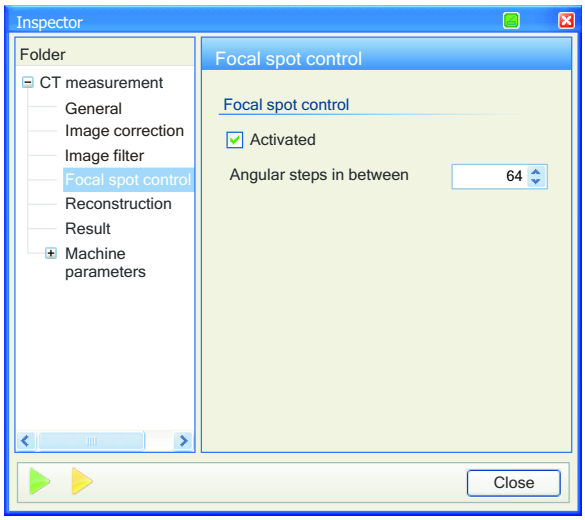
**3** Enable the median filter under **Image filter**, if desired.


*CT measurement inspector; image filter*

**Detailed information about »Image filter« in the CT measurement inspector**

| Text | Description |
|---|---|
| **Median filter** | |
| Activated | You may enable this to smooth noise in projection data and to compensate an undesired line structure in the area of the rotating axis. |
| Filter whole image | The median filter is used for the whole image. |
| Filter in vicinity of rotating axis | The median filter is only applied in the area around the rotating axis. |
| Filter region | Size of the area to be filtered. Specification in pixels. |

**4** Enable the focal spot control under **Focal spot control**, if desired.

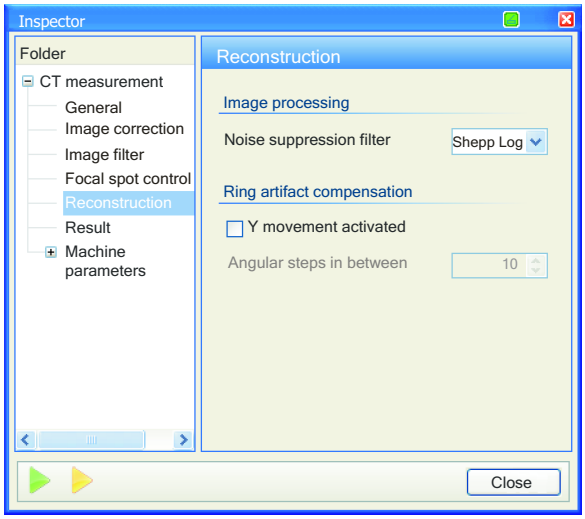



*CT measurement inspector; focal spot control*

**Detailed information about »Focal spot control« in the CT measurement inspector**

| Text | Description |
|---|---|
| **Focal spot control** | |
| Activated | As the repeated measurement of the focal spot position involves additional time, you can activate and deactivate this function.<br>Activation is recommended in the following cases:<br>– In case of high magnification, if the focal point is shifted by several voxels causing visible artifacts in the reconstruction (blurring, double edge).<br>– In case of geometric measurements on the reconstructions, as only the focal spot control can guarantee the reproducibility. |
| Angular steps in between | Focal spot control is performed every «n» angular steps.<br>Default: 64. If you reduce the value, focal spot control will be performed more frequently. Example: You have defined 960 projections for a measurement, i.e. 960/64 (default) = 15 focal spot control cycles, 960/40 = 24.<br>If the focal spot position changes during the measurement, a more frequent focal spot control can improve the measuring result. Consequently, if the focal spot position does not change, the measuring result cannot be improved by performing the focal spot control more frequently.<br>*Note*: Any additional focal spot control will increase the time taken for the measurement. |
|  | If the focal spot control has been activated in the Inspector for CT measurement, the program checks the existence of a correction file for the filter selected. If it is not available, the icon shown here will be displayed.<br>Holding the cursor over the icon will display a quick information.<br>" "The correction file of the selected filter required for focal spot control cannot be found in the following directory: … [path]" |

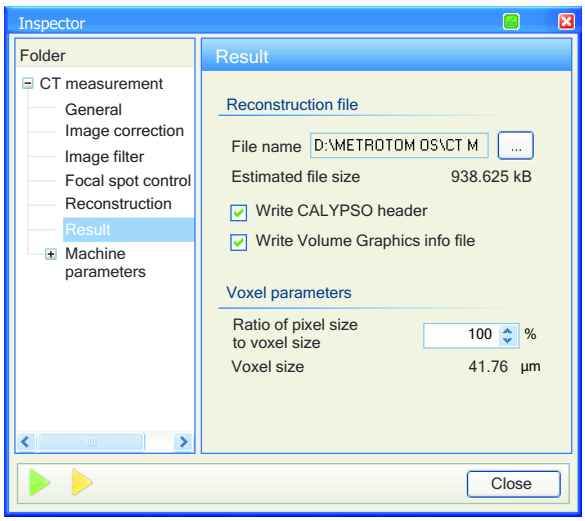
**5** Select a filter under **Reconstruction**.




*CT measurement inspector; reconstruction*

| Text | Description |
|---|---|
| **Image processing** | |
| Noise suppression filter | Filters are used for noise suppression in projections and improve the result of the reconstruction.<br>Default: Shepp Logan |
| **Ring artifact compensation** | |
| Y movement activated | You may enable this to compensate an undesired line structure in the area of the rotating axis. |
| Angular steps in between | The selection field is enabled if you select the check box above.<br>Default: There is a Y axis movement every 10 angular steps. |

**6** Make the entries under **Result**.




*CT measurement inspector; result*

| Text | Description |
|---|---|
| **Reconstruction file** | |
| File name | Name of the reconstruction file.<br>Default name: The name is composed of the following parts:<br>– Folder for reconstructions<br>– Name of the measurement<br>– Current date and time<br>If the *Write Calypso header* check box is activated, the file ending is »_scv«. |
|  | Button used to open the window for file type selection.<br>You have a choice between »*.uint16_scv« and »*.float32_scv«. For »uint16«, the file size is smaller. The file type is not important for later evaluation.<br>The »_scv« ending does not appear if **Write Calypso header** is deactivated. |
| Estimated file size | Estimated size of the reconstruction file.<br>The size depends on the size of the reconstruction area and on the ratio between pixel size and voxel size. If the file is larger than the free space on the disk, a warning is displayed and the field is marked with a red exclamation mark.<br>If the **Write Calypso header** check box is activated, the file size is increased by 1024 bytes. |
| Write Calypso header | If this check box is ticked, the reconstruction file contains data of the CT measurement and a signature in the header line.<br>The signature is required to enable the reconstruction file to be loaded by CALYPSO. This applies to CALYPSO version 4.8.06 and higher.<br>With older CALYPSO versions, the check box must be deactivated. |
| Write Volume Graphics info file | If this check box is activated, the VGI info file is written. The info file is required to enable the reconstruction file to be loaded by VGStudio MAX. |
| **Voxel parameters** | |
| Pixel/voxel size ratio | The voxel size in the reconstruction file can be influenced here.<br>The voxel size here corresponds to the calculated voxel size. It is determined by the resolution of the detector, the distance of the X-ray tube from the detector and the distance of the X-ray tube from the rotating axis of the rotary table. |

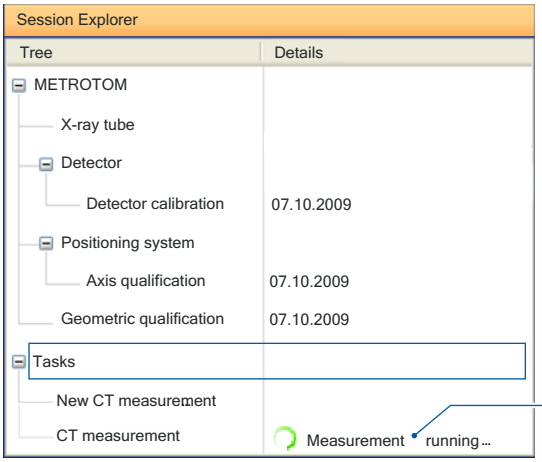
| Text | Description |
|---|---|
| | – 100% means: Voxel size in the reconstruction file = natural voxel size. The full resolution capacity of the detector is used.<br>– > 100%: Voxel size in the reconstruction file > natural voxel size. The full resolution of the detector is not considered. The value is marked with a red exclamation mark.<br>– < 100%: Voxel size in the reconstruction file < natural voxel size. The resolution is larger than the resolution of the detector. The value is marked with a red exclamation mark.<br>Default: 100% |
| Voxel size | Output of the voxel size in the reconstruction file in [µm] |

## Starting the measurement

Once you have made the settings for the measurement, you can start the measurement

**1** Click the green arrow in the »CT measurement« Inspector window.

The measurement is added to the task list. The Inspector window is closed. The measurement status is shown in the *Details* column.




*Session Explorer, Tasks*

1 Status of a new CT measurement

The measurement will be started instantly if presently no other measurement runs. Otherwise, the measurement is added to the task list and gets the »Queued« status.

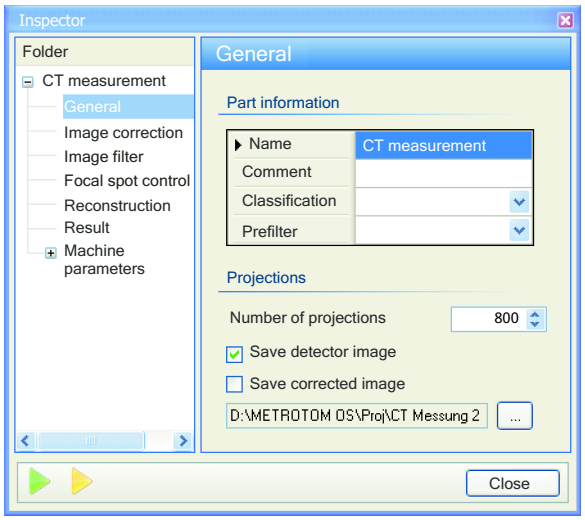
The progress of the measurement is displayed in the status bar.

# Defining the measurement

If you do not want to start a measurement immediately, you may define a future measurement in advance. There is a button in the »CT measurement« inspector. If you click the button, a future measurement is added to the task list. The measurement gets the »In definition« status. Double-click this measurement to open the Inspector. You may start or delete this measurement in the inspector, change the settings or save it by clicking **Close**.

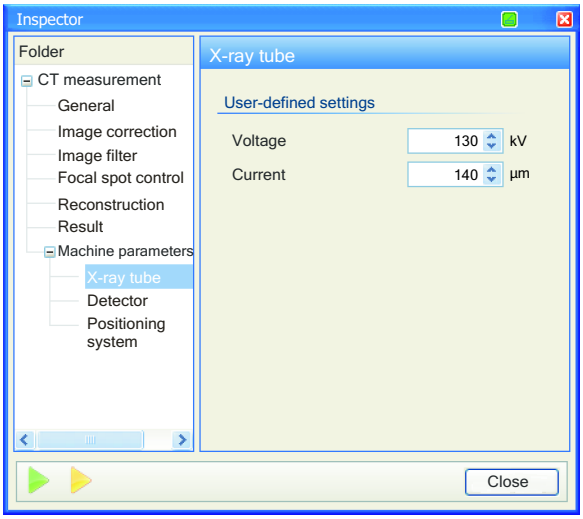
1 Double-click **New CT measurement** in the Session Explorer.

The Inspector window for »CT measurement« opens.




2 Carry out the settings. See ➤ *Creating a new measurement [⇨ 7-34]*

If you define a measurement, make the settings of the CT component under **Machine parameters**.

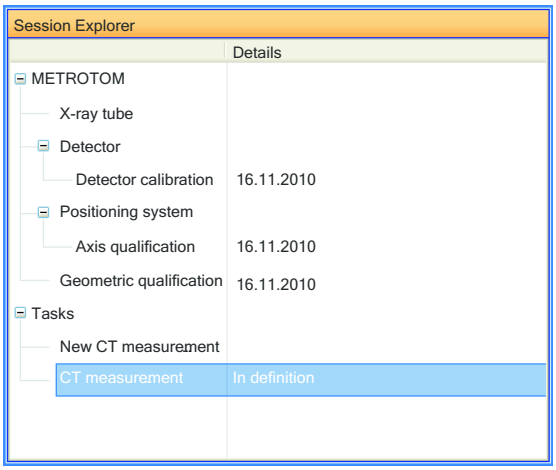



*CT measurement inspector; X-ray tube*

You can make the settings and define the measurement later on or vice versa.

**3** Click the button shown here to define a measurement.

The measurement is added to the task list in the Session Explorer. The measurement gets the »In definition« status.




*Session Explorer, measurement with »In definition« status.*

Double-click the CT measurement to open the Inspector again. If you change the settings and click **Close** in the Inspector, the new settings will be applied.

Starts the measurement

Deletes the defined measurement

# Information on the measurement

## Measuring run

Prior to the actual measurement, first one or more offset images and gain images are scanned according to the settings made under **Image correction**. This serves for the homogenization of the radiation intensity. The corrected images form the basis for the reconstruction. ➢ *Radiation intensity [⇨ 7-33]*

### Measuring run without focal spot control

The following sequence for a measurement is produced:

1. Travel the workpiece out of the beam path.
2. Switch off the X-ray tube.
3. Acquisition of one or more offset images.

   Only the averaged image is used for the calculation.

4. Switch on the X-ray tube and set voltage and current.
5. Acquisition of one or more gain images.

   Gain images are scanned for each homogenization step. For the calculation, only the averaged image is used for each homogenization step.
6. Position the workpiece in the beam path with a rotary table angle of 0°.
7. Measurement of projection 1.
8. Rotate the rotary table to the next angular position.

   The rotation angle depends on the number of projections and is calculated as follows: 360° / number of projections.
9. Measurement of projection 2.
10. Rotate the rotary table to the next angular position.
11. Measurement of projection 3.

Repeat the last two steps until the measurement for the last projection is carried out.

### Measuring run with focal spot control

The sequence for a measurement with focal spot control is as follows:

1. Travel the workpiece out of the beam path.
2. Switch off the X-ray tube.
3. Acquisition of one or more offset images.

   Only the averaged image is used for the calculation.
4. Switch on the X-ray tube and set voltage and current.
5. Acquisition of one or more gain images.

   Gain images are scanned for each homogenization step. For the calculation, only the averaged image is used for each homogenization step.
6. Position the piece for focal spot control.
7. Capture one or several images for focal spot control.
8. Position the workpiece in the beam path with a rotary table angle of 0°.
9. Measurement of projection 1.
10. Rotate the rotary table to the next angular position.

    The rotation angle depends on the number of projections and is calculated as follows: 360° / number of projections.
11. Measurement of projection 2.
12. Rotate the rotary table to the next angular position.
13. Measurement of projection 3.

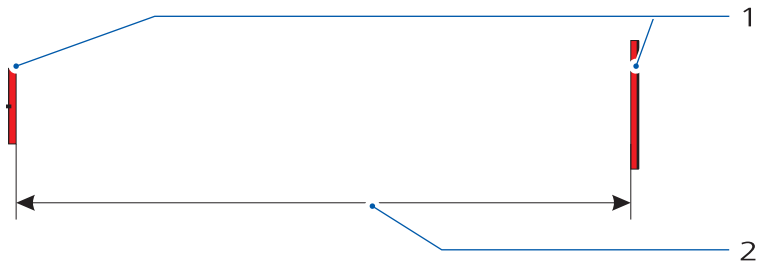
14. Position the piece for focal spot control once N projections have been measured since the last focal spot control.
15. Capture one or several images for focal spot control.
16. Position the workpiece in the beam path and rotate the rotary table to the next angular position.
17. Measurement of projection X.
18. Rotate the rotary table to the next angular position.
19. Measurement of projection X+1.

The steps 14-18 are repeated until the measurement of the last projection has been carried out.

## Possible errors

### Influence of the X position on the CT measurement

Not the entire X range is exactly qualified during the axis qualification. A small zone in front of the X-ray tube and in front of the detector cannot be qualified due to the procedure.




*Area for axis qualification*

1 Range not qualified
2 Qualified by axis qualification

If the X position is in the range that has not been qualified, the following message will appear when you start a CT measurement.

"The current X position is outside of the qualification range of the last axis qualification (10.0000-580.0000)! Click »OK« to proceed with the measurement or »Cancel« to quit the measurement."

If you still wish to carry out the measurement, this may lead to useless measuring results. It is preferable to cancel the measurement and change the X position.

## Locking of functions

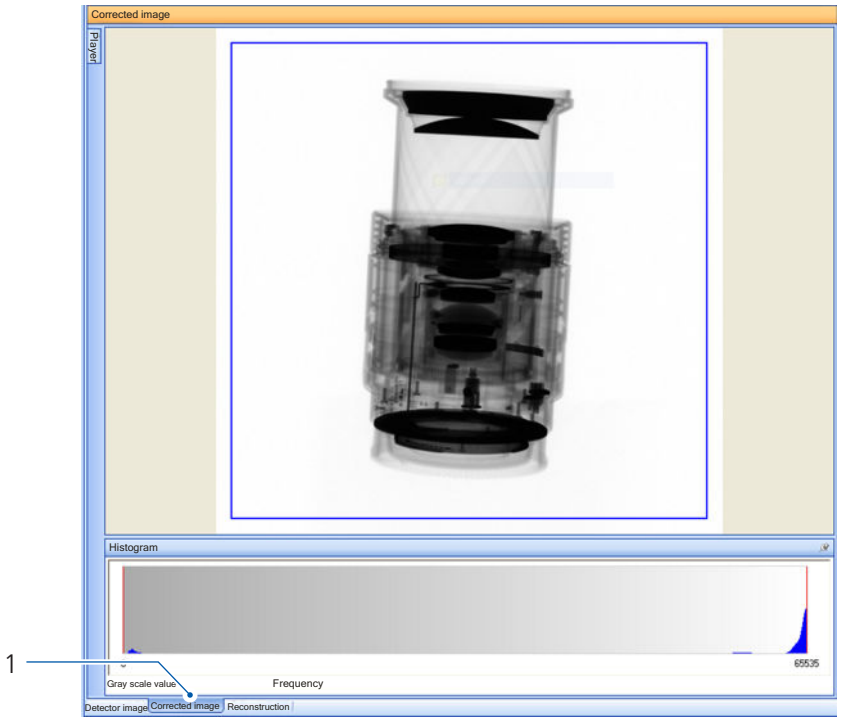
Certain functions are locked during the measurement. These include:

– Control Panel
– Settings for the X-ray tube, detector and positioning system.

Only the button used to switch the X-ray tube off is active in the Control Panel.

## Displaying corrected images

The corrected images are displayed during the measurement in the preview under »Corrected image«.




*Detector image, corrected image*

1 »Corrected image« tab

## Reconstruction

After recording and evaluating the images, a reconstruction is carried out. Normally, the workpiece is reconstructed in one process. The reconstruction works in several steps with large data volumes. This takes place automatically. The time taken for reconstruction is slightly increased by this measure.

**NOTICE**

Large data volumes are produced with high detector resolution, a large reconstruction area and no binning.

## Canceling the measurement

A measurement can be canceled in the Inspector window.

**1** Double-click the respective measurement.

The Inspector window for the selected measurement opens.

**2** Click the button shown here to abort the measurement.

The measurement for the current image is finished and then the measurement is closed.

**NOTICE**

If X-ray radiation is switched off during a measurement, the measurement is also cancelled. In this case, the following error message is output in the Event Viewer: "Image {0} cannot be measured. Measuring run aborted"

## After the end of measurement

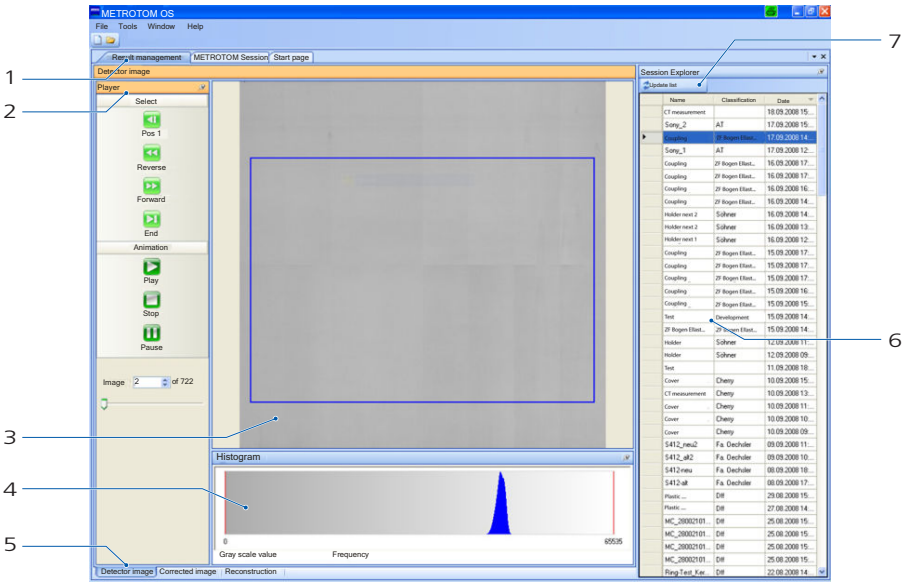
When the measurement is finished, it will be removed from the task list. The settings of the CT components are saved in the database. The reconstruction file and the detector images are saved in the specified folder.

| | |
|---|---|
| Reconstruction file | To enable loading of the reconstruction file with the CALYPSO versions 4.8.06 and higher, the **Write Calypso header** check box under **Result** in the settings must be ticked. In this case, only one file is required for the evaluation with CALYPSO. Make the settings in the Inspector for CT measurement under **Result**. |
| VGI file | With CALYPSO versions prior to 4.8.06, the **Write Calypso header** check box must be unticked. However, to enable an evaluation with CALYPSO, the **Write Volume Graphics info file** check box must be ticked. In this case, a VGI file is saved. This file includes the relevant parameters of the measurement and can be loaded by means of **VGStudio Max** and older CALYPSO versions. |

# Result management

## Window for result management

Click **File** → **New** → **Result management** to open the window for the result management.




*Result management*

1 »Result management« tab
2 Player functions: Buttons for displaying the images
3 Display window for saved images
4 Histogram window
5 Tabs for the selection of the image types
6 List of all measurements performed
7 Updating of the listed measurements

**NOTICE**

All the measurements performed are listed in the Session Explorer. The entries under **Name** and **Classification** originate from the »New CT measurement« Inspector window.

## Image display

Projection images and reconstruction images can be displayed subsequently in the display window. The prerequisite is that the projection images have been saved during the measurement. You can select it under »General« in the Inspector for CT measurement.

## Image types

You can select the images to be displayed via tabs which are displayed in the bottom left area of the database window. There are three image types:

– Detector image

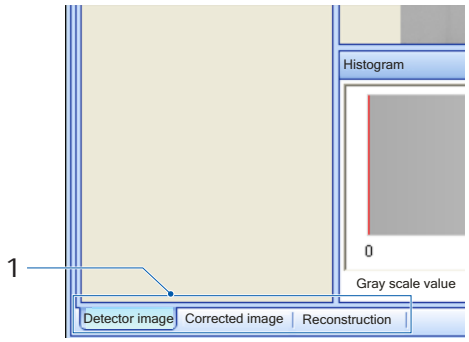
  The uncorrected image projected onto the detector.

– Corrected image

  Display of the corrected detector image.

– Reconstruction

  The reconstructed XY layers of the workpiece are displayed.




*Result management, image types*

1 Tabs for the selection of the image types

Proceed as follows to display images:

**1** Select the measurement in the Session Explorer.

**2** Select the tab for the image type.

The display window shows the first image of the CT measurement after the corrected images. Corrected images are offset images, gain images and possibly images of the focal spot control. You can navigate to other images by using the player.

## Player

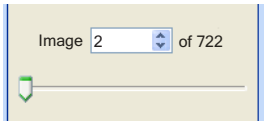
The player is used for the navigation through the saved images. The selected image is displayed in the display window. You can navigate to special positions or have the images displayed in an animation by using the buttons.

**NOTICE**

The buttons are not active unless images exist.

| Buttons for ... | | Meaning |
|---|---|---|
| **Selection** | Pos 1 | Navigation to the first image |
| | Back | Navigation to the previous image |
| | Forward | Navigation to the next image |
| | End | Navigation to the last image |
| **Animation** | Play | Continuous displaying of all images in a sort of a movie |
| | Stop | Interruption of the continuous displaying and navigation to the first image |
| | Pause | Interruption of the continuous displaying at the current position |

In addition to the buttons, the images can also be selected directly.




*Result management, image selection*

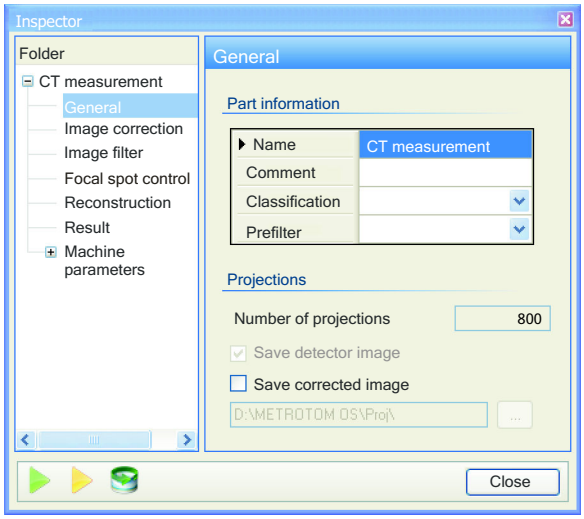
– Enter the image number in the input field.

  Alternatively, you can select the images by using the slider.

# Saved settings

## Displaying the settings

Double-click a measurement to open the Inspector window.




*Result management, CT measurement inspector; general*

In this window you have the following options:

– View the settings for the measurement.

– Change the settings and carry out a new reconstruction.

– Use the settings to define a new measurement.

– Start a new measurement with the old or new settings.

**Buttons in the Inspector for CT measurement**

| Symbol | Meaning |
|---|---|
|  | Starts a new measurement with modified settings. The measurement is added to the task list in the Session Explorer. |
|  | Applies the settings for a new measurement. The measurement is added to the task list in the Session Explorer. The measurement gets the »In definition« status. |
|  | Performs a new reconstruction. |

## Carrying out a new reconstruction

You can carry out a new reconstruction after the uncorrected projection images were saved. You can change the following parameters for the new reconstruction:

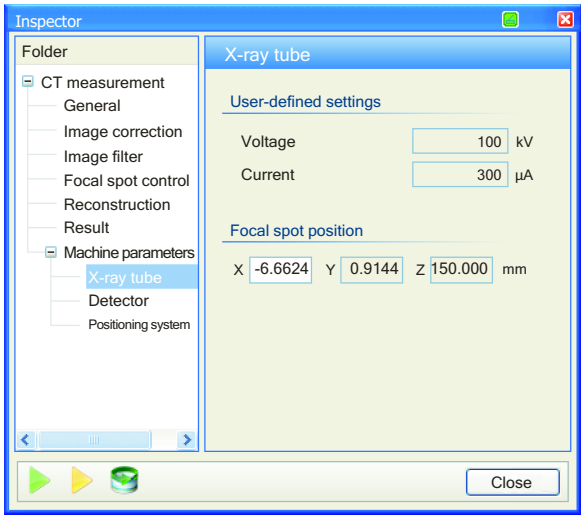
– All settings which can also be made for a new measurement, except the number of projections, the settings for offset image and gain image correction and the ring artifact compensation.

– Reconstruction area

– In addition: Positions of the tube and the detector.

This will be necessary if the axis qualification is no longer valid for the measurement. You can identify this by a double frame in the reconstruction images. ➢ *See [⇨ 7-58]*

– Activate the beam hardening correction. ➢ *Further information [⇨ 7-60]*




*Result management, settings for the X-ray tube*

**Consequences of modifications of the machine parameters**

| Alteration | Component | Influence |
|---|---|---|
| **X Value** | **X-ray tube and detector** | Size of the voxel |
| **Y Value** | **Detector** | Width of the double frame in the detector image |

Proceed as follows to carry out a new reconstruction:

**1** Double-click the CT measurement.

**2** Change the settings if necessary.

**3** Click the button shown here.

A new reconstruction is carried out. The new reconstruction is saved as a new CT measurement in the database.

## Defining the measurement

You can also apply the settings for a measurement you want to carry out later on.

**1** Double-click the CT measurement.

An Inspector window opens.

**2** Change the settings if necessary.

**3** Click the button shown here.

A new measurement is added to the task list in the Session Explorer. The measurement gets the »In definition« status. You can still modify the settings of this measurement later on. Now you can also start the measurement at any time. ➢ *See [⇨ 7-47]*

### Applies the settings

You can apply the settings to a new measurement.

**1** Double-click the CT measurement.

An Inspector window opens.

**2** Change the settings if necessary.

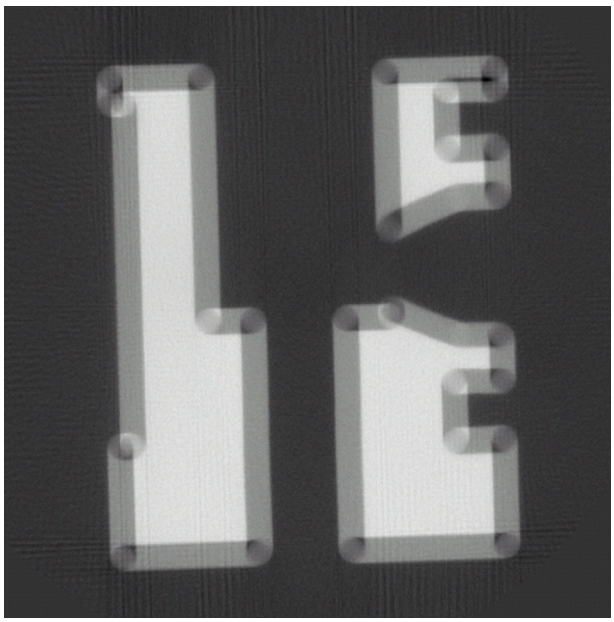
**3** Click the button shown here.

A new measurement is started with the settings in the Inspector. The measurement is added to the task list in the Session Explorer. It gets the »Measurement running...« status. If a measurement is being performed, it gets the »Queued« status.

## Checking the reconstruction

Once the reconstruction has been completed, you should check the result and the quality. Make sure that the contour of the workpiece can be clearly recognized. It is a problem if a double edge is visible at the edges of the workpiece contour. In this case, you must carry out an axis qualification immediately. ➢ *See [⇨ 6-19]*

Example of a hardly recognizable contour:



*Reconstruction, double edge*

The double edge appears to indicate form errors. Example: In the case of a layer of three voxels and a voxel size of 50 µm, the measuring error is 0.15 mm. Such measuring errors can be avoided by carrying out a new reconstruction

## Correction of the reconstruction

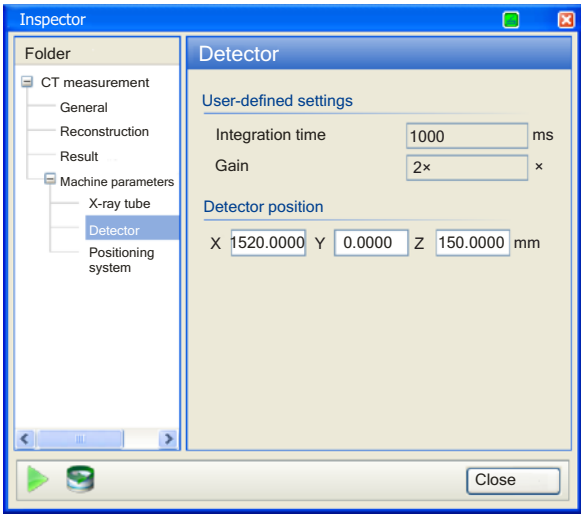
**NOTICE**

If a double edge can be recognized, the measuring data need not be rejected.

1 First qualify the axis.

2 Carry out the reconstruction again with a slight translation of the rotating axis.

- First define a small reconstruction area.
- Open the Inspector with a double click and select **Detector**.
- Modify the Y value, e.g. by ±1 mm.




*Result management, inspector, detector settings*

3 Click the button shown here.

A new reconstruction is carried out. The new reconstruction is saved as a new CT measurement in the database. Several trials, which can be carried out quickly due to the reduced reconstruction area, are generally necessary. The criterion is that there is no double edge and the workpiece contours are as sharp as possible.

4 If the result is satisfactory, select the size of the reconstruction area in such a way that the entire workpiece is located inside the reconstruction area.

5 Start again the reconstruction.

After the reconstruction, the workpiece contour should be clearly recognizable.

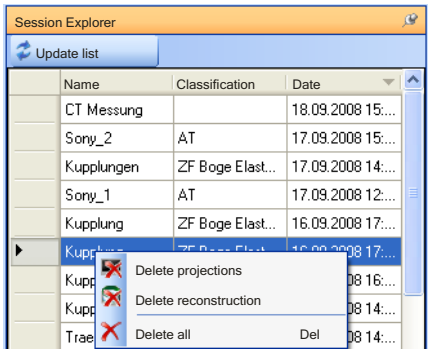
*Workpiece contour after repeated reconstruction*

## Deleting images

You can delete the saved projection images and reconstruction images.

**1** Select a CT measurement.

**2** Open the context menu with the right mouse button.




You can delete projection images and reconstruction images. The corrected and uncorrected projection images are deleted. The settings of the CT components remain unchanged.

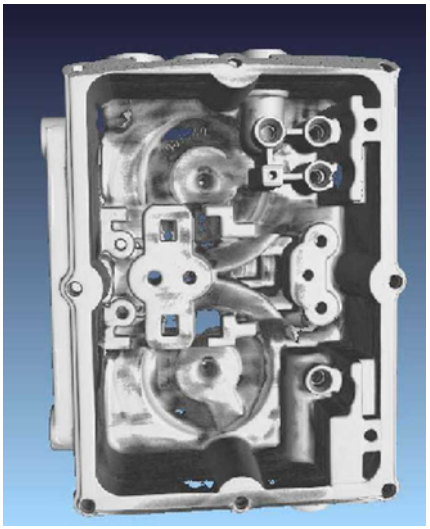
**3** Select the images to be deleted.

## Correcting the beam hardening

If you measure metal pieces, there are often disturbing artifacts due to beam hardening. These artifacts can be reduced subsequently by calculation. The prerequisite is that the projection images have been saved.

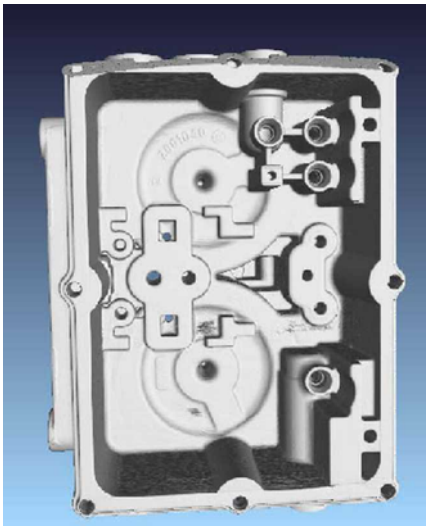
Beam hardening correction is one of METROTOM OS's optional features. To use the functions, you need to purchase a license.

## Example for artifacts



*Reconstruction without beam hardening correction*

Without beam hardening correction, the gray scale values of surfaces may not have a uniform appearance. This may produce an incomplete visualization of the workpiece surface.



*Reconstruction with beam hardening correction*

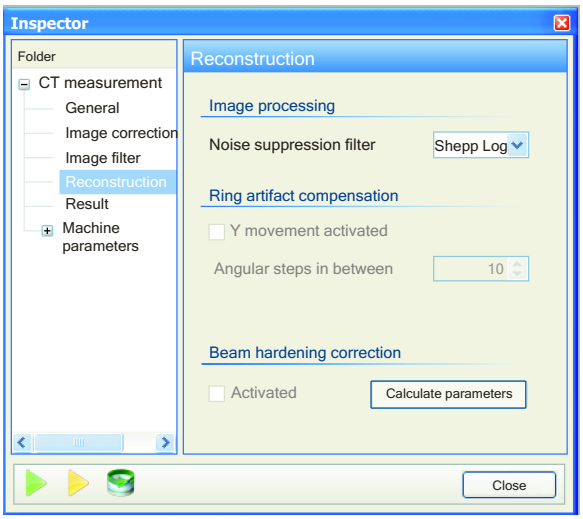
With beam hardening correction, the gray scale values of the surfaces have a uniform appearance. The surfaces of the workpieces are also visualized completely.

## Calculating the parameters

**1** Open the windows for result management.

**2** Double-click a measurement.

The Inspector window for CT measurement opens.

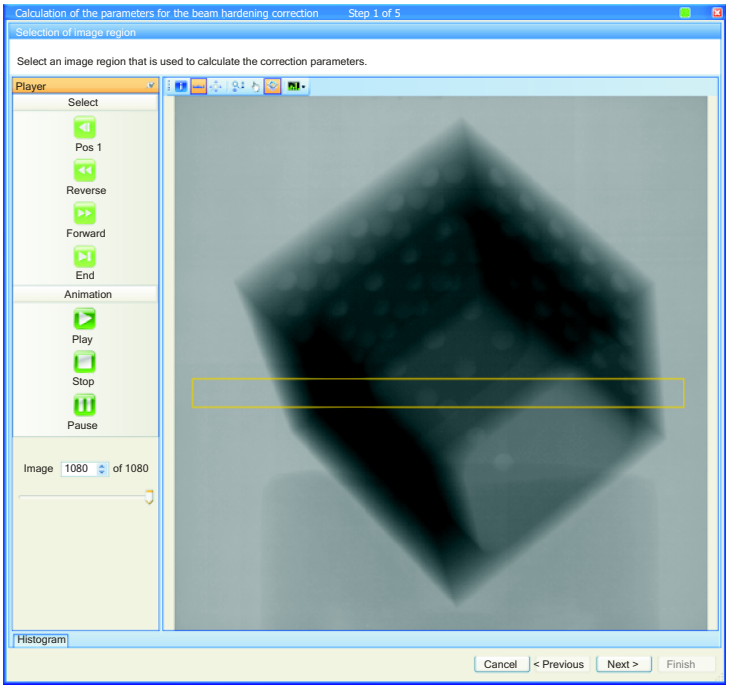



3 Select the »Reconstruction« folder.

The check box under **Beam hardening correction** can be ticked not before the parameters have been calculated. In the following, the procedure for calculating the parameters is described.

4 Click **Calculate parameters**.

The following window opens:



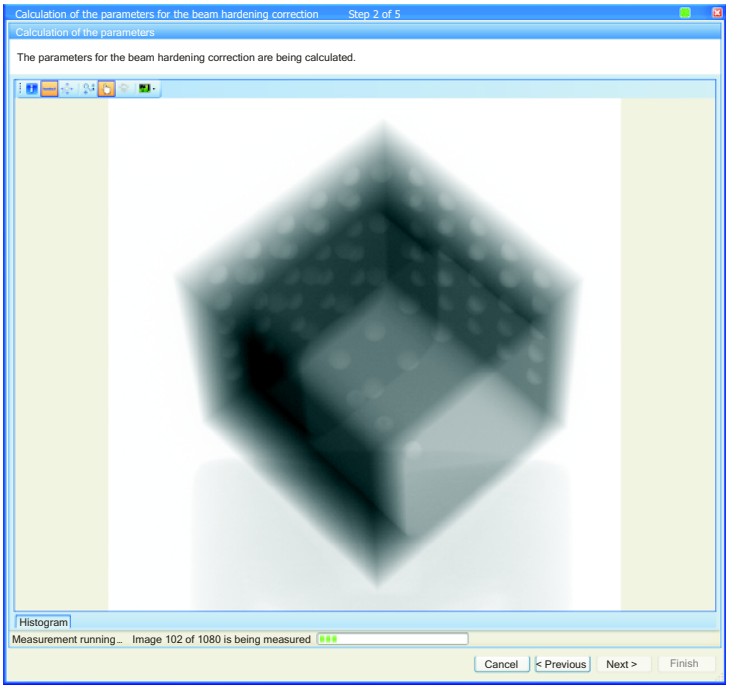

*Beam hardening correction; step 1 of 5*

This is the window for the first of five steps.

- Select the area for the reconstruction.

By default, the reconstruction area selected for the measurement is displayed. It is recommended to use this area.

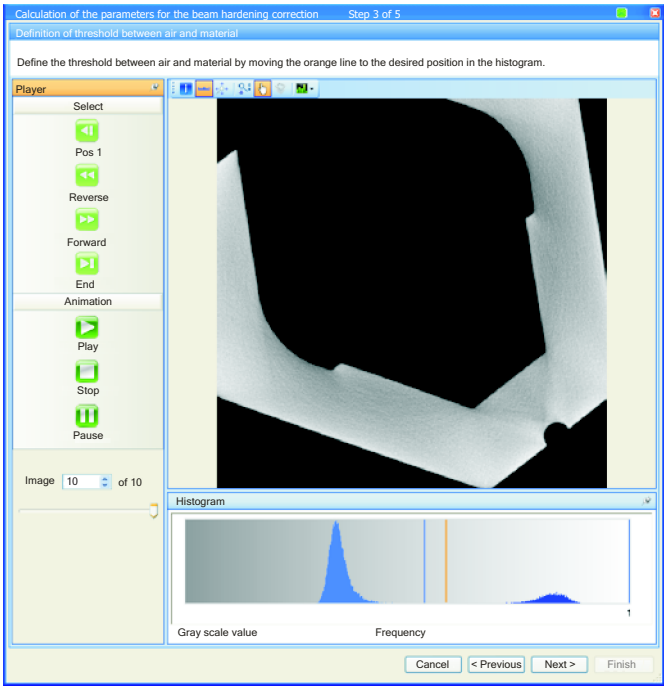
**5** Click **Next**.




*Beam hardening correction; step 2 of 5*

The first reconstruction using ten layers of the selected image region is performed. This is done to calculate the parameters for beam hardening correction. The progress can be seen below the image. Later on six other reconstructions will be performed.

As soon as the first reconstruction is finished, you automatically get to the third step.

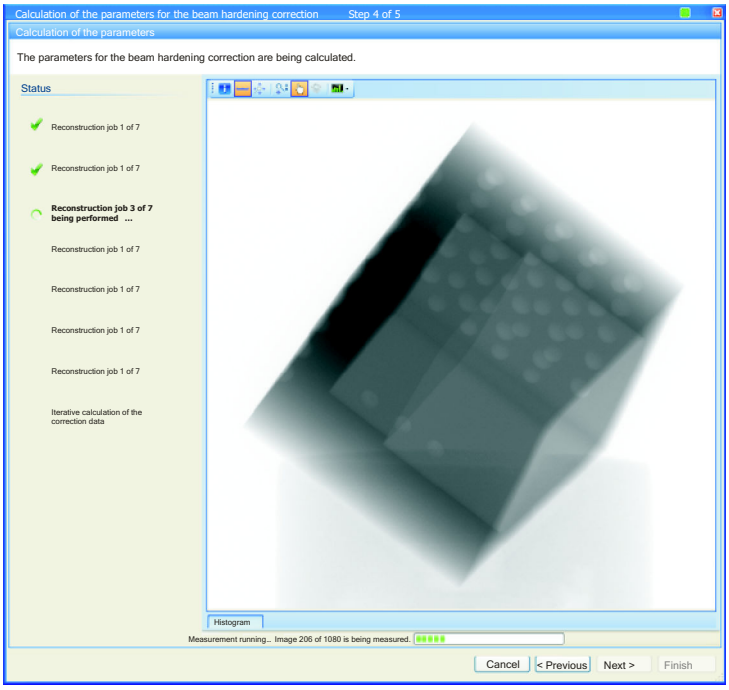



*Beam hardening correction; step 3 of 5*

In a third step, you define the gray value limit between the material of the component and the air.

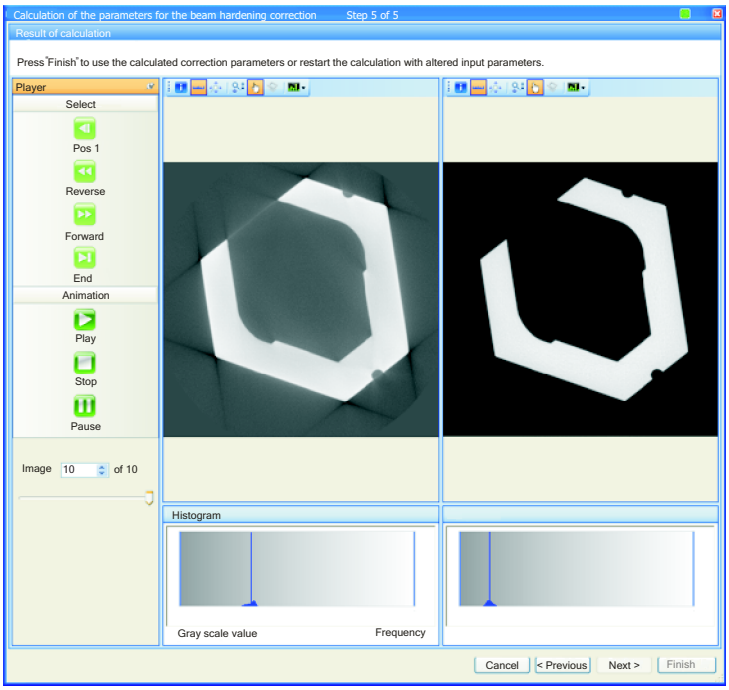
- Move the orange line in the histogram between the two peaks of air and material.

**6** Click **Next**.



After having defined the gray value limit, the remaining six reconstructions required for calculating the correction parameters are performed.

As soon as the sixth reconstruction is finished, you automatically get to the fifth and last step.




In the last step, the corrected and the uncorrected reconstruction are contrasted. On the left, there is an image without correction, and on the right, an image with correction.

If the result is not as good as desired, you may repeat the previous steps with modified parameters.

**7** If the result is satisfactory, click **Finish**.

The parameter calculation has finished.

**NOTICE**

You can now use the calculated parameters for the complete data record. To do so, enable the beam hardening correction under »Reconstruction« in the result management in the Inspector for the CT measurement and then repeat the reconstruction.

# Chapter 8

# Errors and faults

**This chapter contains:**

# Errors occurring prior to the measuring run

If the CT cannot be started, check whether the following errors can be excluded:

**Basic errors**

| Errors | Cause | Measure | Check |
|---|---|---|---|
| The CT cannot be started. | Wrong start-up sequence. | – Follow the given sequence.<br>– First, switch the CT on and then the computer. | |
| Power supply | Main switch is not switched on. | Connect power supply:<br>– Switch the *main switch* to position «1». | Position «1» must be visible. |
| Control unit | Power supply has not been switched on. | Switch the power supply on:<br>– Turn the *rotary switch* clockwise. | The indicator lamp must light up. |
| Drives | The drives have not been switched on. | Switch the drives on:<br>– Press the green *button*. | The indicator lamp must light up. |
| | *EMERGENCY STOP button* is locked on the CT or control cabinet. | Unlock the button:<br>– Turn the *EMERGENCY STOP button* slightly. | The button pops out a few millimeters. |
| Operating mode | The operating mode has not been activated. | Set the operating mode:<br>– Turn the *key switch* to the «AUTO» position. | |
| X-ray system | The X-ray system has not been switched on. | Switch the X-ray system on:<br>– Turn the *key switch* to the «ON» position. | |

1 If the above mentioned errors can be excluded, put the CT out of operation and repeat the start-up procedure.

2 If measuring operation is still not possible, call a ZEISS service engineer or our hotline. ➢*Page [⇨ 8-5]*

# Faults during the measuring run

The following table helps you to identify and eliminate faults occurring during the measuring run. A fault may have different causes. One or more measures may be necessary to eliminate a certain cause. If two measures are proposed, this does not mean that both of them have to be taken to eliminate the fault.

**Faults during the measuring run**

| Fault | Cause | Measure | Check |
|---|---|---|---|
| No travel movement possible. | *EMERGENCY STOP button* is locked on the CT or control cabinet. | Unlock the button:<br>– Turn the *EMERGENCY STOP button* slightly. | The button pops out a few millimeters. |
| | Collision, e.g. workpiece with X-ray tube. | – Eliminate the cause of the collision.<br>– Reactivate the drives.<br>– Reinitialize the X-ray tube if necessary. | |
| | MAN operating mode set or *key switch* in «0» position. | Turn the *key switch* to the AUTO position. | |
| | CT measurement started. | – Wait until the CT measurement is terminated. | |

If measuring operation is still not possible, call a ZEISS service engineer or our hotline. ➢ *See [⇨ 8-5]*

# Measures to be taken after an EMERGENCY STOP

Once an EMERGENCY STOP has been activated, you must proceed as follows:

1 Unlock the EMERGENCY STOP button.

- Unlock the button by turning it slightly.

  Then the button automatically releases and unlocks.

2 Reactivate the drives.

3 Close and restart METROTOM OS.

# Service features

## Hotline

If it is not possible to eliminate a fault and it occurs again after a renewed start-up, call a ZEISS service engineer or our hotline in Oberkochen (Germany). You may also inform us by e-mail.

**Contact data**

| | | |
|---|---|---|
| Phone | Within Germany: | 01803.336336 |
| | From abroad: | +49.7364.20.6337 |
| | Service hours: | Monday to Friday from 8:00 to 17:00 |
| E-mail | imt.hotline.metrotom@zeiss3d.de | |

Chapter 9

# Maintenance and care

**This chapter contains:**

# Maintenance

## Maintenance

### Purpose of maintenance work

The maintenance work is to assure...

– ...safe measuring operation,

– ...that there are no downtimes,

– ...that the CT always measures with maximum accuracy.

In order to guarantee these features in the long run, the CT requires regular maintenance.

**NOTICE**

Maintenance work must be carried out only by competent specialists. These persons must have received special training on the corresponding CT qualifying them to carry out all necessary maintenance work.

### Maintenance agreement

We recommend concluding a maintenance agreement to guarantee safe operation. ZEISS offers maintenance agreements relieving you of any need to worry about maintenance.

– If you wish to subsequently conclude a maintenance agreement, call our hotline. ➢ *See [⇨ 8-5]*

Regarding maintenance work, a distinction is made between *maintenance of the X-ray system* and *extensive maintenance*. The maintenance of the X-ray system is the prerequisite for the operation of the CT system.

## Maintenance intervals

In case of normal operation of the CT system, annual maintenance is sufficient. With a 3-shift operation, however, maintenance work must be performed twice a year.

**NOTICE**

The specified maintenance intervals apply if the required environmental conditions are met.

Non-observance of the maintenance intervals may lead to damage to the CT system. This is the responsibility of the operator.

**Maintenance intervals**

| Degree of utilization | Maintenance interval |
|---|---|
| | Extensive maintenance (maintenance of the entire CT system) |
| One-shift operation | Once a year |
| 2-shift operation | Once a year |
| 3-shift operation | Twice a year |

# Maintenance work

Maintenance work includes inspection of the following:

**Maintenance work**

| Area | Examples |
|---|---|
| Safety devices (standard equipment) | For example drive monitoring; collision protection in the series measurement mode |
| Control unit | For example, the operator's controls on the control cabinet |
| Drive unit | Motor and gearing unit |

When concluding a maintenance agreement, you also must specify any optional equipment to be covered.

## Prerequisite for restart

After completing maintenance work, you may only put the CT into operation again if the following prerequisites are fulfilled:

– All work has been entirely completed.

– The CT is ready for operation.

– The maintenance personnel has left the working area.

# Care

## What you should know!

The CT must be cleaned regularly. Especially the interior of the radiation protection enclosure must be free of dirt and metal particles.

**NOTICE**
You may only carry out those measures for care that can only be performed from the outside. Never step into the interior of the radiation protection enclosure. Call your ZEISS service engineer if there are foreign substances in the radiation protection enclosure.

### Cleaning and checking

The measures for care also include the regular cleaning and checking of certain components. For cleaning, you require:

– Mild detergent

  Use grease dissolving and non-corroding cleaning agents.

– Fluff-free cloth, e.g. made of linen

– Vacuum cleaner

Do not use the following substances:

– Chlorinated hydrocarbons, such as tetrachloroethane or trichloroethane

– Flammable, volatile or caustic liquids

**⚠ CAUTION**

**Risk of injury due to accidental travel movements.**
Risk of crushed parts of the body and eye injuries caused by styli.

a) Switch the drives off in order to enable safe execution of the care measures.

**Damage caused by swirling dust particles due to compressed air**
Dust particles may impair the function of guideways and other components of the CMM.

a) Do not use compressed air for cleaning the CT.

**NOTICE**
Preventive care also includes making sure that all workpieces to be measured are clean. The workpieces must be free from machining residues (e.g. metal chips, oil) and dust. Clean the workpieces before placing them on the rotary table.

# Overview

The components requiring care are listed below. The time intervals only apply if all installation site requirements are met.

**Care measures**

| Object | Interval | Type of care |
|---|---|---|
| Rotary table plate | Every month | Vacuum cleaner, cleaning agent |
| Threaded holes in the rotary table | Every month | Vacuum cleaner |
| Bellows cover | Every month | Vacuum cleaner |
| Housing covers | Every month | Mild, normal cleaning agent |

# Chapter 10

# Shutdown and disposal

**This chapter contains:**

# Shutdown

If you want to shut down the CT system for a longer period of time, the CT system must be disconnected from the power supply. We recommend storing the CT system in a dust-protected place.

1 Close all doors of the CT system.

2 Disconnect the CT system from the power supply.

3 Cover the CT system using a tarpaulin, for example.

# Disposal

## Packaging

The regulations of the country in which the CT scanner is installed apply to the disposal of the packaging material.

## CT scanner

### General information

#### Why is proper disposal necessary?

Proper disposal of the product serves to protect the health and environment.

#### Resale

If you wish to resell the CT scanner or its peripherals, you must inform the buyer about his obligation to ensure proper disposal.

#### Labeling of electronic components

Some components of the CT scanner carry the symbol shown below. This symbol indicates that the component contains electronic component parts that must not be disposed of with general household waste.

**Validity for EU 27 member states**

The marked components must be disposed of correctly according to the WEEE directive 2002/96/EC or the respective country-specific legislation applicable within the EU 27 member states. This symbol is only valid within the European Union.

#### Information about WEEE and RoHS

**Category 9 (WEEE)**

All products by Carl Zeiss IMT GmbH including the trade goods, such as TSK and OEM products, sold by us and carrying the ZEISS logo are assigned to the category 9 of the annex of the WEEE directive.

If the technique permits it, new products are designed according to RoHS.

#### Regulations

**Return according to the general terms and conditions**

The CT scanner and peripherals can be returned to us for disposal. Of course, it is also possible to set up other rules according to the directive ElektroG to govern the disposal. The return of the CT scanner takes place on the basis of the general terms and conditions.

| | |
|---|---|
| For customers within the European Union: | Please contact your dealer or supplier regarding the disposal of electrical and electronic devices. |
| Outside the European Union: | Comply with the corresponding laws and other local regulations regarding the disposal of electrical and electronic devices. |

## Special information about materials

### Beryllium

There is a thin beryllium plate at the outlet window of the X-ray tube. The plate is protected by the collimator plate.

Beryllium is very dangerous to health. Prevent contamination of water, sewage or soil by the material. It must be disposed of properly exercising extreme caution.

**NOTICE**

The surface of this plate must not be damaged under any circumstances. If it gets damaged, particles will be released. They may get into the respiratory system causing health damage.

The beryllium plate weighs less than two grams.

# Alphabetic index

# Glossary

| Begriff | Erklärung |
|---|---|
| CT | Abbreviation for »CT scanner« |
| Equivalent dose | Multiplication of energy dose and X-ray weighting factor |
| Exposure to radiation | Exposure of living things to ionizing radiation |
| RöV | Abbreviation for »Röntgenverordnung« (German X-ray ordinance) |
| Voxel | Made-up word based on »volumetric« and »pixel«. This term refers to the following two points: 1) In the case of a spatial data file which is available in discretized form in cartesian coordinates, voxel represents the discrete value of an XYZ coordinate of a data file. This definition represents the three-dimensional equivalent of a pixel. Thus, a voxel does not have any specific form. It is also referred to as isotropic voxel or »volume pixel«. The data contained in voxel matrixes are very often color values which are used for visualization together with the functions of the volume graphics. 2) In all other cases, voxel refers to a cuboid cell within a regularly divided cuboid or unlimited space. In most cases, this definition is used for certain techniques for the acceleration of ray tracing or for certain methods of numeric simulation. |

# Annex

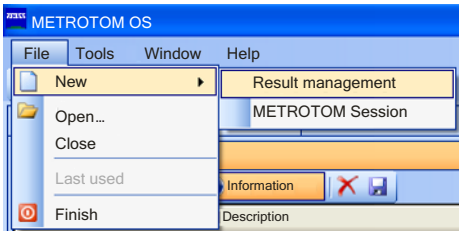
**This chapter contains:**

# Further information about METROTOM OS

## Menu bar – User software

### File ➛ ...

#### File → New




*Menu: **File***

| Menu | Description |
|---|---|
| Result management | Opens the database in which all measurements carried out are stored. ➛ *See [⇨ 7-53]* |
| METROTOM Session | Creates a new measurement session. |

#### File → Open ...

Currently no function.

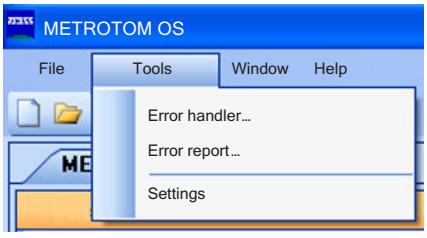
#### File → Close

Closes the current »METROTOM Session« or »Result management« tab.

#### File → Exit

Quits the user software.

### Tools ➛ ...



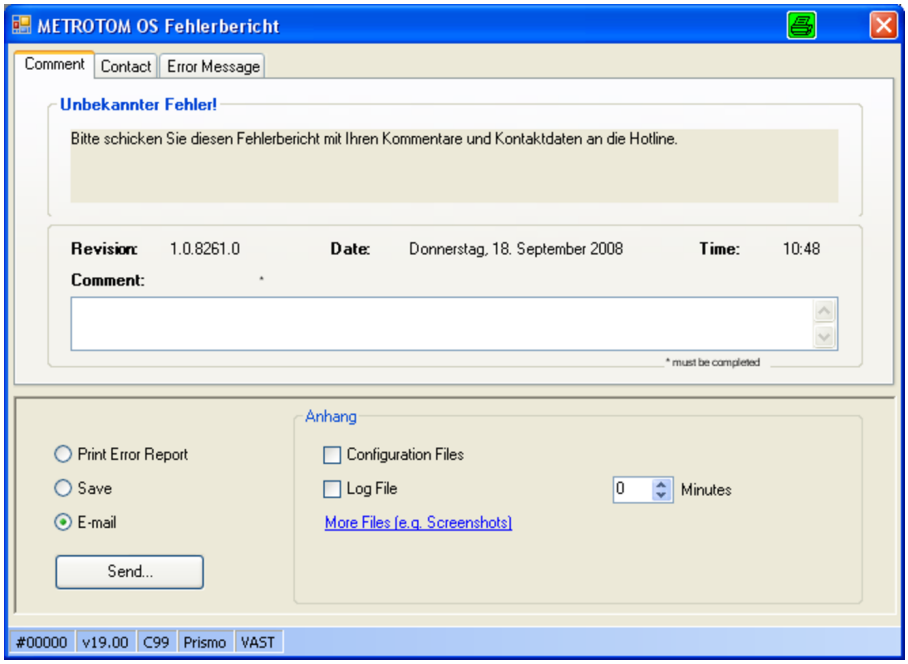

*Menu: **Tools***

#### Tools ➛ Error handler ...

Currently no function.

### Tools ➛ Error report ...

Display of logged messages after an error occurred. »Comment« tab:



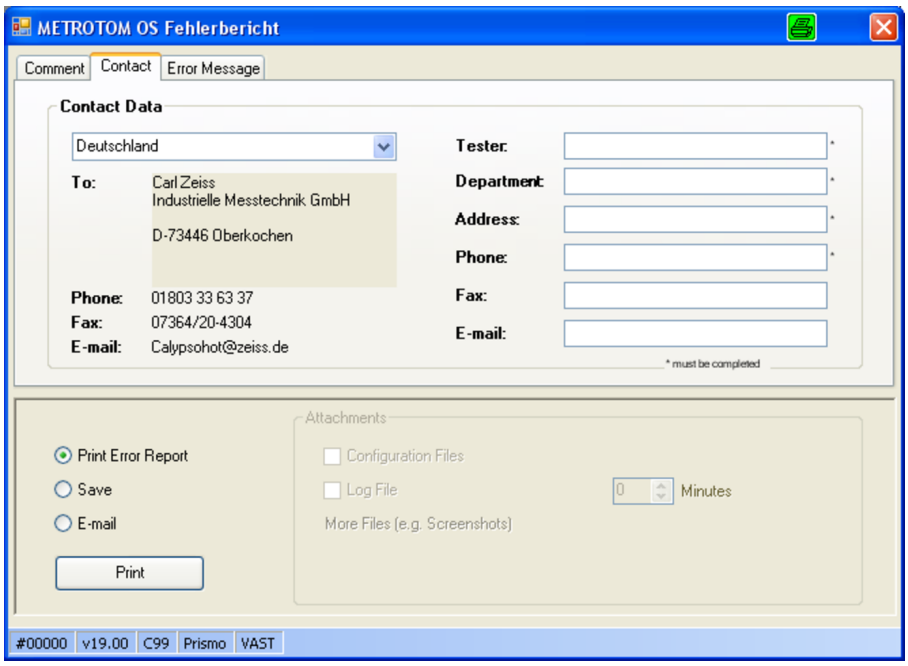

*»Comment« error report*

| Text | Description |
|---|---|
| **Unknown error** | Should an unknown error occur, you are requested to inform the hotline. |
| Revision | User software version. |
| Date | Date when the error occurred. |
| Time | Time when the error occurred. |
| Comment | Comments regarding the error occurred can be entered here. |
| Print Error Report | The error report can be printed |
| **Print** | Printing of the error report. |
| Save | The error report can be saved in any directory. |
| **Save as** | Opens a dialog box where you can enter the name and storage location for the error report. |
| E-mail | The error report can be sent by e-mail |
| **Send** | Sending of the error report. |
| **Annex** | |

| Text | Description |
|---|---|
| Save additional files / annex | Activated if **Save** or **Email** has been selected. |
| Configuration Files | The configuration file can be saved together with the error report. |
| Log File | The log file can be saved together with the error report. |
| More Files (e.g. screenshots) | Any files. |
| Minutes | Length of the log file in minutes, e.g. 3. |

**NOTICE**

You can speed up the assistance if you describe the condition when the error occurred in the comment field. Furthermore, the configuration file and the log file of the last minutes before the error occurred are very helpful.



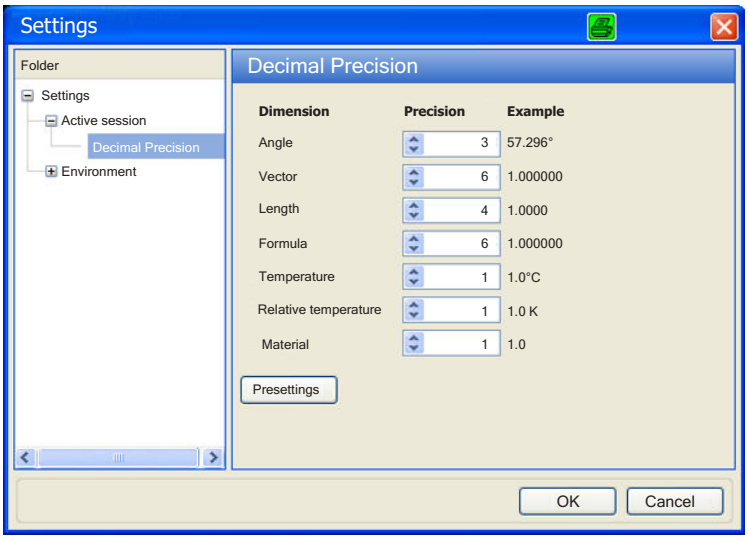

*»Contact« error report*

Enter your contact information in this dialog box, e.g. name, company and e-mail address.

Error messages are listed on the »Error Message« tab.

### Tools ➛ Settings ...

A dialog box appears for the settings. The basic settings can be done here:



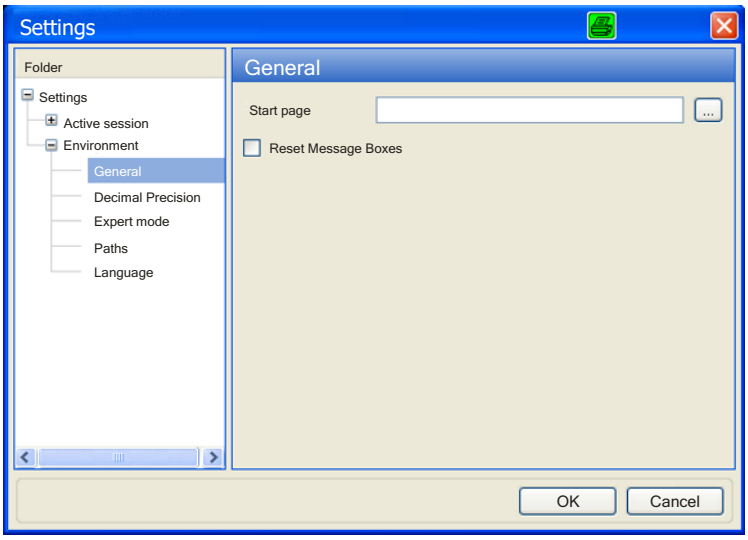

*Settings »Active session -> Decimal Precision«*

You can specify the number of decimal places to be displayed for the parameter value in the input fields.

| Text | Description |
|---|---|
| **Dimension** | |
| Angle | Angular position of the rotary table. |
| Vector | Currently not relevant. |
| Length | Position of the X, Y and Z axes. |
| Formula | Currently not relevant. |
| Temperature | Temperature of the temperature sensors. |
| Relative | Temperature. Currently not relevant. |
| Material | Currently not relevant. |
| **Presetting** | Setting of the default values. |
| **OK** | Closes the window. |
| **Cancel** | Cancels the inputs. |

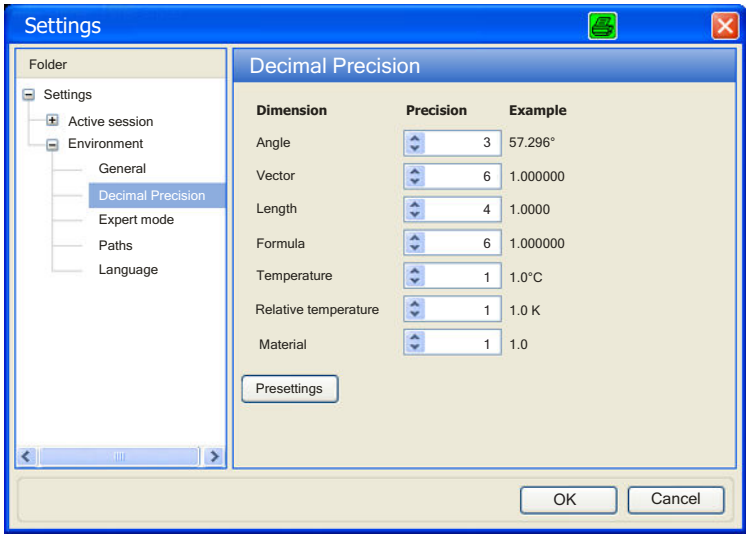
**NOTICE**

The settings apply only to the active session (METROTOM Session).




*Settings »Environment -> General«*

| Text | Description |
|---|---|
| Start page | Setting up the start page is currently not possible. |
| Reset Message Boxes | Check box to reset the blocking of the info windows. The check box in the info window can be used to decide whether the info window is displayed or hidden. If you decided in some cases to hide the info window, you can undo the blocking by using this check box. |
| **OK** | Closes the window. |
| **Cancel** | Cancels the inputs. |



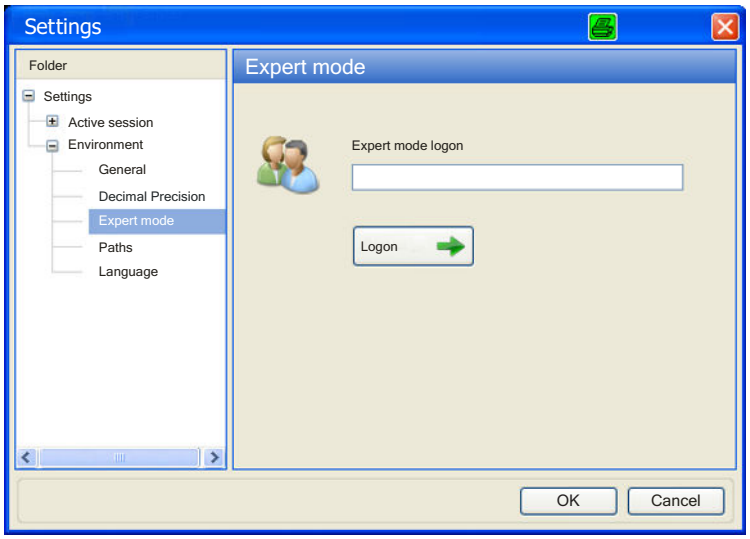

*Settings »Environment -> Decimal Precision«*

You can specify the number of decimal places to be displayed for the parameter value in the input fields.

| Text | Description |
|---|---|
| **Dimensions** | |
| Angle | Angular position of the rotary table. |
| Vector | Currently not relevant. |
| Length | Position of the X, Y and Z axes. |
| Formula | Currently not relevant. |
| Temperature | Temperature of the temperature sensors. |
| Relative | Temperature. Currently not relevant. |
| Material | Currently not relevant. |
| **Presetting** | Setting of the default values. |
| **OK** | Closes the window. |
| **Cancel** | Cancels the inputs. |

**NOTICE**

The settings apply to all measurement sessions. For changing the settings for a single measurement session, open the window under »Active session ➔ Decimal Precision«. ➔ *See [⇨ Annex 5]*

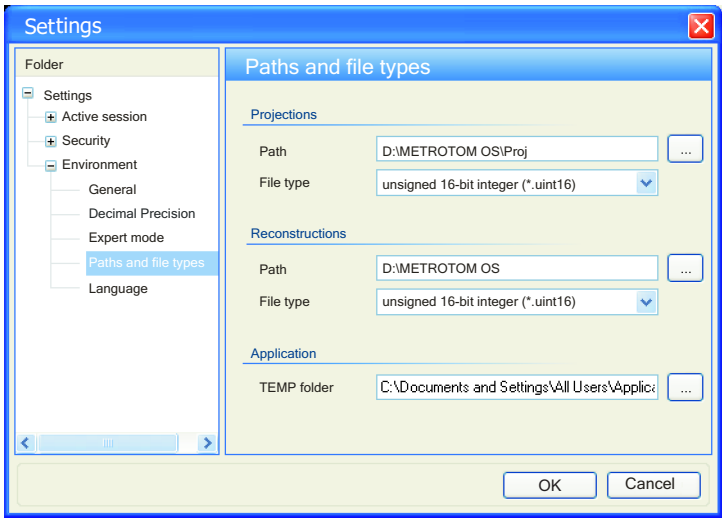



*Settings »Environment -> Expert mode«*

| Text | Description |
|---|---|
| **Expert mode logon** | Input field for the password. |
| **Log-in** | Logon to the expert mode. |

| Text | Description |
|---|---|
| **OK** | Closes the window. |
| **Cancel** | Cancels the inputs. |

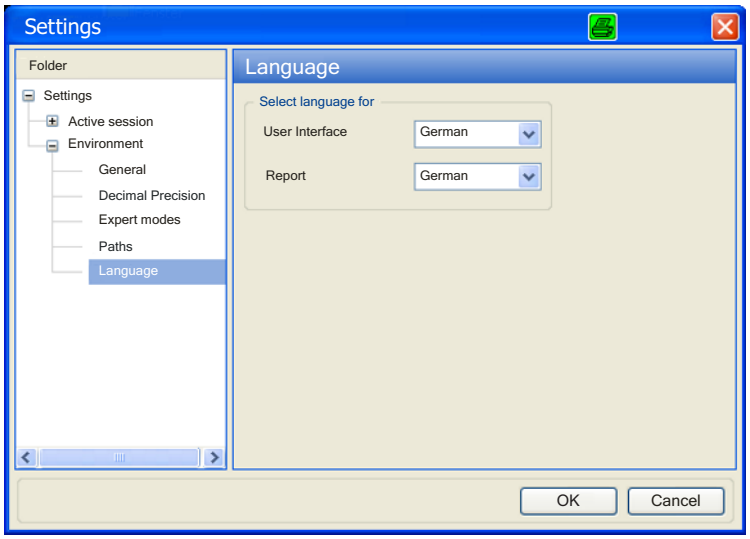
**NOTICE**
The expert mode allows additional settings.




*Settings »Environment -> Paths«*

| Text | Description |
|---|---|
| **Projections** | |
| Path | Selection of the directory for the image data. |
| File type | File type selection: The image can be saved with a color depth of 16 or 32 bits. Default: 16 bit<br>The images are saved in the selected folder with the «Uncorrected + image counter» file name. The file extension is «.uint16» or «.float32».<br>Example: Uncorrected153.uint16 |
| **Reconstructions** | |
| Path | Selection of the directory for the reconstruction |
| File type | See »Projections«. |
| **Application** | |
| TEMP folder | Folder for temporary files during the measurement. |

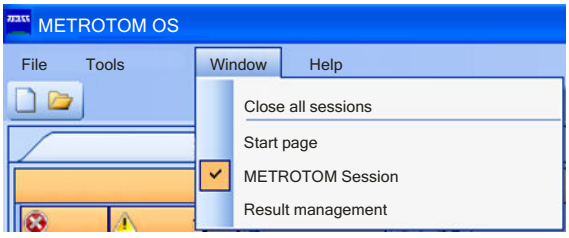
| Text | Description |
|---|---|
| **OK** | Closes the window. |
| **Cancel** | Cancels the inputs. |




*Settings »Environment -> Language«*

| Text | Description |
|---|---|
| **Select language for** | |
| User Interface | Selection of the language: German, English |
| Report | Selection of the language: German, English<br>Is not supported in the METROTOM. |
| **OK** | Closes the window. |
| **Cancel** | Cancels the inputs. |

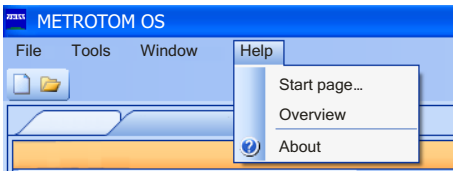
## Window ➔ ...




*Menu: **Window***

| Menu | Description |
|---|---|
| Close all sessions. | All open sessions are closed. |
| Start page | The start page contains links to documentation, e.g. release information. |
| METROTOM Session | Window for the measurement session. |
| Result management | Overview of all opened measurement sessions. |

### Help ➔ ...

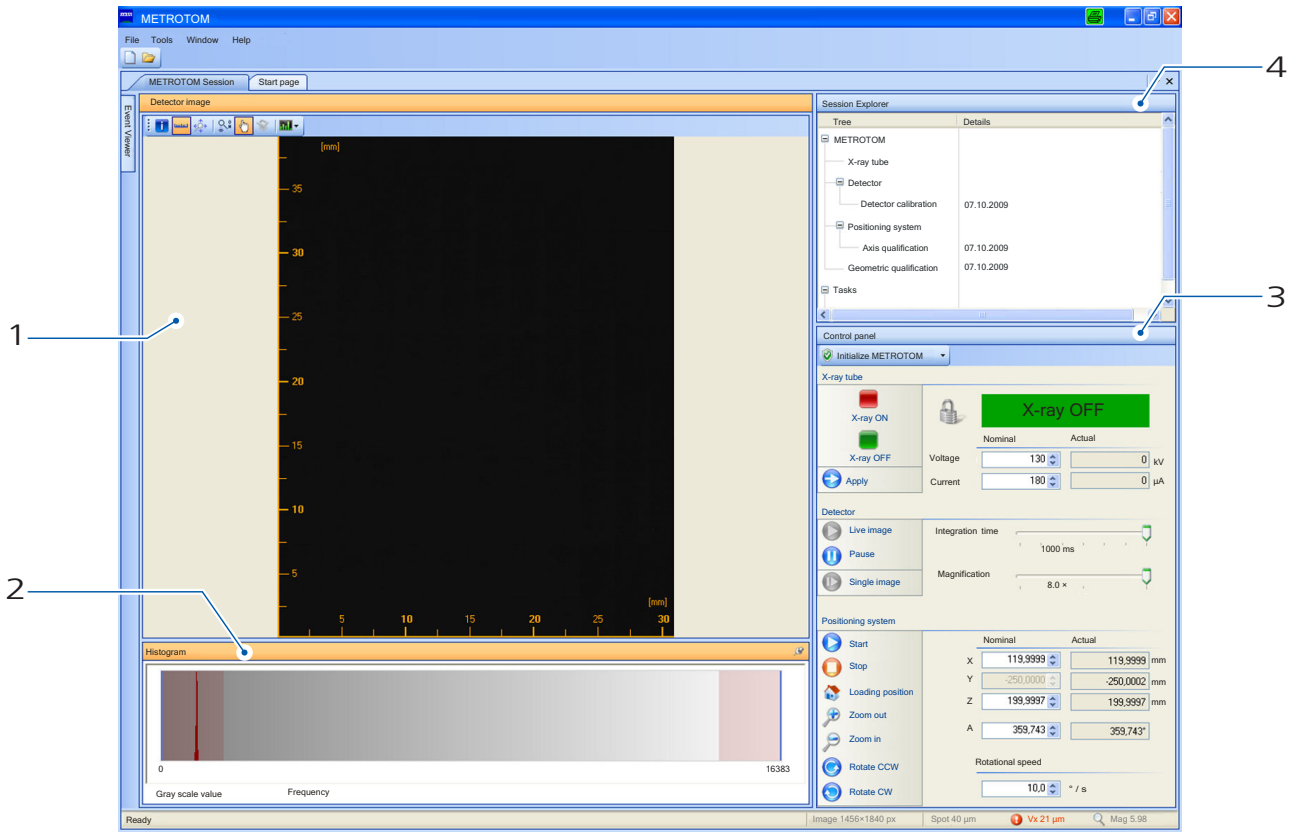



*Menu:* ***Help***

| Menu | Description |
|---|---|
| Start page | The start page contains links to documentation, e.g. release information. ➔ *See [⇨ Annex 16]* |
| Overview | All windows are displayed in an overview. |
| About | Information about the user software version. |

## User Desk

The User Desk is sub-divided into several areas:




*User Desk*

1 Display window
2 Histogram window
3 Control Panel
4 Session Explorer

## Display window

The display window serves the following purpose:

– Preview of the detector image

  Once a workpiece has been set up, a preview of the workpiece is displayed in the window. You must have enabled **Single image** or **Live image** in the Control Panel for the detector.

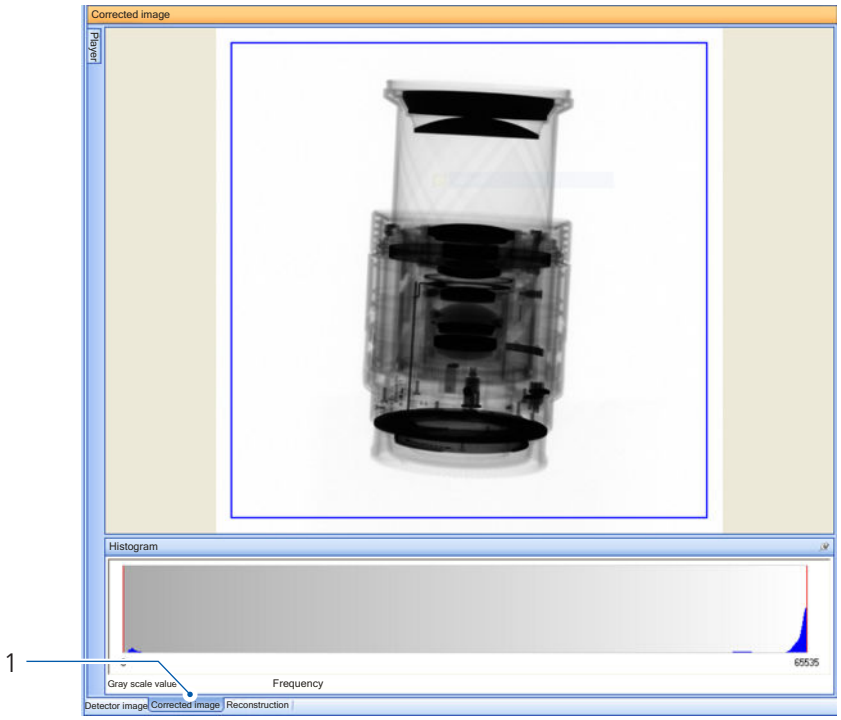
  However, it is possible that the illumination is not sufficient and therefore the preview is black. In this case, you must modify the settings for the X-ray tube or the detector. For variables influencing the brightness of the preview, see the following table:

| Component | Influencing variable |
|---|---|
| X-ray tube | Voltage and current |
| Detector | Integration time and gain |

The image scanned last is displayed. A histogram can also be displayed.

– Display of calculated and corrected images

The corrected images can be displayed during the measurement on an index card. In the case of corrected images, faulty pixels are interpolated and an offset and gain correction is performed for all pixels. The corrected images are used for the reconstruction.




*Display of the corrected image*

## Histogram window

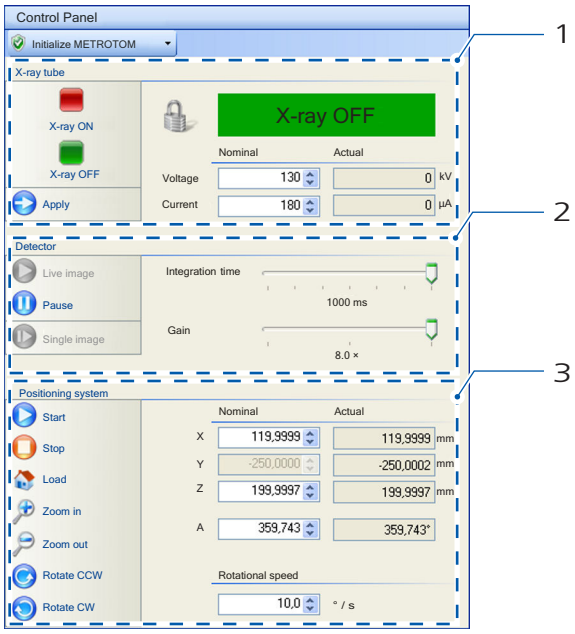

*Histogram window*

A histogram is displayed in the histogram window. A histogram is the graphic display of the frequency distribution of the gray scale values of the detector image. ➢ *Further information [⇨ 7-24]*

The window can be hidden using the icon shown here. Then an index card is displayed which can be used to reopen the window.

## Control Panel

The »Control Panel« window contains buttons and input fields for controlling the X-ray tube, the detector and the positioning system.

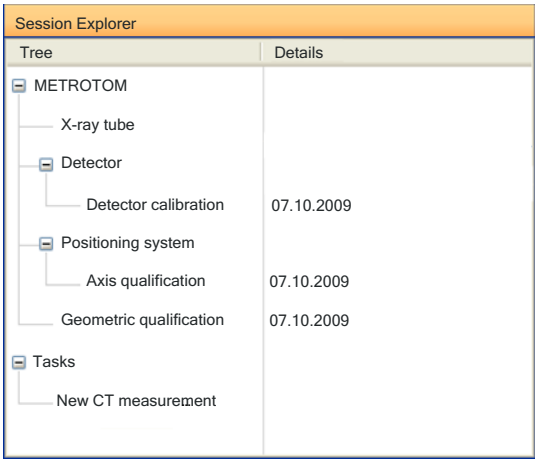



*Control Panel*

1 X-ray tube
2 Detector
3 Positioning system

## Session Explorer

Inspector windows for the CT components can be opened in the Session Explorer. Furthermore, all started and predefined measuring runs are displayed on the task list.




*Session Explorer*

**Inspector**

Double-click the respective component to open the Inspector window. Inspector windows serve several purposes:

– Displaying the settings and the status
– Defining the settings

– Starting a process, e.g. warm-up
– Carrying out a measurement

**Task**

A new CT measurement is called »Task« and is entered automatically under »Tasks« after it has been started. If there is no CT measurement in the list yet, the measurement will start immediately.

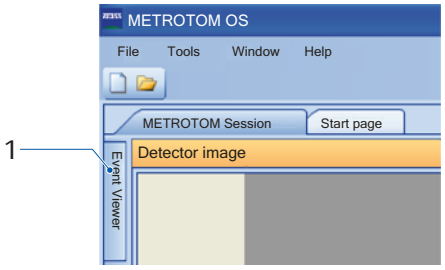
The measurement status is shown in the »Details« column, e.g. »Measurement running …«. Further measurements of the list get the »Queued« or »In definition« status. If a measurement is already in progress, the new measurement gets the »Queued« status. Predefined measurements have the »In definition« status. Once a measurement has been completed, it disappears from the list and the following measurement with »Queued« status starts automatically.

Started qualification and calibrations cycles are also entered under «Tasks». Their status is indicated in the »Details« column.

# Event Viewer

Events occurring during operation of the CT system are logged in the Event Viewer. There are three types of events: Error messages, warnings and information.

## Displaying the Event Viewer



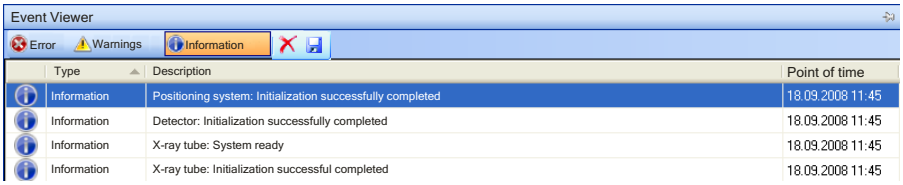

*Button for Event Viewer*

1 Button for displaying the Event Viewer

– Click the **Event Viewer** button or position the mouse pointer over the button.

| | Action | Consequence |
|---|---|---|
| | Position the mouse pointer over the button. | The Event Viewer is displayed. |
| | Move the mouse pointer away. | The Event Viewer is hidden. |
| | Click the button. | The Event Viewer is activated and remains open while the mouse is moved. |

| | Action | Consequence |
|---|---|---|
| | Click in another area, e.g. Session Explorer. | The Session Explorer is activated and the Event Viewer disappears. |
|  | Click the icon at the top right to fix the window. | The Event Viewer is arranged parallel to the display window. |
|  | Click the icon at the top right to release the window. | The Event Viewer is hidden, the index card is displayed. |




*Event display*

All events are normally displayed. Use the **Error**, **Warnings** and **Information** buttons to display or hide the respective event types. Meaning of the other buttons:

| | |
|---|---|
|  | All event messages are deleted, also the hidden ones, when you use the button shown beside.<br>Single event messages can be deleted via a context menu. See below. |
|  | Saving all event messages.<br>Single event messages can be saved via a context menu. See below.<br>In both cases, a window opens to select the directory for saving the events. |

## Sorting the events

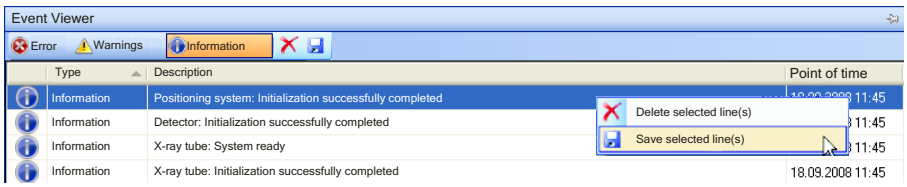
The events are normally sorted by date of occurrence. Click the titled column headers to sort the events in ascending and descending order.

An arrow in the column header pointing downwards identifies a descending sorting. An arrow pointing upwards identifies an ascending sorting of the events.

## Deleting and saving selected event messages

Having selected one or several messages, you can open a context menu by right clicking.

– Select **Delete selected line/s** → or **Save selected line/s**.

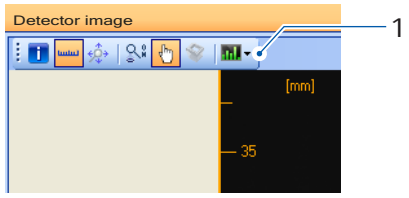



# Start page

From the start page, you can access the Operating Instructions and the Release information.


# Buttons in the detector image

## Overview




*Buttons in the detector image*

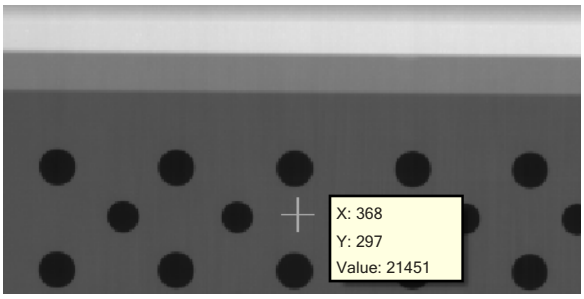
1 Toolbar

After successful initialization of the detector, the detector image is displayed with a histogram. A toolbar is displayed at the top left of the detector image. Its buttons have the following functions:

| | |
|---|---|
|  | Showing and hiding of pixel information |
|  | Showing and hiding the ruler |
|  | Showing the entire image, after zooming for example |
|  | Choosing an image area by drawing a rectangle |
|  | Shifting the visible image section |
|  | Defining the reconstruction area by dragging a rectangle.<br>This button will only be active if you have opened the Inspector for CT measurement. |
|  | Selecting the image interpolation mode |
|  | Saving the detector image |

## Pixel information

Click on the button shown here to display a small window in the detector image next to the current cursor position. The window contains information on the X value, Y value and the gray value of the pixel at the cursor position. If you move the cursor, the window will move, too and different values will be displayed. To hide the window, click the button again.



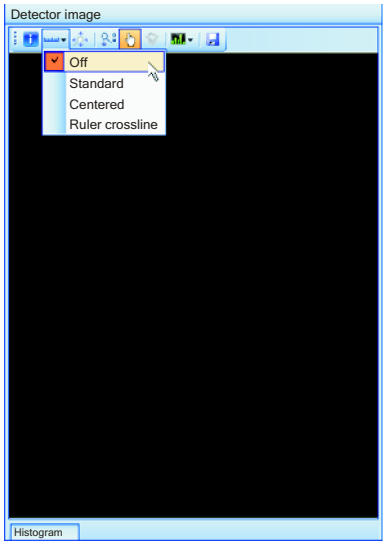
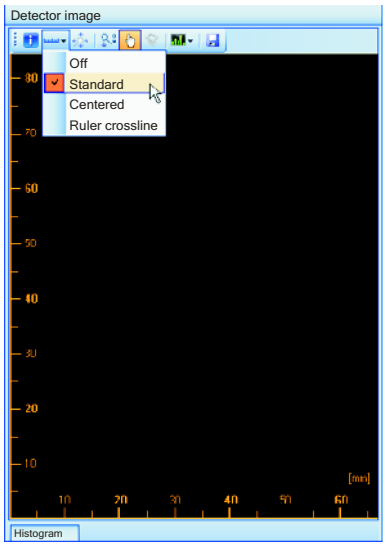

*Information about a pixel*

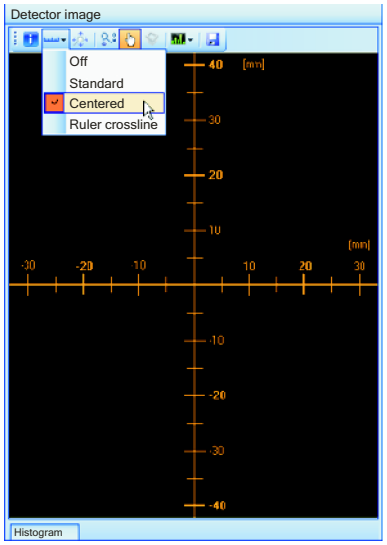
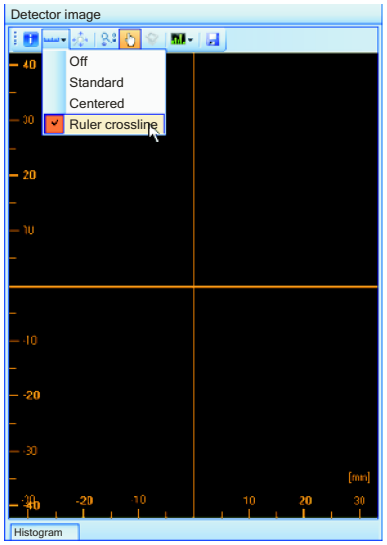
## Scale in the detector image

A scale can be shown in the detector image for Y and Z axis. The size of the image section can be read from the scale. The scale is variable, it adapts automatically to the image section selected. The unit of the scale values is millimeters.

Click the button shown here to open a drop-down menu. You have four selection options: Off, Standard, Centered and Ruler crossline.

**Selection options in the drop-down menu:**

| Selection option | Caption | Remark |
|---|---|---|
| **Off** |  | A scale is not visualized. |
| **Default** |  | The scale is at the left and bottom edge of the detector image. The origin is at the bottom left. |

| Selection option | Caption | Remark |
|---|---|---|
| **Centered** |  | The scale is in the center of the detector image. The origin is in the intersection of the scales. |
| **Ruler crossline** |  | The scale is at the left and bottom edge of the detector image. The position of the origin is variable. By default, the origin is in the center of the detector image. When you zoom an image section, the position of the origin might change. |

**NOTICE**

The scale is a mean scale. By reason of the perspective projection, the X-ray image has no individual scale. Those parts of the workpiece that are nearer to the X-ray tube are represented larger than those which are more distant from the X-ray tube.

**Calculating the scale**

For calculation of the scale, the magnification factor, the pixel size and the size of the image section are needed. If one of these parameters changes, the scale will be recalculated.

| Alteration | Effect on ... | Consequence |
|---|---|---|
| Changing the X position. | Zoom factor | In both cases, the new values are buffered and taken into account for calculation of the new scale.<br>The new scale will be shown in the next image to be represented. |
| Zooming the detector image or selecting a certain image section. | Image size | |

### Zooming the detector image

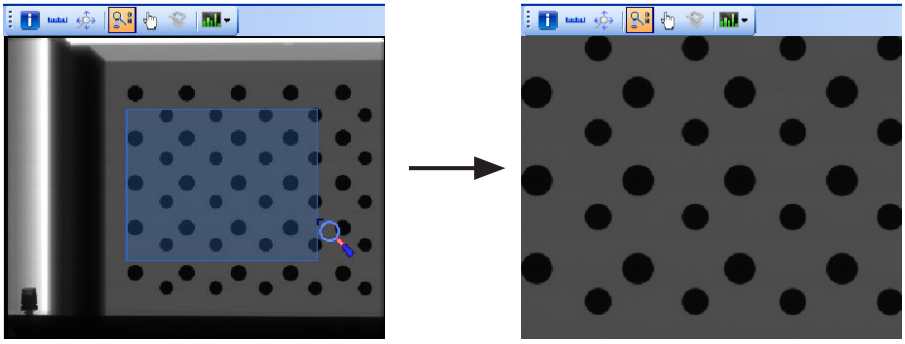
The entire workpiece is represented by default in the detector image. To view details of the image, you can use different zooming methods.

– Drawing a rectangle.

– Scrolling the image with the mouse wheel.

### Drawing a rectangle

Click the button shown here to start the function. Then draw a rectangle keeping the left mouse button pressed. The selected image section is scaled according to the entire surface area available.



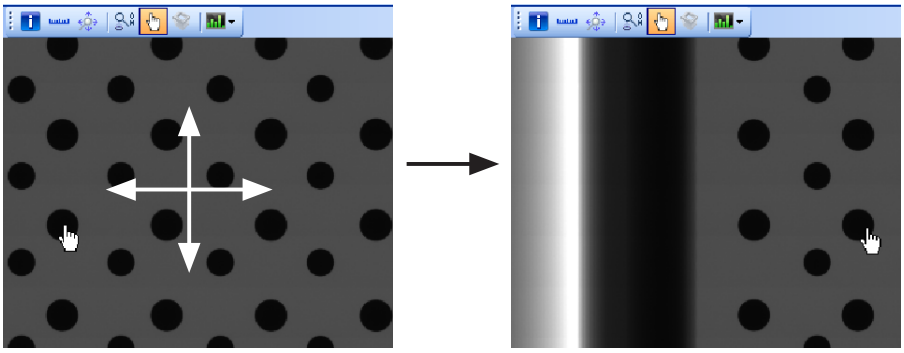
*Changing a section of the detector image*

### Scrolling with the mouse wheel

You can use the mouse wheel for zooming in and out. The cursor position indicates the area of the image to be zoomed.

### Shifting the zoomed image section

If the cursor is located within the zoomed image section, you can move the displayed image section by pressing the left mouse button and dragging the cursor.



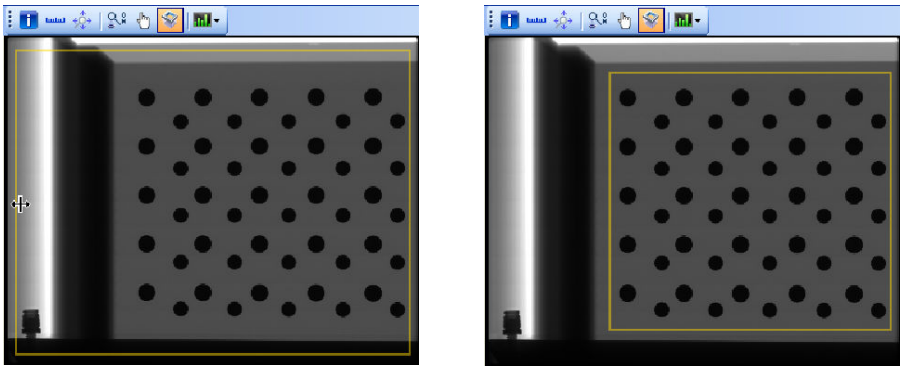
*Moving the detector image*

## Showing the whole image

After having zoomed the image, you can have it displayed again as a whole by means of the button shown here.

## Setting the reconstruction area

When you open the Inspector for a new CT measurement, the adjacent button becomes active in the toolbar of the detector. Furthermore, a yellow frame appears in the detector image. The frame defines the reconstruction area.

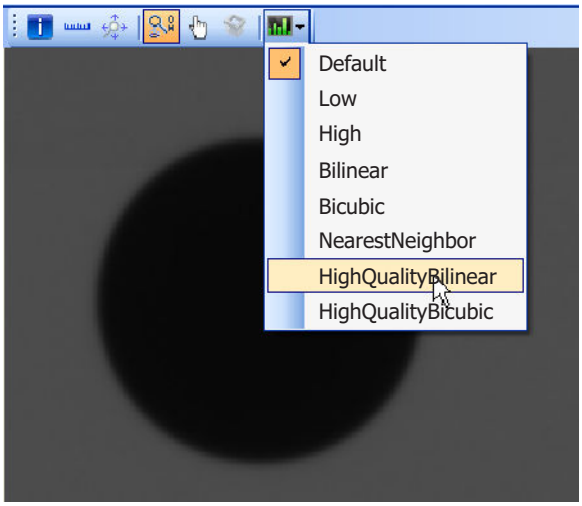


*Defining a reconstruction area*

Further information is given elsewhere. >…

## Selecting the interpolation mode

Several interpolation modes are available for representation of the image on the screen. Click the button shown here to display the modes.




*Interpolation modes*

If you hold the cursor over an interpolation mode, a preview becomes visible. Click on the selected interpolation mode to enable it. This means: All detector images will be interpolated according to the selected procedure, e.g. HighQualityBilinear.

| Consequences of the different interpolation modes for detector image | |
|---|---|
| »NearestNeighbor« | Step-like edge of the ball |
| »HighQualityBilinear« | Smooth edge of the ball |

| Interpolation mode | Description |
|---|---|
| Default | Indicates the standard mode. |
| Low | Lowest interpolation quality. |
| High | Highest interpolation quality. |
| Bilinear | Indicates a bilinear interpolation. No preliminary filtering is performed. This mode is not suitable to reduce an image to less than 50 percent of its original size. |
| Bicubic | Indicates a bicubic interpolation. No preliminary filtering is performed. This mode is not suitable to reduce an image to less than 25 percent of its original size. |
| NearestNeighbor | Indicates a nearest-neighbor interpolation. |

| Interpolation mode | Description |
|---|---|
| HighQualityBilinear | Indicates a bilinear interpolation with high quality. Preliminary filtering is performed to guarantee high quality reduction in size. |
| HighQualityBicubic | Indicates a bicubic interpolation with highest quality. Preliminary filtering is performed to guarantee high quality reduction in size. This mode generates transformed images of highest quality. |

### Save detector image

Detector images can be saved in different formats.

**Formats**

| Format | Remark |
|---|---|
| BMP | |
| JPG | Images is packed. Quality: 75 % |
| GIF | |
| PNG | |
| TIFF | No packing |

# Messages in the Event Viewer and messages windows

## Messages for components in the Event Viewer

### Messages for the X-ray tube

| Category | Text | Remark | Measure |
|---|---|---|---|
| Errors | Supply voltage error 1 | Hardware error | – Inform ZEISS service. |
| Errors | Supply voltage error 2 (voltage too low) | Hardware error | – Inform ZEISS service. |
| Errors | Supply voltage error 3 (voltage too high) | Hardware error | – Inform ZEISS service. |
| Errors | Initialization failed | | – See the Event Viewer for the exact cause. |
| Errors | Fan error | Hardware error | – Inform ZEISS service. |

| Category | Text | Remark | Measure |
|---|---|---|---|
| Errors | No connection to X-ray tube | | – Check the connecting cable.<br>– Restart the computer.<br>– If the error still occurs, call a ZEISS service engineer. |
| Errors | Controller card error x (with x = 1 to 6) | Hardware error | – Inform ZEISS service. |
| Errors | Overload reset failed | | – Inform ZEISS service. |
| Errors | System not ready | The X-ray tube cannot be switched on. Two causes.<br>– Preheating.<br>– Hardware error | – Wait until preheating is finished.<br>– In case of hardware error, inform ZEISS service. |
| Errors | Temperature alarm | Hardware error | – Inform ZEISS service. |
| Errors | Overload | | – Wait for overload protection reset. |
| Errors | Warm-up failed | The following causes are possible:<br>– Overload<br>– Loading door open<br>– Hardware error | – In case of overload, wait for reset of the overload protection and repeat warm-up.<br>– Close the loading door and repeat warm-up.<br>– In case of hardware error, inform ZEISS service. |
| Warning | Battery voltage too low | | – Replace battery during next maintenance. |
| Warning | Voltage: Deviation of x kV between act. and nom. value | | |
| Warning | Current: Deviation of x µA between actual and nominal value | | |
| Warning | Reset of the overload protection aborted | The user aborted resetting the overload protection. | |
| Warning | Warm-up failed | Warm-up is automatically performed during initialization when the tube is switched on. | |

| Category | Text | Remark | Measure |
|---|---|---|---|
| Information | Overload reset finished | | |
| Information | Initialization successfully completed | | |
| Information | System ready | The X-ray tube can be switched on. | |
| Information | Overload reset started ... | | – Wait for overload protection reset. |
| Information | Preheating ... | Will only be done if the voltage supply is re-established after previous disconnection. | |
| Information | Preheating finished | | |
| Information | Warm-up finished | | |
| Information | Warm-up started … | | |

### Messages for the detector

| Category | Text | Remark | Measure |
|---|---|---|---|
| Errors | Initialization failed | | – Repeat initialization. |
| Information | Initialization successfully completed. | | |

### Messages for the positioning system

| Category | Text | Remark | Measure |
|---|---|---|---|
| Errors | Initialization failed | Concerns the positioning system | Repeat initialization of the positioning system. |
| Errors | Reference point invalid | | Set the reference point in the Inspector for positioning system. |

| Category | Text | Remark | Measure |
|---|---|---|---|
| Errors | Initialization failed | Concerns the control unit. Check:<br>– Has the control unit been switched on?<br>– Is the »CMM Control Center« running?<br>– Is the »CMM Control Center« connected to the control unit? | The measures to be taken depend on the cause:<br>– Switch on the control unit.<br>– Finish and restart METROTOM OS.<br>– In the »CMM Control Center«, establish a connection to the control unit.<br>– If the problem cannot be eliminated, inform ZEISS service. |
| Errors | No connection to the 'CMM Control Center' | Concerns the control unit.<br>Check:<br>– Is the »CMM Control Center« running?<br>– Is the »CMM Control Center« connected to the control unit? | – Start the »CMM Control Center«.<br>– In the »CMM Control Center«, establish a connection to the control unit. |
| Errors | Drives off | Concerns the control unit. | – Switch on the drives. |
| Information | Initialization successfully completed | Concerns the positioning system | |
| Information | Reference point valid | Concerns the positioning system | |
| Information | Initialization successfully completed | Concerns the control unit. | |
| Information | »CMM Control Center« connected. | Concerns the control unit. | |
| Information | Drives on | Concerns the control unit. | |

# Other messages

## Checking memory space - influencing variables

The memory space is an important criterion for the CT measurement. It is always checked after a parameter was changed which influences the required disk space. These parameters are:

- Saving or not saving the corrected and uncorrected projections
- Number of projections if the projections are saved
- Size of the reconstruction area
- Format of the reconstruction file
- Ratio between pixel size and natural voxel size

## Display of messages

Messages and errors for the measurement and the reconstruction are logged. Some messages are displayed in dialog boxes, others in the Event Viewer.

**Different messages**

| Message window | Event Viewer | Description |
|---|---|---|
| "Not enough storage space available on C:\ drive for this measurement." | | Insufficient memory space. |
| "This identifier cannot be used as a file name or path. Please make sure that you want to keep this identifier anyway." | | Forbidden characters. |
| "The folder *C:\Documents and Settings\ZOCKU\My Documents\Zeiss\Metrotom OS\CT Messung 1* for saving the projection data already exists. The files in the existing folder will be replaced by files with the same names if you proceed. Press **OK** to continue the measurement and overwrite the existing files or **Cancel** to end the measurement." | | File name already exists. |
| "Reconstruction could not be initialized." | | Problem with the initialization of the reconstruction. The error is explained in detail in the event viewer. |

| Message window | Event Viewer | Description |
|---|---|---|
| "Errors or warnings occurred during the measuring run. For more information, refer to the Event Viewer." | | |
| | No IPP version available. The reconstruction job could not be initialized. | Installation problem. |
| | Initialization failed in reconstruction library: ERROR CODE The reconstruction job could not be initialized. | Problem with the parameters. |
| | New measuring run started | No errors occurred. |
| | Image evaluation started | No errors occurred. |
| | Warning: Image {0} cannot be measured. New try. | Parameters cannot be set. |
| | Error: Image {0} cannot be measured. Measuring run aborted | Parameters cannot be set even after several attempts. Result: The measurement is aborted. |
| | Measuring run aborted | The measurement was aborted manually. |
| | Reconstruction job aborted | The message is displayed with aborting of the measurement. |
| | Measuring run finished | Measurement successfully completed. |
| | Image evaluation finished | Measurement successfully completed. |

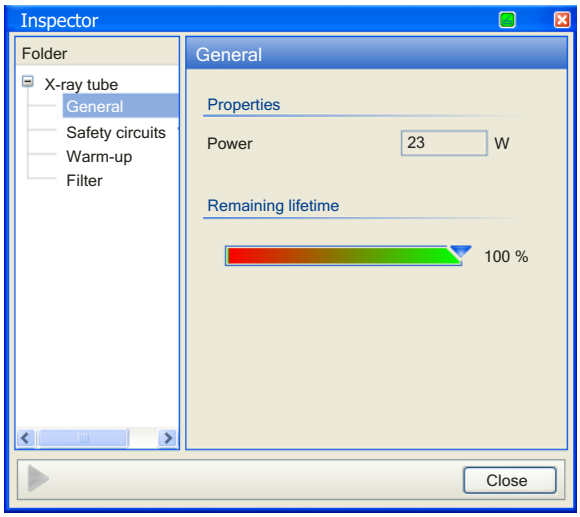
**Messages for focal spot control**

| Message window | Event Viewer | Description |
|---|---|---|
| "The "CMM" file cannot be found under the selected path: ...[path]" | | The test piece has been measured by a coordinate measuring machine (CMM). The measuring results are contained in the CMM file. The file is needed for the focal spot control. |
| "The "Selection" file cannot be found under the selected path: …[path]" | | The Selection file contains information on the CMM measuring results. The file is needed for the focal spot control. |

| Message window | Event Viewer | Description |
|---|---|---|
| "The correction file of the selected filter required for focal spot control cannot be found in the following directory: … [path]" | | If you use a filter on the collimator and select this filter for the CT measurement, a correction file of the filter must be available then for the focal spot control. |
| "The focal spot control is activated for the CT measurement. The required results from the geometric qualification with the focal spot control activated are, however, not yet available." | | To enable a CT measurement with activated focal spot control, a geometric qualification must have already been performed with activated focal spot control. |
| "Calculation of focal spot position failed during focal spot control" | Error: Calculation of focal spot position failed during focal spot control | |
| | Warning: The focal spot position of the focal spot control is not available. | |
| | Error: Reading of filter correction value failed during focal spot control. Voltage: …, filter thickness: …, file: …[path] | |

# Inspector for X-ray tube

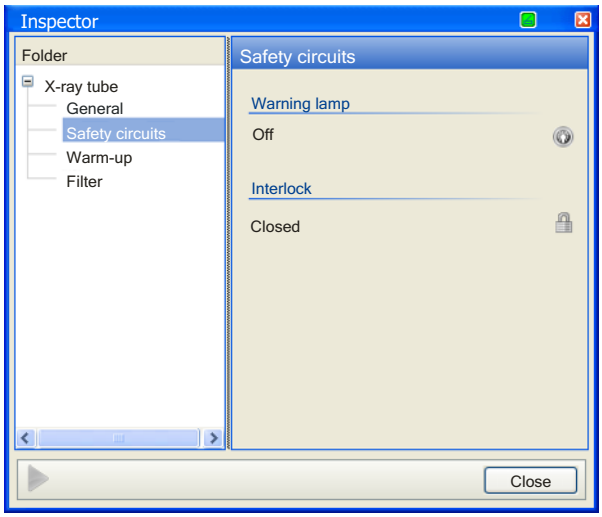
## Inspector window »General«




*Inspector »X-ray tube«,* ***General***

| Text | Description |
|---|---|
| **Properties** | |
| Power | Display of the current power in [W], determined by the nominal values for voltage and current. |
| Remaining lifetime | Remaining service life of the X-ray tube in percent. |

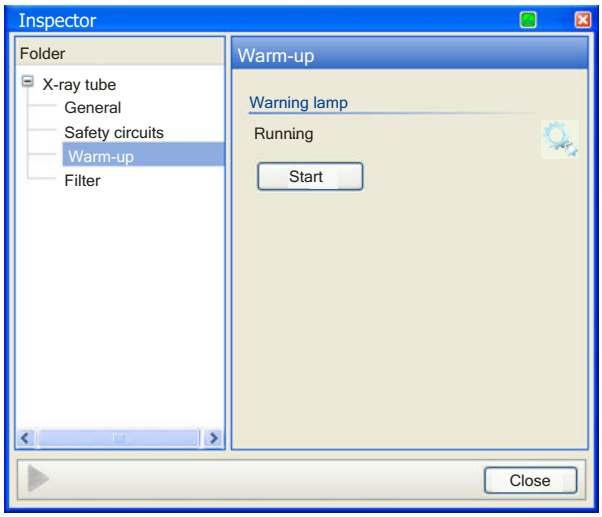
## Inspector window »Safety circuits«




*Inspector »X-ray tube«,* ***Safety circuits***

| Text | Description | Remark |
|---|---|---|
| **Warning lamp** | | |
| On |  The X-ray tube is in operation. | |
| Off |  The X-ray tube has not been switched on. | |
| **Interlock** | | |
| Closed |  The X-ray tube is ready for operation. | |
| Open |  The X-ray tube is not ready for operation. | |

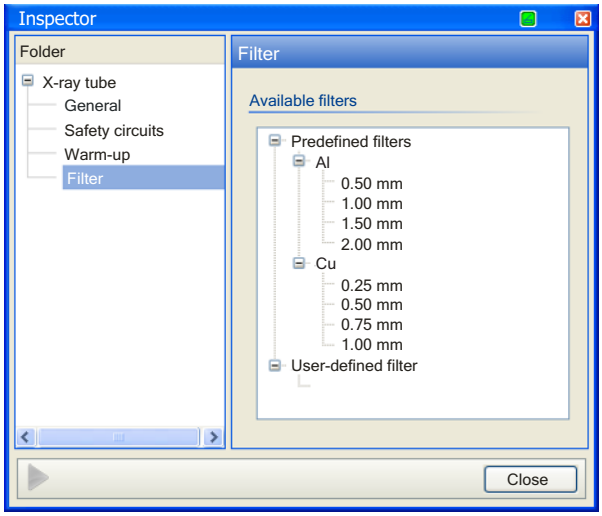
## Inspector window »Warm-up«




*Inspector »X-ray tube«,* ***Warm-up***

| Text | | Description | Remark |
|---|---|---|---|
| **Warm-up** | | | |
| Running… |  | Warm-up is performed. | |
| Failed |  | Warm-up was interrupted. | – Repeat the warm-up.<br>– If an error still occurs, inform the ZEISS service engineer. |
| Ready |  | The X-ray tube is ready for operation. | |
| Expired |  | | – Perform a warm-up. |
| **Start** | | Starting the warm-up. | Warm-up to the maximum voltage.<br>The process can be canceled in the Control Panel via **X-Ray Off**. |

## Inspector window »Filter«



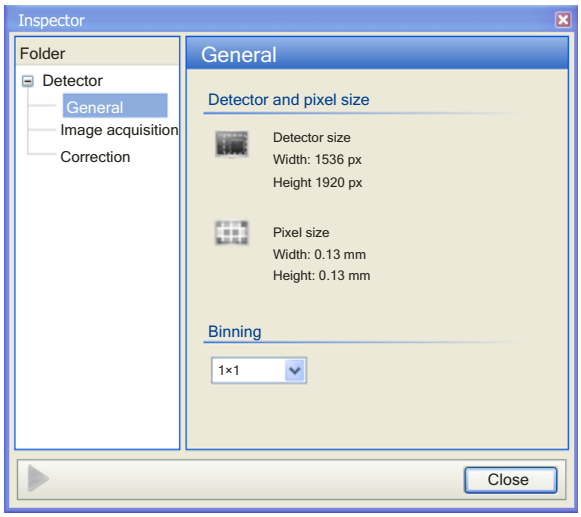

*Inspector »X-ray tube«,* ***Filter***

| Text | Description | Remark |
|---|---|---|
| **Available filters** | Representation of standard filters and user-defined filters in a tree view. | |
| Predefined filters | For two filter materials there are predefined filters of different thickness.<br>You may choose between aluminum (Al) and copper (Cu). | |
| User-defined filters | You can create your own filters and delete them. | Create a filter:<br>– Position the cursor in the line below **User-defined filters**.<br>– Name the filter<br>– Confirm by pressing Enter (keyboard).<br>Delete a filter:<br>– Right-click a user-defined filter. A context menu opens.<br>– Select **Delete entry**. |

# Inspector for detector

The inputs and selections in the inspector only impair the displayed images, not the calculated images.

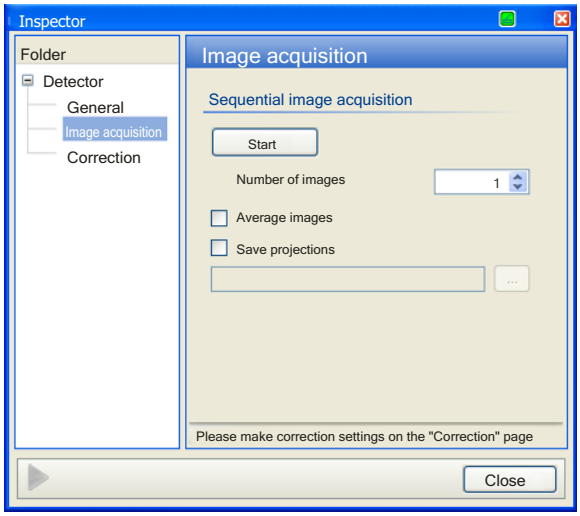
# Inspector window »General«




*Inspector »Detector«,* ***General***

| Text | Description |
|---|---|
| **Detector- and pixel size** | |
| Detector size | Display of the detector size in pixel. |
| Pixel size | Display of the pixel size of the detector in [mm]. |
| **Binning** | |
| 1×1 | Binning mode during which the original detector resolution is applied. This means: The image size corresponds to the active area of the image.<br>*Note*: The edge area of the detector is not taken into consideration during image acquisition. The active image area is 1456×1840 pixels. |
| 2×2 | Binning mode during which several image spots are combined to form a new image spot. This reduces the data volume.<br>*Example*: With a detector having an active image area of 1456 × 1840 pixels, the acquired images have a resolution of 728 × 920 pixels. |

## Inspector window »Image acquisition«




*Inspector »Detector«,* ***Image acquisition***

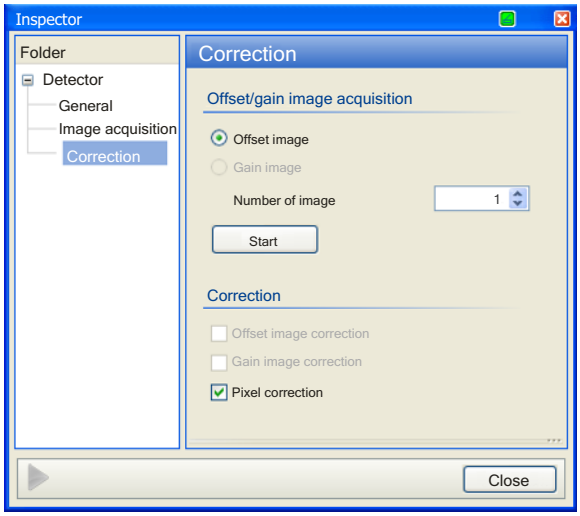
Detector images can be requested and saved in this window. One or several images are requested. The image request is stopped when the number of images is reached. The request can be canceled at any time.

| Text | Description |
|---|---|
| **Image sequence acquisition** | |
| **Start** | Starts an image request.<br>Once this function has been started, the **Cancel** button appears. If the request for many images takes too long, the procedure can be stopped.<br>At the end of the image request, **Start** appears again. |
| No. of images | Input field for the number of images to be requested. |
| Average images | The requested images are averaged. |
| Save projections | The requested images or their average are/is saved. Any directory is possible for the saved images. You can select it with this button.<br>  |

## Inspector window »Correction«

The images acquired under **Image acquisition** can be corrected. For this, at least one offset image must be captured first and then at least one gain image. You can determine the number of images in the selection field.

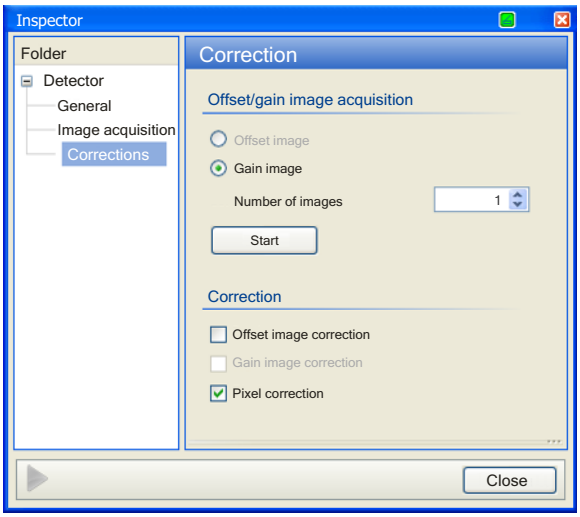
### Scanning of offset images




*Inspector »Detector«, **Correction**, acquisition of offset images*

| Text | Description |
|---|---|
| **Acquisition of offset / gain images** | |
| Offset image | To acquire an offset image, the **Offset image** radio button must be selected. If you have not yet acquired an offset image, only this radio button is active. |
| No. of images | Number of images to be requested.<br>For values higher than 1, the images are averaged. This means: Only one image is saved internally. |
| **Start** | Button for starting the offset image acquisition.<br>The **Gain image** radio button and the **Offset image correction** check box will be enabled after having acquired an offset image. |
| **Correction** | |
| Pixel correction | See »Acquiring gain images«. If you acquire offset images, the pixel correction does not have any effect. |

## Acquiring gain images



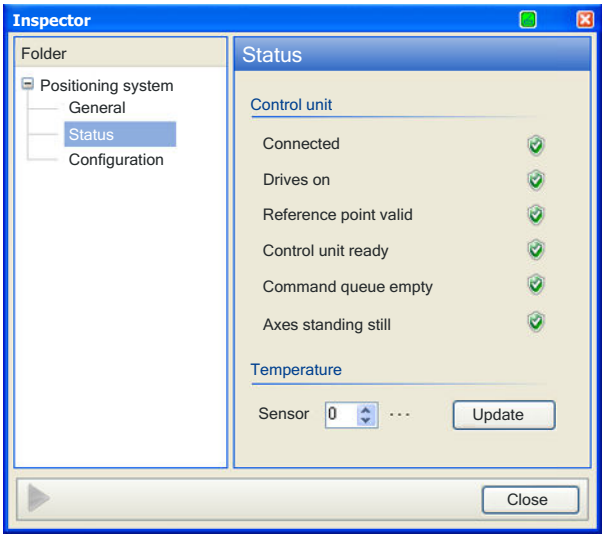

*Inspector »Detector«, **Correction**, acquisition of gain images*

| Text | Description |
|---|---|
| **Acquisition of offset / gain images** | |
| Gain image | To capture gain images, the »Gain image« radio button must be selected. |
| No. of images | Number of images to be requested.<br>For values higher than 1, the images are averaged. This means: Only one image is saved internally. |
| **Start** | Button for starting the gain image acquisition.<br>The **Gain image correction** check box will be enabled after having acquired a gain image. |
| **Correction** | |
| Offset image correction | The offset image is subtracted from every image scanned.<br>For activating an offset image correction, one or several offset images must be captured. The images are saved internally and are valid until new offset images are captured or until the user software is closed. |

| Text | Description |
|---|---|
| Gain correction | Serves for the homogenization of the radiation intensity. ➢ *See [⇨ 7-33]*<br>For activating a gain correction, offset images and one or several gain images must be captured. The images are saved internally and are valid until new gain images are captured or until the user software is closed. |
| Pixel correction | Faulty pixels are corrected.<br>This requires a correction file which is generated with the detector calibration. The file is imported automatically with the start of the user software.<br>During the CT measurement, faulty pixels in the images are always corrected even if the pixel correction is deactivated. A deactivation has an impact only on the representation on the screen.<br>The pixel correction is activated by default. |

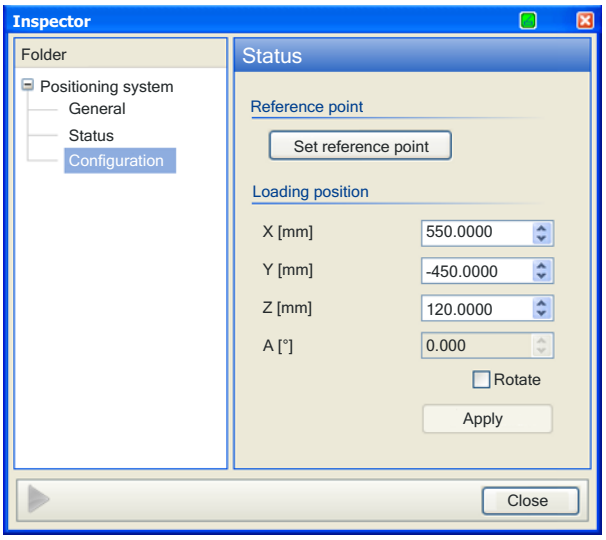
# Inspector for the positioning system

## Inspector window »Status«



| Text | | Status | Description |
|---|---|---|---|
| **Control unit** | | | |
| Connected |  | Connected with the CMM Control Center | |
| |  | Disconnected | |
| Drives on |  | Drives on | |
| |  | Drives off | |
| Reference point valid |  | Reference point valid | |
| |  | Reference point invalid | |
| Control unit ready |  | Control unit ready | |
| |  | Control unit busy | |
| Command queue empty |  | Command queue empty | |
| |  | Commands waiting | |
| Axes standing still |  | Axes are standing still. | |
| |  | Axes moving | |
| **Temperature** | | | |
| Sensor | | | Selection field |
| **Update** | | | Updates the temperature for the selected sensor.<br>The temperature is displayed next to the selection field. |

## Inspector window »Configuration«



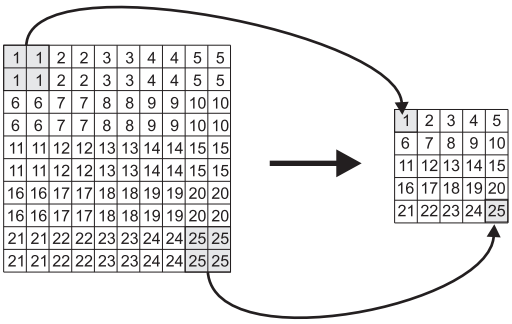

*Inspector »Positioning system«,* ***Configuration***

| Text | Description |
|---|---|
| **Reference point** | |
| **Set reference point** | Start of the reference point travel. |
| **Loading position** | |
| X[mm] | X coordinate of the loading position |
| Y[mm] | Y coordinate of the loading position |
| Z[mm] | Z coordinate of the loading position |
| A[°] | Rotary table angle<br>*Note*: The input field is disabled if the **Rotate** check box is not ticked. |
| Rotate | Check box for the activation of the input field for the rotary table angle |
| **Apply** | Saves the set values. |

# Binning of detector images

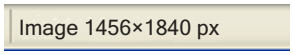
The binning function can be used to reduce the data quantity. A distinction is made between two binning modes:

| | |
|---|---|
| 1×1 | No binning |
| 2×2 | Four adjacent pixels are combined. |




The resolution of a detector installed in upright position is 1536 × 1920 pixels. The active image area is 1456 × 1840 pixels. This corresponds to binning mode 1×1. In the binning mode 2×2, the resolution of the images is halved. Their resolution is then 728 × 920 pixels. With a transversally installed detector, the values are inverted.

When you change the binning mode, the new image size is displayed in the status bar.




*Status line: Image size*

If 2x2 binning is selected, the symbol shown here is displayed next to »Image«.

The binning mode is selected in the Inspector for the detector. ➢ *See [⇨ Annex 33]*

# More information about metrotomography

## Image formation

### Data acquisition

Metrotomography comprises data acquisition and reconstruction operations.

X-ray beams are generated in the X-ray tube. The radiation emerges in the form of a conical beam via the diaphragm towards the X-ray detector. First, the beams hit the workpiece and then the detector surface.

**Gray image**

Depending on the geometry and the absorption characteristics of the workpiece, the beams are absorbed with different degrees of attenuation. A two-dimensional gray image is created in the detector.

The workpiece is rotated step-by-step 360° about the rotating axis. Thus, a large number of workpiece images is created.

### 3D image by reconstructing the volume

**Data volume**

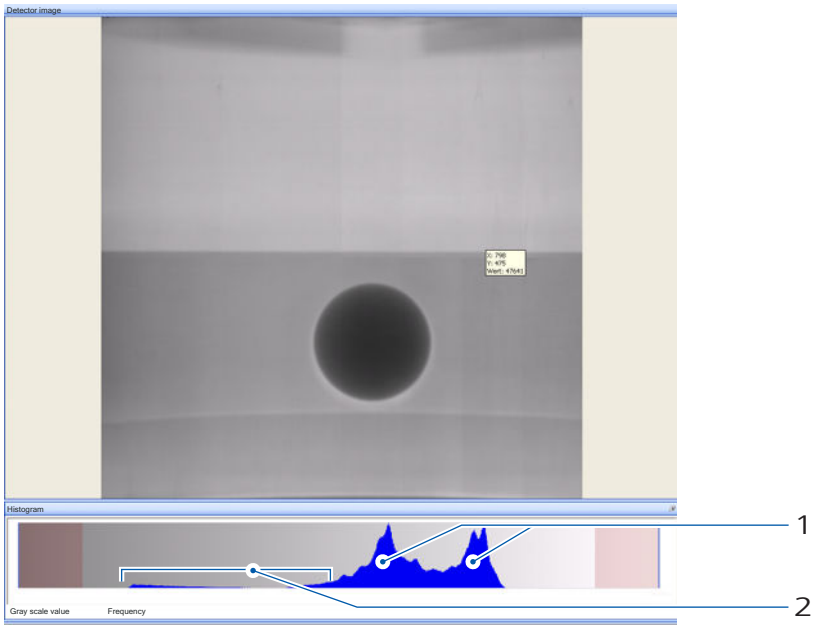
The data recorded by the tomography are converted into a voxel model during the reconstruction.

The data volume of the reconstruction corresponds to the product of voxel number and memory space required for a voxel. A voxel needs two bytes in »uint16« format. The number of voxels results from the volume defined by the reconstruction frame. The volume is calculated based on HxWxW, H being the height and W being the width of the reconstruction frame in pixels.

The reconstruction time depends on various influencing variables. The most important influencing variables are the size of the reconstruction frame in pixels and the number of projections.

### Histogram

The histogram is a graphic display of the frequency distribution of the gray scale values of the detector image. The background of uncorrected images is inhomogeneous; it can always be seen as peak in the right half of the histogram.




*Histogram*

1 Gray scale values of the background

2 Gray scale values of the workpiece

The workpiece has mostly a high variance of gray scale values. In the histogram, the workpiece is represented by the surface area on the left of the background peak. Very often it cannot be clearly recognized because of the small height of the individual values.

## From pixel to voxel

### Voxel

Voxel means a three-dimensional pixel to which a certain gray scale value is assigned. The natural voxel size can be determined based on detector resolution and magnification.

Generally, a reconstruction can be performed using any voxel size. Mostly, the appropriate voxel size is the natural voxel size, i.e. the pixel size of the detector reduced according to the current magnification.

*Influence of the voxel size*:

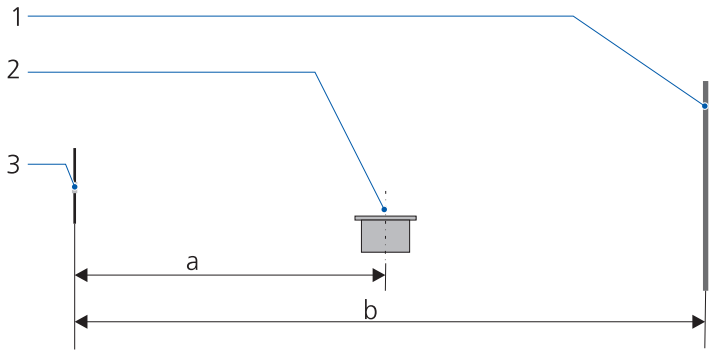
– If you perform the reconstruction with a voxel size smaller than the natural one, you get an »empty resolution«. The data volume of the reconstruction increases without new details of the workpiece becoming visible.

– If you perform the reconstruction with a larger voxel size than the natural one, details of the workpiece which would still be visible in the detector images will be suppressed.

  This is useful if you need the results quickly and a rough reconstruction is sufficient.

In general:

| | |
|---|---|
| Voxel size | = pixel size / magnification. |
| Magnification | factor M, used to project the workpiece onto the detector.<br>M = b /a<br>In words: Distance between the X-ray source and the detector / distance between the X-ray source and the workpiece. |




*Factors for magnification*

1 Detector
2 Rotary table axis
3 X-ray source

# Focus (focal spot)

If high voltage is applied between the cathode and the anode in the X-ray tube and tube current is conducted, the electrons are accelerated in the direction of the anode. They hit the anode at high speed. This point is called "focal spot". At this point, the kinetic energy of the electrons is converted into X-ray radiation.

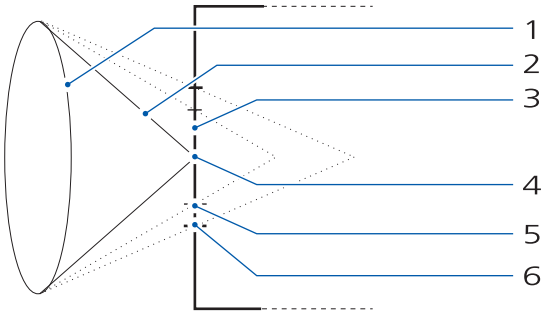
The focus represents the smallest diameter of the electron beam bundled in the X-ray tube. When the electron beam is focused, the focus lies on the target surface.

**NOTICE**

The two designations focus and focal spot are generally used as synonyms. Strictly speaking, this is only valid if the focus lies in the same plane as the focal spot. However, this is not the case when defocusing takes place at higher power. The focus is shifted and the focal spot is thus magnified. See illustration below.

## Defocusing

If the radiation intensity must be increased, the focal spot must be magnified to avoid melting of the target material. This is achieved by defocusing the electron beam. Then the focus no longer lies on the target surface. See diagram.




*Defocusing*

1 Focusing unit
2 Electron beam
3 Target
4 Focus with 8 W; the focus lies exactly on the surface of the target
5 Limit of the focal spot in the case of a shifted focus at medium power, e.g. 20 W
6 Limit of the focal spot in the case of a shifted focus at high power, e.g. 40 W

**NOTICE**

Defocusing starts at a power of 8 W. If the power is increased, the focal spot must be magnified by about 1 µm per watt to avoid melting of the target.

**Focal spot size**

The focal spot size depends on the power and lies in the µm range. It is related to blurring of the X-ray image: The smaller the focal spot, the clearer the image.

**Target material**

The physical loading capacity of the target material influences the focal spot size. For this reason, tungsten is used as anode material. It has the highest melting point of all metals and a high ordinal number.

## Effect of larger workpieces

Higher radiation intensities are required for the penetration of larger workpieces. The focal spot is magnified and blurring increases. As larger workpieces can only be represented slightly magnified, the blurring is not very significant.

**NOTICE**

To avoid increased blurring of the voxel matrix due to the larger focal spot, the focal spot size must be correlated with the voxel size prior to the measurement. In general: The focal spot should be smaller than the voxel size.

# Blurring

## Geometric blurring

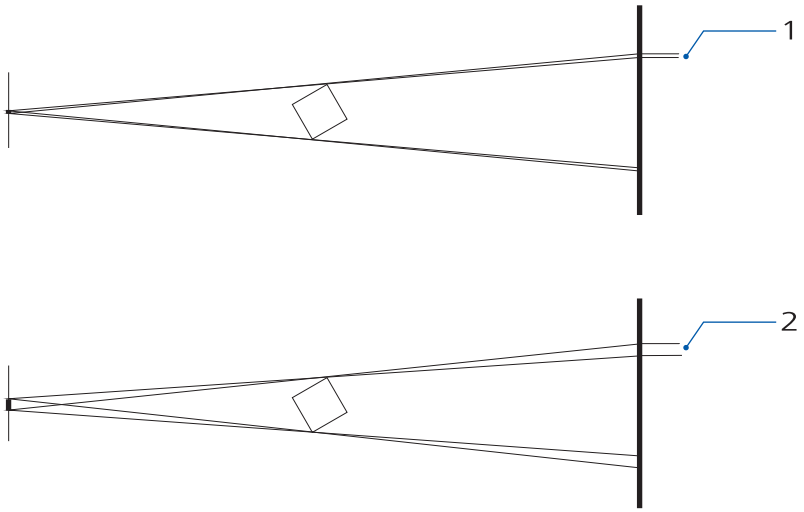
The geometric blurring $U_G$ can be determined by the following formula:

UG = f (M-1),

In general: f = Focal spot diameter M = Geometric magnification.

## Influence on blurring

The geometric blurring is determined by the focal spot size and the distance between X-ray source and workpiece.

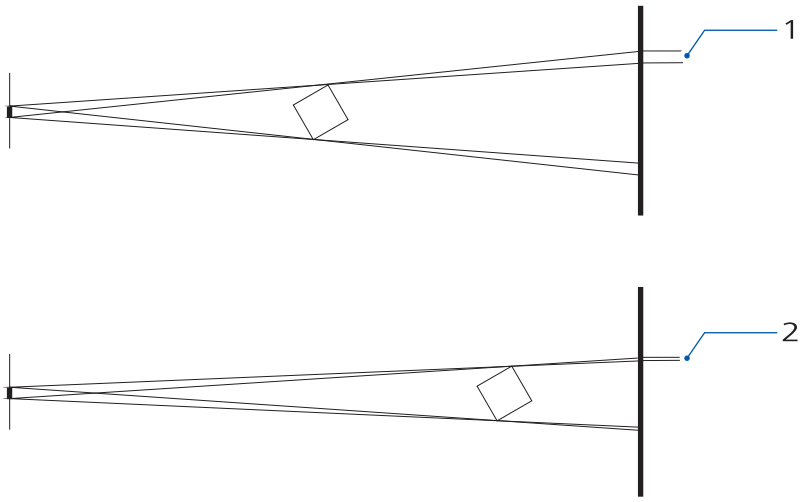



*Influence of the focal spot size on blurring*

| | |
|---|---|
| 1 | Slight blurring in the case of a small focal spot |
| 2 | Considerable blurring in the case of a large focal spot |

### Influence of the focal spot size

| | |
|---|---|
| Small focal spot: | Slight blurring |
| Large focal spot: | Large blurring |




*Influence of the distance between the X-ray source and the workpiece on blurring*

1 Considerable blurring in the case of a small distance between the X-ray source and the workpiece

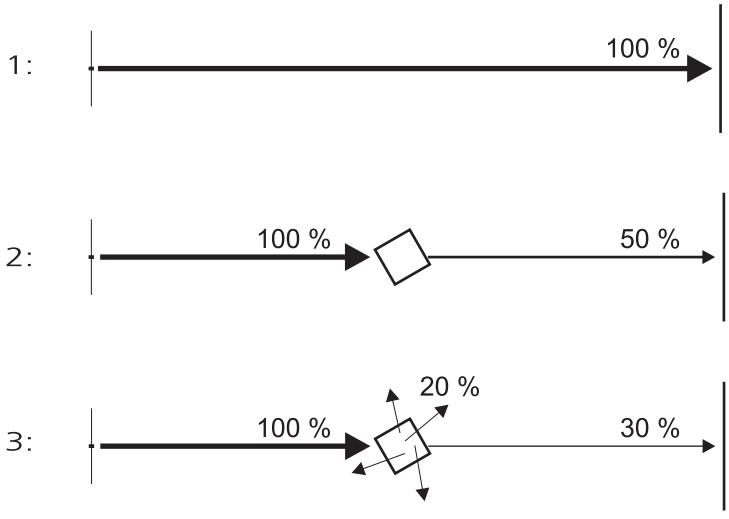
2 Slight blurring in the case of a large distance between the X-ray source and the workpiece

**Influence of the distance between the X-ray source and the workpiece**

| | |
|---|---|
| Small distance: | Large blurring |
| Large distance: | Slight blurring |

## Scattered radiation

The attenuation of X-ray radiation is always a coupled process of absorption and scattering.



1 No absorption: 100 % of the X-ray beams hit the detector

2 Absorption: 50 % of the X-ray beams are absorbed by the workpiece; the remaining 50 % hit the detector

3 Absorption and scattering: X-ray radiation with workpiece: 50 % of the X-ray beams are absorbed by the workpiece; 20 % of the X-ray beams are deflected and scattered in different directions: the remaining 30 % hit the detector

**NOTICE**

Scattered radiation generated in the workpiece or in the detector itself is relatively undirected. If it is detected, the contrast gets worse. The percentage of the scattered radiation increases with increasing X-ray energy (keV).

**NOTICE**

The gray scale value of a detector pixel represents the weakening of those X-ray beams that penetrate the workpiece and hit the detector.

## More information about metrotomography

METROTOM 800
Operating Instructions
2011-05-02
61211-8030202