
**Non-destructive testing — Radiation
methods for computed tomography —**

**Part 3:
Operation and interpretation**

*Essais non destructifs — Méthodes par rayonnements pour la
tomographie informatisée —*

Partie 3: Fonctionnement et interprétation

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Contents

Page

Foreword	iv
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Operational procedure	1
4.1 General	1
4.2 CT system set-up	2
4.2.1 General	2
4.2.2 Geometry	2
4.2.3 X-ray source	3
4.2.4 Detector	3
4.3 Reconstruction parameters	3
4.4 Visualization	3
4.5 Analysis and interpretation of CT images	4
4.5.1 General	4
4.5.2 Feature testing/defect testing	4
4.5.3 Dimensional testing	4
5 Requirements for acceptable results	7
5.1 Image quality parameters	7
5.1.1 Contrast	7
5.1.2 Noise	8
5.1.3 Signal to noise ratio	9
5.1.4 Contrast to noise ratio	9
5.1.5 Spatial resolution	10
5.2 Suitability of testing	12
5.3 CT examination interpretation and acceptance criteria	12
5.4 Records and reports	12
5.5 Artefacts	13
5.5.1 General	13
5.5.2 Beam hardening artefacts	13
5.5.3 Edge artefacts	14
5.5.4 Scattered radiation	15
5.5.5 Instabilities	15
5.5.6 Ring artefacts	15
5.5.7 Centre of rotation error artefacts	16
5.5.8 Motion artefacts	17
5.5.9 Artefacts due to an insufficient number of projections	18
5.5.10 Cone beam artefacts	18
Annex A (informative) Spatial resolution measurement using line pair gauges	19
Bibliography	23

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html

This document was prepared by the European Committee for Standardization (CEN) (as EN 16016-3) and was adopted, under a special "fast-track procedure", by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiographic testing*, in parallel with its approval by the ISO member bodies.

This first edition of ISO 15708-3 cancels and replaces ISO 15708-2:2002, of which it forms the subject of a technical revision. It takes into consideration developments in computed tomography (CT) and computational power over the preceding decade.

A list of all parts in the ISO 15708 series can be found on the ISO website.

Non-destructive testing — Radiation methods for computed tomography —

Part 3: Operation and interpretation

1 Scope

This document presents an outline of the operation of a computed tomography (CT) system and the interpretation of results with the aim of providing the operator with technical information to enable the selection of suitable parameters.

It is applicable to *industrial* imaging (i.e. non-medical applications) and gives a consistent set of CT performance parameter definitions, including how those performance parameters relate to CT system specifications.

This document deals with computed axial tomography and excludes other types of tomography such as translational tomography and tomosynthesis.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15708-1:2017, *Non-destructive testing — Radiation methods for computed tomography — Part 1: Terminology*

ISO 15708-2:2017, *Non-destructive testing — Radiation methods for computed tomography — Part 2: Principle, equipment and samples*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15708-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Operational procedure

4.1 General

For target-oriented computer tomography (CT) inspection procedures, the test and measurement tasks are defined in advance with regard to the size and type of features/defects to be verified; for example, through the specification of appropriate acceptance levels and geometry deviations. In the following, the process steps of a CT application are described and information on its implementation provided.

4.2 CT system set-up

4.2.1 General

The CT system set-up is oriented towards the requirements for the given task. The required spatial resolution (taking into account the tube focal spot size), contrast resolution, voxel size and the CT image quality can be derived from these requirements. The quality of the CT image is determined by different parameters, which under certain circumstances counteract each other.

In the following, system parameters are described and information is provided on setting up a CT system for inspection. Due to the interactions of the different system parameters, it may be necessary to run through the set-up steps several times in order to acquire optimal data.

The optimal energy is that which gives the best signal-to-noise ratio and not necessarily that which gives the clearest radiograph (the dependency of the detector efficiency on the energy is to be taken into account). However, in order to differentiate between materials of different chemical composition it may be necessary to adjust the accelerating voltage to maximise the difference in their linear attenuation coefficients.

4.2.2 Geometry

The source-detector and source-object distances and thus also the beam angle used should be specified. In order to achieve high resolutions, the projection can be magnified onto the detector. The magnification is equal to the ratio of the source-detector distance to the source-object distance. Increasing source-detector distance leads to a reduced intensity at the detector and thus to a reduced signal to noise ratio. Accordingly, this also applies when using detectors with improved detector resolution, which can result in a reduction of the signal-to-noise ratio due to the reduced intensity per pixel. In general, for this reason, minimisation of the source-object distance is to be preferred.

In order to obtain high beam intensity at the detector, the source-detector distance should be selected so that it is as small as possible taking into account the required resolution so that the beam cone still fully illuminates the detector. In the case of 3D-CT, the (in general vertical) total cone beam angle measured parallel to the rotation axis should typically be less than 15°, but this is specimen dependant, in order to minimise reconstruction-determined (Feldkamp) distortions of the 3D model. In addition, these restrictions do not apply for the perpendicular (in general horizontal) beam angle. For a higher geometric magnification, the object must be positioned as near as possible to the source, taking into consideration the limit on sharpness imposed by focal spot size. The rotation of the object must take place at at least 180° plus beam angle of the X-ray beam, whereby an improved data quality is the result of an increasing number of angular increments. For this reason, the object is typically turned through 360°. Ideally, the number of angular increments should be at least $\pi/2 \times$ matrix size (uneven number of projections per 360°) where the matrix size is the number of voxels across the sample diameter or the largest dimension. For more information, refer to [5.5](#).

The number of projections should be $> \pi \times$ matrix size for best reconstruction quality (even or uneven number of projections per 360°).

In order to obtain as complete information as possible on the specimen, the requirement in general for a CT is that the object (or the interesting section of the object) is completely mapped in each projection on the detector. For large components that exceed the beam cone, a so-called measurement range extension is used. This measurement range extension is accomplished by laterally displacing either the object or the detector, recording the projection data in sequential measurements, and finally concatenating (joining) them. Under certain circumstances, it is also possible to only scan a part of the object (region-of-interest CT), which may lead to a restricted data quality in the form of so-called truncations.

A possible deviation of the recording geometry (offset between the projected axis of rotation and the centre line of the image) must be corrected for in order to obtain a reconstruction which is as precise as possible. This can be achieved by careful realignment of the system or be corrected using software.

4.2.3 X-ray source

At the X-ray source, the maximum beam energy and tube current are to be set such that sufficient penetration of the test object and tube power with a sufficiently small focal spot are ensured. The required voltage shall be determined by the maximum path length in the material to be X-rayed in accordance with ISO 15708-2:2017, 8.2. For the best measurement results, an attenuation ratio of approx. 1:10 should be used. That is the grey level through the sample should be about 10 % of the white level (both measured with respect to the dark level). The optimal range can be achieved through the use of pre-filters. It should be noted that every pre-filter reduces the intensity. Pre-filters have the additional advantage of reducing beam hardening, though further improvements can be made with software correction.

4.2.4 Detector

The following detector settings need to be set appropriately for the sample being scanned:

- exposure time (frame rate);
- number of integrations per projection;
- digitisation gain and offset;
- binning.

If necessary, corrections for offset, gain and bad pixels (which may depend on X-ray settings) should be applied.

The individual CT projection is determined by the detector properties: its geometric resolution, its sensitivity, dynamics and noise. The gain and exposure time can be adjusted together with the radiation intensity of the source so that the maximum digitised intensity does not exceed 90 % of the saturation level.

To reduce scattered radiation, a thin filter, grid or lamellae can be used directly in front of the detector (intermediate-filtering).

The ideal acquisition time is dependent on the required quality of the CT image and it is often limited by the time available for inspection.

4.3 Reconstruction parameters

The volumetric region to be reconstructed, the size of the CT image (in terms of voxels) as well as its dynamic range (which should take into account the detector dynamic range) shall be specified. In order to achieve sufficient CT image quality, settings for the reconstruction algorithm or corrections should be optimised.

The volumetric region is defined by the number of voxels along the X, Y and Z axes.

4.4 Visualization

Using volume visualisation, the CT image can be presented as a 3D object. Individual grey values can be assigned any colour and opacity values to highlight or hide materials with different X-ray densities. Zooming, scrolling, setting contrast, brightness, colour and lighting facilitate an optimal presentation of the CT image. In addition, it is possible to place user-defined sectional planes through the object in order to examine the internal structure, or to interactively visualise the CT image, for example by rotating and moving it as a 3D object. Image processing can be applied to CT images to improve feature recognition.

It may not be possible to load the whole CT image at full resolution into memory at once.