IEC 62963

Edition 1.0 2020-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Radiation protection instrumentation – X-ray computed tomography (CT) inspection systems of bottled/canned liquids

Instrumentation pour la radioprotection – Systèmes d'inspection par tomographie aux rayons x par ordinateur (CT) des liquides en bouteille ou en canette

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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RADIATION PROTECTION INSTRUMENTATION – X-RAY COMPUTED TOMOGRAPHY (CT) INSPECTION SYSTEMS OF BOTTLED/CANNED LIQUIDS

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
45B/958/FDIS	45B/962/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
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RADIATION PROTECTION INSTRUMENTATION – X-RAY COMPUTED TOMOGRAPHY (CT) INSPECTION SYSTEMS OF BOTTLED/CANNED LIQUIDS

1 Scope

This document describes the technical requirements, test methods, inspection requirements, markings and labelling, and requirements on the accompanying documents, packaging, shipping and storage for X-ray security inspection systems that inspect bottled or canned liquids (hereinafter referred to as "the system") based on X-ray computed tomography (CT). Here, the system is limited to those that feature tomographic scanning, not standard X-ray projection. This document is applicable to liquids, aerosols and gelatinous objects in transparent or visually opaque containers.

This technical performance document includes minimum or baseline performance requirements; regulators may require additional performance testing.

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.

IEC 60068-2-1, *Environmental testing – Part 2-1:Tests – Test A:Cold*

IEC 60068-2-2, *Environmental testing – Part 2-2:Tests – Test B:Dry heat*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 61000-6-1:2016, *Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity standard for residential, commercial and light-industrial environments*

IEC 61000-6-3:2006, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61010-1:2010, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

ISO 780:2015, *Packaging – Distribution packaging – Graphical symbols for handling and storage of packages*

ISO 13849 (all parts), *Safety of machinery – Safety-related parts of control systems*

ASTM A624/624M:2013, *Standard Specification for Tin Mill Products, Electrolytic Tin Plate, Single Reduced*

ASTM B221:2014, *Standard Specification for Aluminium and Aluminium-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes*

EN 546-1:2006, *Aluminium and aluminium alloys – Foil – Part 1: Technical conditions for inspection and delivery*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

3.1
ambient dose equivalent
***H**(10)**
dose equivalent at a point in a radiation field that would be produced by the corresponding expanded and aligned field in the ICRU sphere at a depth of 10 mm on the radius opposing the direction of the aligned field

Note 1 to entry: The SI unit of ambient dose equivalent is the sievert (Sv) or its decimal multiples or submultiples (e.g. mSv).

Note 2 to entry: The ambient dose equivalent (rate), used for the monitoring of strongly penetrating radiation, is not an appropriate quantity for any beta radiation even that which is nominally penetrating (ICRU Report 47, 1992).

Note 3 to entry: When the term dose equivalent alone is used in this document, the quantities ambient dose equivalent and directional dose equivalent are implied.

3.2
ambient dose equivalent rate
ratio of d*H**(10) by d*t*, where d*H**(10) is the increment of ambient dose equivalent in the time interval d*t:*

$$\dot{H}^*(10) = \frac{\mathrm{d}H^*(10)}{\mathrm{d}t}$$

Note 1 to entry: The SI unit of ambient dose equivalent rate is the sievert per second ($Sv \cdot s^{-1}$). Units of ambient dose equivalent rate are any quotient of the sievert or its decimal multiples or submultiples by a suitable unit of time (e.g., $mSv \cdot h^{-1}$).

3.3
CT value
value reported by CT systems on a per voxel basis that is a function of the material's density and atomic number

Note 1 to entry: It is expressed in Hounsfield units (HU) in which the value of air at standard pressure and temperature (STP) is defined as zero HU, while the value of distilled water at STP is defined as 1 000 HU.

3.4
density resolution
measure of the extent to which a tomograph or radiograph can be used to detect physical differences in the test object

3.5
effective atomic number
Z_{eff}
material property that represents the atomic number of a theoretical element that, if the material were replaced by the element, would produce the same x-ray attenuation characteristics

Note 1 to entry: Z_{eff} measurements can be scanner-dependent and its value shall not be considered as absolute.

3.6
electron density
material property defined as:

$$\rho_e = \rho \times 2Z/A$$

Where

ρ_e is electron density,

ρ is physical density,

Z is atomic number, and

A is atomic weight.

3.7
object inspection time
time interval from when the object to be inspected is inserted into the system to the time when the system shows the result for the whole object. This does not include initial system warm up time

Note 1 to entry: Object inspection may contain one or more single slices.

3.8
single slice inspection time
time interval from when the object to be inspected is inserted into the system, to the time that the system shows the result for only one two-dimensional imaged slice of the object, a single voxel in height

Note 1 to entry: This definition applies only to systems that have a single-slice mode available. This does not include initial system warm up time.

3.9
spatial resolution
smallest separation distance at which two points (or line pairs) can be distinguished as separate entities

3.10
test sample
combination of designated container and its content to be scanned

3.11
X-ray computed tomography (CT)
technique that uses computer-processed combinations of many X-ray images taken from different angles to produce cross-sectional (tomographic) images (virtual 'slices') of specific areas of a scanned object

3.12
X-ray inspection system of bottled/canned liquids
system that applies X-ray CT to bottles or cans with the intent of identifying liquids, aerosols, or gels for security purposes

4 Requirements

4.1 Structure and appearance

Protection grade for the system's shell shall be subject to rules of IEC 60529, which shall not be rated lower than the international protection marking code IP20.

4.2 Functionality

4.2.1 Threat alarm

The system shall automatically provide warning by audible or visual signals when threats are detected. The signals may be disabled by configuration, if desired.

4.2.2 Image display

a) The system shall designate the position(s) that a container should be placed for inspection.

b) The system shall display images of inspected position(s).

4.2.3 Data storage

a) Data stored in the system shall include the resulting image, device identification number (ID), operator ID and image generation time.

b) Image retrieval: functionality shall be provided to retrieve result images by operator ID, image generation time and alarm result.

c) Image storage capacity: The system shall save images and results of a minimum of 10 000 scanned objects.

d) Image storage security: Images saved in the system shall be secured. Only authorized personnel should be able to access to operate on the images.

e) Image export: The system shall export images into an open image format that can be easily transferred or exported.

4.3 Performance

4.3.1 Reference environmental conditions and standard test requirements

Except where otherwise specified, tests shall be carried out within the standard test conditions shown in the third column of Table 1. For tests performed outside the standard test conditions, the values of temperature, pressure and relative humidity shall be stated and the appropriate corrections, if any, made to give the response under reference conditions. All tests in 4.3 shall be performed with the same values of these reference environmental conditions. Reference conditions are given in the second column of Table 1.

The values in Table 1 are intended for tests performed in temperate climates. In other climates, the actual values for the test shall be stated. Similarly atmospheric pressure lower than 70 kPa may be permitted at higher altitudes. If the system is to be operate outside the environmental standard test conditions, testing shall be performed at these non-standard conditions.

Table 1 – Reference condition and standard test condition

Environment condition	Reference condition	Standard test conditions
Environment temperature	20 °C	15 °C to 35 °C
Relative humidity	65 %	45 % to 75 %
Atmospheric pressure	101,3 kPa	70 kPa to 106,6 kPa
Background radiation dose rate	Ambient dose equivalent rate no greater than 0,1 μSv·h^{-1}	Ambient dose equivalent rate less than 0,25 μSv·h-1
Ambient electromagnetic field	Negligible	Less than the lowest value that causes interference
Ambient magnetic induction	Negligible	Less than twice the value of the induction due to earth's magnetic field

For the system under test, the image quality test report shall include manufacturer, manufacture date, model No., serial No., software version, environmental conditions, serial No. of the test articles, type and serial No. of X-ray emitter. For all performance requirements in 4.3, image evaluation shall be based on images acquired under normal security-screening operation mode including exposure time, high voltage, and any other adjustable parameters.

4.3.2 Requirement on inspection time

4.3.2.1 Requirements

The object inspection time shall not be more than 30 s. In single slice mode, if available, the inspection time shall be no more than 10 s.

4.3.2.2 Test method

The system shall conduct an inspection for a test sample and the measurement/scanning time and mode shall be recorded, and comply with the requirement of 4.3.2.1.

4.3.3 Requirement on minimum volume of liquid to be inspected

4.3.3.1 Requirements

The system shall be able to inspect volumes of liquid that are ≥ 100 ml. The shape of the container used to test for minimum scannable volume shall be a cylinder with a diameter of 50 mm.

4.3.3.2 Test method

Fill the container TC01, defined in Table 2, with water, and use the sample to perform inspection. Such test shall be normally achieved and finally give an inspection result.

Table 2 – Container for minimum volume test

Code	Name	Specification
TC01	Container for minimum volume of liquid-to-be-inspected test sample	Cross-section is circular; external diameter: 50±1 mm; wall thickness: 1±0,5 mm; polyethylene plastic bottle

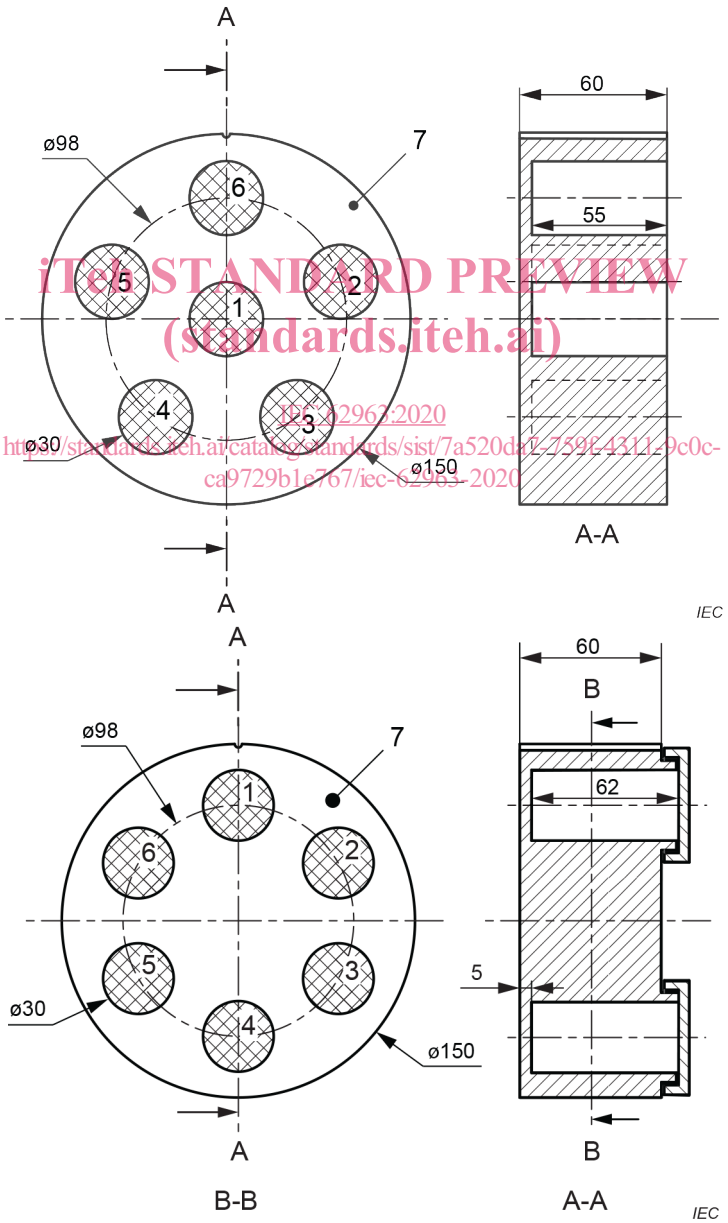
4.3.4 Image contrast sensitivity

4.3.4.1 Requirements

The system's image contrast sensitivity shall be sufficient to achieve discrimination between samples with physical density that differs by less than or equal to 3 % from that of water. The evaluation report format for this metric is given in Annex A, Table A.1.

4.3.4.2 Description of the image-contrast-sensitivity test article

Using image contrast, this metric gauges effective liquid density resolution or sensitivity. The test article consists of 6 cylindrical cavities in a large cylindrical base, each filled with a different density liquid, as shown in Figure 1. The large cylinder is made of polyethylene. Each cavity is filled with distilled water or NaCl water solutions of different concentrations which is contained with a lid. Ensure the liquids are chemically stable over the period of testing. Relative densities of the liquids are given in Table 3.



Key

1 to 6 Test samples at different densities

7 Base of the cylinder

Figure 1 – The image-contrast-sensitivity test article (all units are in mm)

Table 3 – Densities of test samples and respective NaCl concentrations

Sample No.	Physical density of test liquid	NaCl concentration (20 °C)
1	Water	0
2	Base density of water +1 %	1,66 ± 0,05 %
3	Base density of water +2 %	3,06 ± 0,05 %
4	Base density of water +3 %	4,44 ± 0,05 %
5	Base density of water +4 %	5,83 ± 0,05 %
6	Base density of water +5 %	7,20 ± 0,05 %

4.3.4.3 Test method

Place the image-contrast-sensitivity test article at the center of the inspection volume with the axis of the cylinder vertically upwards. Scan the test object such that the central position of the article that contains the test samples is imaged. Visually determine which of the NaCl test samples can be discriminated from the water test sample by comparing the imaged samples within one of the following reconstructed images: CT value, electron density or Z_{eff}. If the reconstructed image includes more than one vertical voxel, before performing the evaluation, produce a two-dimensional image using a projection method in the vertical direction that produces the best signal to noise. Otherwise, evaluate directly the acquired single slice, two-dimensional image of the samples. The system shall achieve discrimination between samples with physical densities that differ by less than or equal to 3 % from that of water; i.e., at least 4 samples (namely, #1, #4, #5, #6) shall be discriminable. The image inspection shall be taken by at least 5 different persons with normal vision and at least 3 persons shall produce the same result as defined in Table A.1.

4.3.5 Spatial resolution

4.3.5.1 Requirements

The system shall be able to entirely resolve line pairs with spatial frequencies of less than or equal to 2,0 mm. Evaluation of the sample is described in Clause A.2.

4.3.5.2 The spatial-resolution test article

The spatial-resolution test article is a plastic cylinder with a diameter of 150 mm and a height of 50 mm into which iron plates are inserted. Three iron plates form each line-pair gauge. The article is composed of eight line-pair gauges of different thicknesses as shown in Figure 2.

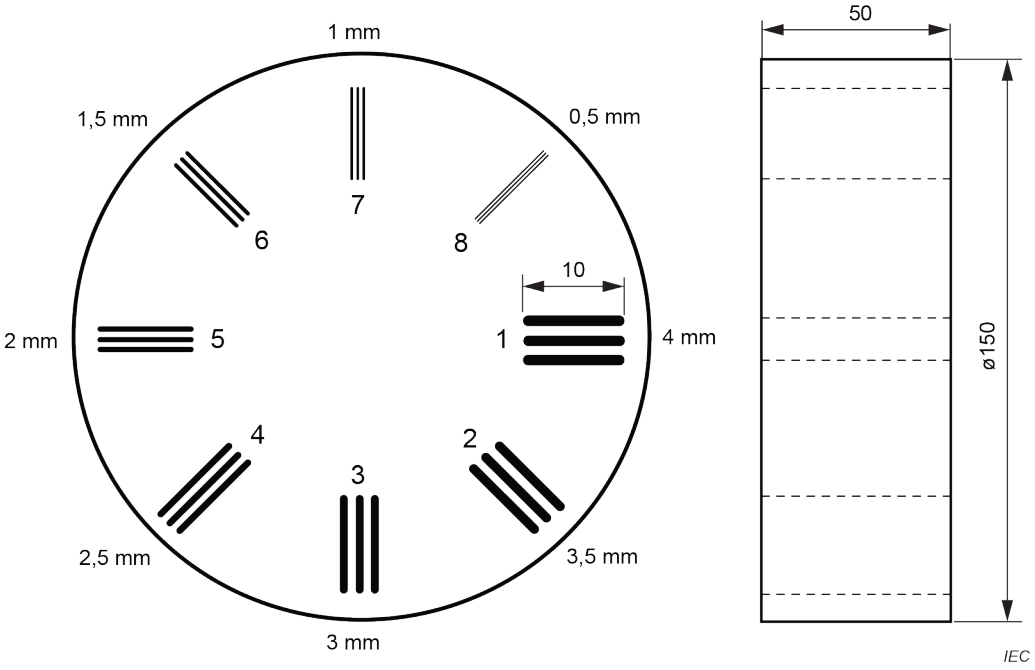


Figure 2 – The spatial-resolution test article (all the units are in mm)

The line-pair gauge dimensions and positions are given in Table 4.

Table 4 – Position versus dimension of line pairs

Code No.	Inserted iron plate dimensions length × width × thickness mm	Thickness of the gap between the plates mm
1	50×10×(4,00 ± 0,05)	4,00 ± 0,05
2	50×10×(3,50 ± 0,05)	3,50 ± 0,05
3	50×10×(3,00 ± 0,05)	3,00 ± 0,05
4	50×10×(2,50 ± 0,05)	2,50 ± 0,05
5	50×10×(2,00 ± 0,05)	2,00 ± 0,05
6	50×10×(1,50 ± 0,05)	1,50 ± 0,05
7	50×10×(1,00 ± 0,05)	1,00 ± 0,05
8	50×10×(0,50 ± 0,05)	0,50 ± 0,05

4.3.5.3 Test method

Place the spatial-resolution test article at the center of the scanning volume with the axis of the cylinder vertically upwards. Scan the central position of the article. Visually inspect the imaged test object within one of the following slice images: CT value, electron density or Z_{eff}. A line-pair gauge with all three lines visually complete and separable from others is judged as resolvable. Record each of the resolvable line-pair gauge with code number designated in Table 4. At least codes 1 to 5 (4,0 mm to 2,0 mm) shall be entirely resolved. Such inspection shall be taken by at least 5 different persons with normal vision and at least 3 persons shall produce the same conclusion.

4.3.6 Container artifacts

4.3.6.1 Container-artifacts test article

This test article is used to measure the influence of the container size and material on the CT value, electron density and Z_{eff} determined for the liquid within the container. The container-artifacts test article is an object constructed by binding to a polyformaldehyde cuboid and cylinder thick/thin strips of aluminum and thick/thin strips of iron including 14 steps, with a 100 mm diameter 210 mm height polyethylene barrel as protective sleeve on the outside. Here, the polyformaldehyde cuboid has 7 steps in total at the height of 105 ± 3 mm and the polyformaldehyde cylinder has 7 steps too, at the height of 105 ± 3 mm as shown in Figure 3. For detailed parameters, see Table 5.

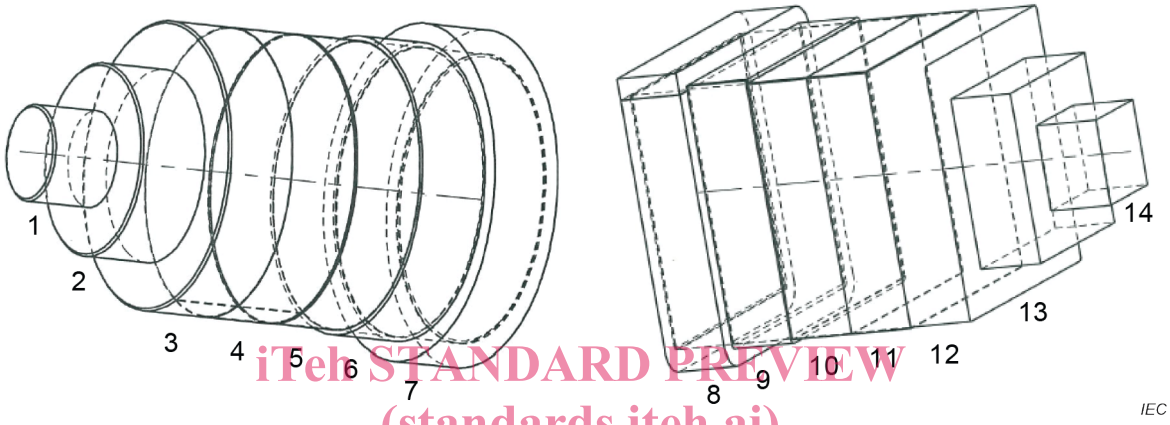


Figure 3 – The container-artifacts test article

Table 5 – The recording form for container-artifacts test object's parameters

Step No.	Specification of inner materials	Covering material grade	Cross-section mm	Height mm	Covering thickness mm	Representative
1	polyformaldehyde Φ20 mm	--	20 ± 1	15 ± 1	--	small-sized round plastic container
2	polyformaldehyde Φ40 mm	--	40±1	15±1	--	medium-sized round plastic container
3	polyformaldehyde Φ60 mm	--	60±1	15±1	--	large-sized round plastic container
4	polyformaldehyde	ASTM A624/A624M:2013 Single reduced, electrolytic tin plate, L,T-2, or equivalent, thickness 0,2 mm	60±1	15±1	0,2 ± 0,01	round iron can
5	polyformaldehyde Φ60 mm	EN 546-1:2006 Aluminium Foil Al 6061, or equivalent, thickness 0,2 mm	60±1	15±1	0,2 ± 0,01	round Al container