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Phantoms for X-ray computed tomography

1 Scope This Japanese Industrial Standard specifies the phantoms used for routine check ⁽¹⁾ of medical X-ray computed tomography (hereafter referred to as “phantoms” and referred to X-ray computed tomography as “X-ray CT equipment”).

Note ⁽¹⁾ “Daily check” in this Standard means that the checks are performed at periodical intervals or at any time to keep the performance characteristics of the X-ray CT equipment.

Remarks: The normative references to this Standard are as follows.

JIS G 4309 *Stainless steel wires*

JIS H 4000 *Aluminium and aluminium alloy sheets and plates, strip and coiled sheets*

JIS K 6717 *Polymethyl methacrylate moulding materials*

JIS K 6718 *Polymethyl methacrylate sheets*

JIS Z 4005 *Medical radiology—terminology*

JIS Z 8103 *Glossary of Terms used in instrumentation*

2 Definitions For the main terms used in this Standard, the definitions in **JIS Z 4005** and **JIS Z 8103** apply, and the rest of the terms are as follows.

- (1) **CT value** Unit making up CT image. The value proportional to X-ray absorption coefficient with making water zero and air −1 000 and taking those as the reference. Unit is expressed by HU (Hounsfield Unit).
- (2) **noise** The standard deviation of CT value fluctuation of pixel in a specific region of water phantom images.
- (3) **contrast scale** The ratio of difference of CT value of water and some material to difference of respective absorption coefficients.

$$CS = \frac{\mu_x - \mu_w}{(CT)_x - (CT)_w}$$

where,

CS : contrast scale

μ_x : absorption coefficient of a material

μ_w : absorption coefficient of water

$(CT)_x$: CT value of a material

$(CT)_w$: CT value of water

- (4) **space resolution** The power of X-ray CT equipment capable of resolving different materials in image assessment.

- (5) **slice thickness** The half value width of slice profile.
 - (6) **slice central plane** The section including the center of slice thickness.
 - (7) **high contrast resolution** In the case where X-ray absorption difference between some material and the environment is large, the power of X-ray CT equipment capable of discriminating the material on the image.
 - (8) **low contrast resolution** In the case where X-ray absorption difference between some material and the environment is small, the power of X-ray CT equipment capable of discriminating the material on the image.
 - (9) **CTDI (Computed Tomography Dose Index)** The value evaluated by dividing the integration value of dose profile on the line perpendicular to the slice plane by the product of nominal slice thickness and number of tomograms obtained in mono-scanning.
 - (10) **dose** The dose obtained by measuring computed tomography dose index (CTDI) at 10 mm inside positions from surface and central portion of measuring device by using a dose meter ⁽²⁾.
- Note ⁽²⁾ As for dose meter, refer to the Informative reference appended to this Standard.
- (11) **cylindrical container** A cylindrical container made of polymethyl methacrylate, which is used for storing the measuring devices in it.
 - (12) **measuring device** Generic term of substances making the phantom for performing the daily check of 4 (2) to (7).

3 Performance characteristics The performance characteristics shall be as follows.

- (1) **Water leak** The water leak shall not be confirmed in the case where the test is performed in accordance with 7.3 (2).
- (2) **Appearance** The deformation, flaws, crack and air bubbles are not confirmed in the case where the test is performed in accordance with 7.3 (3).

4 Daily check items The phantom shall be able to be used for the following daily checks.

- (1) Noise
- (2) Contrast scale
- (3) Space resolution
- (4) Slice thickness
- (5) High contrast resolution

- (6) Low contrast resolution
- (7) Computed tomography dose index (CTDI)

5 Structure, shape, materials and dimensions

5.1 Cylindrical container The structure, shape, materials and dimensions of cylindrical container shall be as follows.

- (1) The cylindrical container shall be made of polymethyl methacrylate conforming to the requirements given in **JIS K 6717** or **JIS K 6718** (hereafter referred to as "polymethyl methacrylate"), shall be able to contain all measuring devices given in **5.2** and able to fill water in it. And its dimensions shall be 190 mm in inner diameter, 5 mm in wall thickness, 10 mm in thickness of both bottom surfaces, 200 mm in total length (however, excluding protruding portions).
- (2) The cylindrical container shall have a noise measuring part of 20 mm in thickness as shown in Attached Fig. 1, in the case of containing all measuring devices in it.
- (3) The cylindrical container shall have such a structure as the measuring devices can be contained from the bottom of one side.
- (4) The surface of cylindrical container shall be smooth and capable of observing inside easily.
- (5) A mark shall be attached on the surface of the cylindrical container corresponding to slice central plane of respective measuring devices by the indelible method without giving any influence on the measurement.
- (6) To remove air in the phantom, air vent part shall be provided.
- (7) The phantom shall have such a structure as to be able to fix itself in the space.

5.2 Measuring devices The structure, shape, dimensions and materials of measuring devices shall be as follows.

- (1) **Contrast scale measuring device** The contrast scale measuring device shall be that in which between two plates of polymethyl methacrylate disc of 189 mm in diameter and 5 mm in thickness (In Attached Table 1, it is called "supporting disc"), a polymethyl methacrylate cylinder of 50 mm in outer diameter, 5 mm in wall thickness and 20 mm in length is equipped at the central portions of respective disc plates. Air shall be tightly closed in the inside of cylinder (refer to Attached Fig. 2).
- (2) **Space resolution measuring device** The space resolution measuring device shall be that in which between two plates of polymethyl methacrylate disc of 189 mm in diameter and 5 mm in thickness (In Attached Table 1, it is called "supporting disc"), at the position apart by 15 mm from its center, a stainless steel wire of 0.2 mm in diameter, 20 mm length which conforms to **SUS 305** of **JIS G 4309** is equipped vertically to respective disc surfaces. The two plates of polymethyl methacrylate disc shall be

mutually fixed by the method without giving any influence on the measurement (refer to Attached Fig. 3).

- (3) **Slice thickness measuring device** The slice thickness measuring device shall be that in which between two plates of polymethyl methacrylate disc of 189 mm in diameter and 5 mm in thickness, aluminium sheets of 40 mm in length, 20 mm in width and 0.5 mm in thickness conform to **JIS H 4000** are equipped at the angle of 30° to the surface of this plate at respective centers of these discs and two positions apart by 70 mm from the center by the method without giving influence on the measurement. The direction of aluminium sheet equipped at the center shall be in reverse direction of inclination to the other sheet. Two plates of polymethyl methacrylate disc shall be fixed by the method without giving any influence on the measurement (refer to Attached Fig. 4).
- (4) **High contrast resolution measuring device** The holes of 0.3 mm, 0.4 mm, 0.5 mm, 0.7 mm 1.0 mm, 1.5 mm and 2.0 mm in diameter shall be created in the disc made of polymethyl methacrylate of 100 mm in diameter and 15 mm in thickness so as the holes of same diameter to be in a row for each three pieces vertically to the disc surface. However, holes of 0.7 mm shall be five pieces and the central hole, be at the position of center of disc. The distance between centers of holes of same diameter shall be two times the diameter of hole, the distance between central line of hole row, be 10 mm (refer to Attached Fig. 5). This disc shall be equipped at the central portion of two plates of polymethyl methacrylate disc of 189 mm in diameter and 5 mm in thickness.

Air shall be tightly closed in these holes.

- (5) **Low contrast resolution measuring device** The holes of 2.0 mm, 3.0 mm, 4.0 mm, 5.0 mm, 10.0 mm and 20.0 mm in diameter shall be vertically created to surface of disc of 140 mm in diameter and 20 mm in thickness at the position indicated in Attached Fig. 6, and the disc shall be made of such a material as its X-ray energy dependence is small and its CT value is approximately 50. The distance between centers of holes of the same diameter shall be two times the diameter. The number of holes shall be 5 pieces in each for 2.0 mm to 4.0 mm, 6 pieces with adding the hole of central portion for 5.0 mm, 3 pieces for 10.0 mm, 1 piece for 20.0 mm. Excluding the hole at central portion, the center of central hole of group of holes having the same diameter shall be placed on the circumference of 35 mm in radius from the center of the disc (refer to Attached Fig. 6). The inside of the hole shall be filled by a material lower by 5 ± 1 in CT value than the environmental material. This disc shall be equipped at the central portion between two plates made of polymethyl methacrylate disc of 189 mm in diameter and 5 mm in thickness (In Attached Table 1, it is called "supporting disc").

5.3 Dose measuring device The structure, shape, dimensions and materials of dose measuring devices shall be as follows.

- (1) **Measuring device for head** The holes of 13 mm in diameter shall be created in the circular column made of polymethyl methacrylate of 160 mm in diameter and 150 mm in total length in parallel to the central axis of circular column with 90 degrees in intervals in circumferential direction of the column at the central portion of column and at the positions where the center of hole is inside by 10 mm from column surface (refer to Attached Fig. 7).

- (2) **Measuring device for body** The holes of 13 mm in diameter shall be created in the circular column made of polymethyl methacrylate of 320 mm in diameter and 150 mm in total length in parallel to the central axis of circular column with 90 degrees in intervals in circumferential direction of the column at the central portion of column and the positions where the center of hole is inside by 10 mm from column surface (refer to Attached Fig. 8).
- (3) **Filler** The filler shall be inserted to the holes which are not used during measurement. Filler shall be the bar made of polymethyl methacrylate of 13 mm in diameter and 150 mm in total length (refer to Attached Fig. 9).
- (4) **Marks of position** A mark shall be attached on the surface positions corresponding to slice center and central line of three measuring holes of dose measuring device by the indelible method without giving any influence on the measurement.

6 Dimensional tolerance The dimensional tolerance of the phantom shall be as given in Attached Table 1.

7 Test

7.1 Environmental conditions of test The environment conditions shall be as follows.

- (1) Ambient temperature shall be 10 °C to 40 °C .
- (2) Relative humidity shall be $(60 \pm 25) \%$.

7.2 Test items The test items shall be as follows.

- (1) Dimension test
- (2) Water leak test
- (3) Appearance test

7.3 Test methods The test methods shall be as follows.

- (1) **Dimension test** Examine dimensions of each part by using a dimension measuring device having appropriate precision for this purpose and whether the dimensions conform to Attached Table 1 or not.
- (2) **Water leak test** Fill water in the cylindrical container and close tightly it. Examine existence of water leak after the cylindrical container was left under longitudinal and transverse conditions for each 24 h.
- (3) **Appearance test** Examine the existence of deformation, flaws, cracks and air bubbles visually.