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KS107QN-4B Type Internal Cavity Scanning Ultrasonic Body Model (YY/T 1659-2019)

Overview

The KS107QN-4B type internal cavity scanning ultrasonic body model is a human physical model that mimics the ultrasonic propagation characteristics of tissues. It is a testing device composed of Ultrasonically Tissue-Mimicking Material (referred to as TM material) and various test targets embedded within it (including target lines, simulated cysts, simulated stones, simulated tumors), as well as sound windows, shells, and indicative decorative panels.

At the center position of the upper panel of the phantom, there are two scanning holes with an inner diameter of 10mm, which are used to insert the intracavitary probe for ultrasound scanning. They are specifically designed to examine the imaging characteristic parameters of the B-ultrasound imaging device that is equipped with an intracavitary ultrasound probe, including blind zone, lateral (transverse) resolution, axial (longitudinal) resolution, lateral geometric position accuracy, axial geometric position accuracy, and the diameter error of the simulated lesion. The left and right side panels of the phantom have probe hole channels for measuring the withdrawal direction resolution and the geometric position accuracy of the withdrawal direction, with an inner diameter of 10mm. The schematic diagram of the appearance and internal structure of the phantom is shown in Figure 1.

Basic Structure

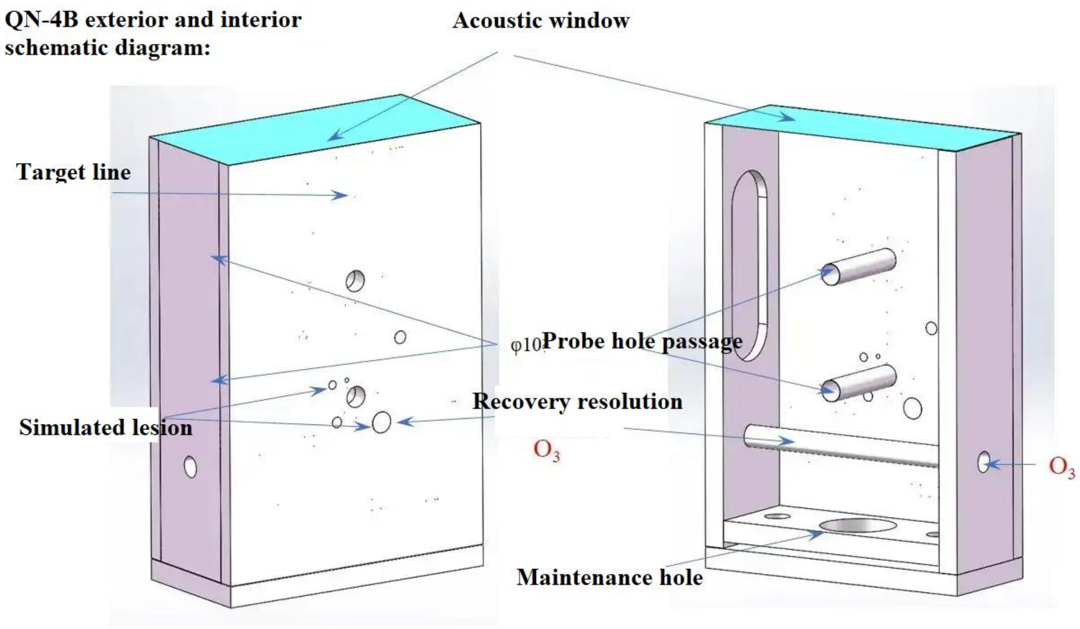

Figure 1: Exterior and internal schematic diagram of the KS107QN-4B ultrasonic body model

1.The four walls and the bottom are made by assembling pieces of plexiglass. The outer surfaces of the four walls are covered with plastic film panels for indication and decoration.
2. The overall dimensions are 210mm (length) × 140mm (width) × 66mm (height).
3. The bottom plate is equipped with a circular hole with a diameter of 36mm, which is sealed with a rubber sheet of 50mm in diameter and 2mm in thickness. This serves as a passage for injecting the maintenance fluid and removing air.
4. The body model is filled with TM material that meets the requirements of national standards as the standard sound transmission medium.
5. On the upper panel of the phantom, there are two central probe access channels with a diameter of Φ10mm at 60mm and 120mm from the sound window. These channels are through-hole channels, allowing the probe to be inserted into them for ultrasonic scanning. The left and right side panels of the phantom have probe access channels with an inner diameter of 10mm for measuring the resolution in the retraction direction and the geometric position accuracy of the retraction direction. These channels are through-hole channels running through the left and right side panels, and the internal probe can be inserted through them for scanning.
6. Linear Target System

The TM material is embedded with the following target groups, whose distribution is shown in Figure 2. There are a total of:

(1) O1-O3 probing holes.

There are two probing holes with a diameter of Φ10mm on the upper and lower panels of the phantom, located at the center of the upper and lower halves of the panel respectively. Around probing hole O1, there are axial lateral resolution target groups, lateral target groups, and longitudinal target groups. Around probing hole O2, there are blind zone target groups, imaging geometric distortion target groups, simulated cystic lesions, simulated tumor lesions, simulated cyst and simulated calculus lesions. Probing hole O3 is located on the left and right panels of the phantom, used for measuring the direction resolution and geometric position accuracy of the withdrawal direction. This channel is a through-channel between the left and right panels, and the internal probe can be inserted from the left and right panels for scanning.

(2) A: Blind zone target group.

The blind zone target group is arranged around the probe hole O2. There are a total of 8 target lines, with one set every 45°. The setting depth starts from 1 mm above the center probe hole O2's edge and increases by 1 mm at each step, ranging from 1 mm to 8 mm.

(3) B1 - B4: Axial lateral resolution target group.

The axial lateral resolution target groups are arranged around the probe hole O1. Their lateral branches are respectively located on the circular arcs with radii of 5, 10, 20, and 30 mm from the edge of the central probe hole O1, namely groups B1, B2, B3, and B4. Each target line is distributed on the circular arcs with radii of 10 mm, 15 mm, 25 mm, and 35 mm around the center of the probe hole. The lateral spacing between the centers of two adjacent target lines (the chord length of the distance between the two target lines) is successively 3, 2, 1, and 0.5 mm.
This target group has two adjacent target lines in its axial branches both located within a radius

centered on the center of the probe hole. The differences in the radius between the centers of the adjacent target lines and the center of the probe hole are 0.5, 1, 2, and 3 mm respectively. Taking the axial lateral resolution of the target group located at the radius of the probe hole center (i.e., 5 mm from the edge of the probe hole) as an example, the schematic diagram of the distribution of the axial lateral resolution target group is shown in Figure 3. Here, in the axially projected resolution target group, the intervals between the target lines are the straight-line distances of the target lines, while in the lateral resolution target group, the intervals between the target lines are the chord lengths (not the arc lengths of the circle).

(4) C1 - C3: Lateral target group (used to evaluate the lateral (horizontal) geometric position accuracy)

The lateral target groups are arranged around the exploration hole O1, located at 5mm, 10mm, and 30mm from the upper edge of the central exploration hole respectively. Among the C2-C3 target groups, the lateral distance between the centers of the two target lines (the straight-line distance between the two target lines) is 10mm. In the C1 target group, the lateral distance between the centers of the two target lines (the straight-line distance between the two target lines) is 5mm. The target lines are distributed on arcs with radii of 10mm, 15mm, and 35mm around the center of the exploration hole. The lateral target group at 5mm is distributed in a semi-circular shape starting from the horizontal position on the left side of the exploration hole, with a total of 5 target points. The lateral target group C2 at 10mm starts from the horizontal position on the left side of the exploration hole and is distributed in a semi-circular shape, with a total of 4 target points. The lateral target group C3 at 30mm starts from the horizontal position on the left side of the exploration hole and is distributed in a semi-circular shape, with a total of 10 target points.

(5) D1 - D2: Vertical target group

1.The longitudinal target group D1 is arranged around the exploration hole O1. There are 6 target lines within it, located at 5, 10, 20, 30, 40, and 50 mm from the left edge of the central exploration hole O1.

2.The longitudinal target group D2 is arranged around the exploration hole O1, containing a total of 4 target lines, located at 5, 10, 20, and 30 mm below the edge directly beneath the central exploration hole O1.

(6) J: Image geometric distortion target group

The image geometric distortion target group is arranged around the probe hole O2. There are 4 target lines within it, each located at the upper, lower, left, and right corners of a square shape, 10mm away from the edge of the central probe hole O2.

(7) H1 - H4: Detection of the retreat direction resolution target group of the voids

Retract direction resolution This is to examine the minimum distance between two target lines that can display two distinct echo signals when the transducer retracts along the axial direction of the exploration hole. The target groups are arranged near the exploration hole O3. The H1-H4 target groups are located at 5, 10, 15, and 20 mm away from the edge of the central exploration hole O3. The resolution of each group of target groups from the innermost exploration

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hole to the outermost one is 3, 2, 1, and 0.5 mm respectively.

(8) H5 - H6: Target group for discrimination of the direction of sound window retraction

The target groups H5 and H6 for the direction discrimination of the acoustic window retreat are respectively arranged at a depth of 5mm and 10mm below the acoustic window. The resolution of the H5 target group from the right to the left of the acoustic window is 3, 2, 1, and 0.5mm, while the resolution of the H6 target group from the left to the right of the acoustic window is 3, 2, 1, and 0.5mm. This group of target groups can also be used as the lateral resolution target groups for the side array ultrasonic probe.

(9) I1 - I2: Detection of the geometric position accuracy of the target group for the withdrawal direction of the probe hole

The geometric position accuracy of the withdrawal direction target group is arranged near the probe hole O3. The I1 target group is located 5 and 10 mm away from the edge of the central probe hole O3's channel, while the I2 target group is located 15 and 20 mm away from the edge of the central probe hole O3's channel. The spacing between the target lines of each group is 5 mm.

(10) I3: Geometric position accuracy target group for the sound window retraction direction

The geometric position accuracy of the sound window withdrawal direction is as follows: Target group I3 is arranged at a depth of 5mm, 15mm, and 25mm below the sound window. The target line spacing of target group I3 is 5mm.

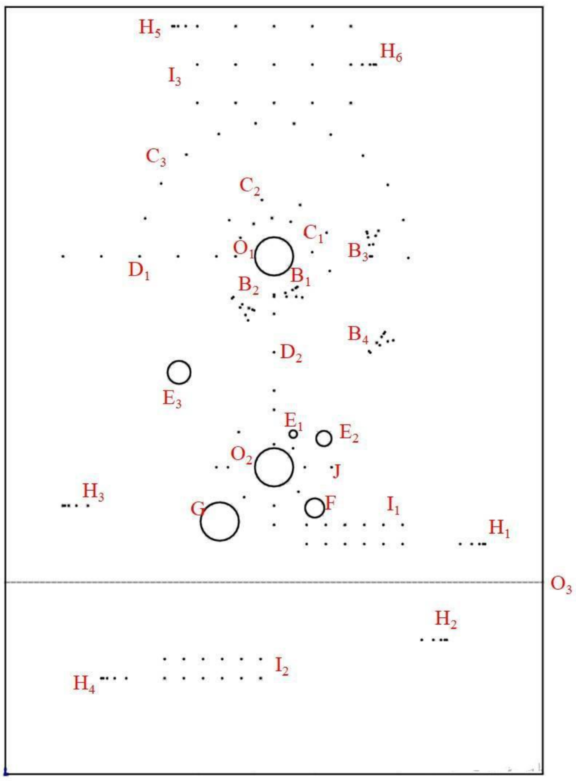

Figure 2: Probe holes, target lines and simulated lesion distribution of the KS107QN-4B type phantom

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7. Simulated Lesion

(1) E1 - E3: Simulated Cyst

The E1-E3 structures are arranged around the exploration hole O2, and three cystic simulated lesions are embedded, all of which are cylindrical in shape, with diameters of 2, 4, and 6 mm respectively. The column axes are all parallel to the target line, and the centers are located at 5, 10, and 30 mm above the edge of the central exploration hole, respectively.

(2) F simulated tumor,

The E1-E3 structures are arranged around the exploration hole O2, located on the right lower side of the central exploration hole. The axis of the simulated tumor is 10 mm away from the edge of the central exploration hole, and it is cylindrical in shape, with a diameter of 5 mm. The column axis is parallel to the target line.

(3) G simulated cyst and stone,

The simulated cyst and stone are arranged around the exploration hole O2. The simulated cyst is cylindrical and located at the horizontal position on the lower left side of the central exploration hole, with a distance of 5 to 15 mm from the edge of the central exploration hole. The diameter is 10 mm, and the column axis is parallel to the target line. The simulated stone is irregular in shape and is located in the middle of the cyst, with the maximum size being approximately 4-6 mm.

Technical Characteristics

According to the technical requirements of the general body model in the national standard GB10152—2009, the technical parameters of the body model are:

1. The sound velocity of TM material: (1540 ± 10) m/s (at 23 ± 3℃)
2. Slope of the acoustic attenuation coefficient of TM material: (0.70 ± 0.05) dB/cm/MHz (23 ± 3℃)
3. Diameter of nylon target line: (0.1 ± 0.02) mm
4. Tolerance of nylon target line position: ±0.05mm

Usage Instructions

1. For the KS107QN-4B Intracavitary Ultrasound Phantom, since its scanning mechanism involves intracavitary insertion, special care must be taken to insert the probe vertically to avoid damaging the TM material within the scanning cavity.

As the probe insertion channel is a through-hole, two preparation methods are recommended as alternatives:

(1) Option 1: After inserting the intracavitary ultrasound probe, seal the hole on one side of the phantom using transparent adhesive tape. Place the phantom horizontally on a flat surface, then pour an appropriate amount of ultrasound maintenance fluid around the scanning aperture. Alternatively, you may first seal the probe insertion hole on one side of the phantom with tape, pour the maintenance fluid into the hole on the other side, and then slowly insert the probe. When selecting a method for scanning, the primary principle is to ensure that the internal materials of the phantom are not damaged.

(2) Option 2: Select a container of suitable size and fill it with a generous amount of

ultrasound maintenance fluid. Place the entire phantom horizontally inside the container, ensuring its bottom is slightly elevated (suspended) so that the fluid level rises above the upper surface of the phantom. At this point, slowly and vertically insert the intracavitary ultrasound probe to prepare for the ultrasound scan.

2. Power on the instrument under test in accordance with the prescribed procedures.

3. Insert the probe of the instrument under test into the probe insertion channel, ensuring that the channel remains filled with maintenance fluid to maintain proper acoustic coupling for scanning. Record the probe model, scanning mode, and operating frequency.

4. Measurement of (Maximum) Penetration Depth
(1) Align the probe with the longitudinal target group.
(2) Increase the overall gain, adjust the STC (Time-Gain Compensation) settings, increase the far-field gain, and adjust the near-field gain to an appropriate level.
(3) Increase the contrast (for instruments with adjustable settings; the same applies to subsequent steps) to an appropriate level.
(4) Increase the brightness (for instruments with adjustable settings; the same applies to subsequent steps), but limit the adjustment to a level where no defocusing or "halo" effects appear across the full screen.
(5) Adjust the focus settings (for instruments with adjustable settings; the same applies to subsequent steps) to either far-field focus, multi-zone focus, or full-depth simultaneous focus mode.
(6) Through the adjustments described above, obtain a uniform image display covering the maximum depth range achievable by the instrument under test.
(7) Make slight, fine adjustments to the probe position, then read and record the depth (in millimeters) corresponding to the deepest visible target line; this value represents the (maximum) penetration depth.

5. Blind Zone Measurement
(1) Aim the probe at the blind zone target group. If the entire group cannot be covered in a single view, rotate the probe to observe it in sections.
(2) Appropriately reduce the overall gain, near-field gain, and brightness to attenuate the backscattered speckles from the TM material, ensuring that the target lines remain clearly visible.
(3) Set the focus adjustment to the near-field focus mode.
(4) Read the depth (in mm) of the shallowest visible target line; this value represents the blind zone.

6. (Threshold) Lateral Resolution Measurement
(1) Aim the probe at a specific lateral resolution target group, or at the lateral branch of an axial/lateral resolution target group.
(2) Reduce the overall gain, and—based on the depth of the target group—attenuate the TGC

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(or STC/DGC) settings.
(3) Reduce the brightness.
(4) Maintain a relatively high contrast setting.
(5) Set the focus adjustment to the depth of the target group under examination (or to a depth close to it), or set it to a multi-zone/full-depth simultaneous focus mode.
(6) Through the adjustments described above, suppress the backscattered speckles from the TM material in the vicinity of the measurement depth while ensuring that the target lines remain clearly visible.
(7) Read the smallest target line spacing (in mm) that can be resolved (i.e., where the brightness between the target lines matches the background brightness); this value represents the (threshold) lateral resolution at that specific depth.

7. (Threshold) Axial Resolution Measurement
(1) Aim the probe at a specific axial resolution target group, or at the axial branch of an axial/lateral resolution target group.
(2) Adjust the instrument under test using the same procedure as described in the "(Threshold) Lateral Resolution Measurement" section; immediately after measuring the lateral resolution at a specific depth, proceed to measure the axial resolution at that same depth.
(3) Read the smallest target line spacing (in mm) that can be resolved; this value represents the axial resolution at that specific depth. Note: Due to the presence of shadowing effects, it may sometimes be necessary to slightly increase the gain and brightness settings to clearly visualize the 1 mm and 0.5 mm gaps within the KS107QN-4B phantom.

8. Measurement of Axial Geometric Position Indication Error (Accuracy)
(1) Aim the probe at the axial target group.
(2) Adjust the overall gain, TGC (or STC/DGC), contrast, and brightness to a medium level.
(3) Set the focus adjustment to a multi-zone or full-depth focus mode.
(4) Through the adjustments described above, obtain a clear image of the axial target group against the background of faint backscattered echoes from the TM material.
(5) Freeze the image. Within the effective detection depth range, use electronic calipers to sequentially measure the center-to-center distances (in mm) between pairs of target lines spaced 20 mm apart (or, if the overall scanning range is limited, a spacing of 10 mm may be considered). Calculate the relative error (%) based on the measurement exhibiting the largest deviation from the nominal 20 mm (or 10 mm) spacing; this value represents the axial geometric position indication error (accuracy).

9. Measurement of Lateral Geometric Position Indication Error (Accuracy)
(1) Aim the probe at the lateral target group (C1/C2).
(2) Adjust the overall gain, TGC (or STC/DGC), contrast, and brightness to a medium level.
(3) Set the focus adjustment to the depth corresponding to the lateral target group (or a depth close to it), or set it to a multi-zone or full-depth focus mode.
(4) Freeze the image. Use electronic calipers to sequentially measure the center-to-center distances (in mm) between pairs of target lines spaced 20 mm (or 10 mm) apart. Calculate the

relative error (%) based on the measurement exhibiting the largest deviation from the nominal 20 mm (or 10 mm) spacing; this value represents the lateral geometric position indication error (accuracy).

10. Observation of Simulated Lesions
(1) Aim the probe at the simulated lesion of interest.
(2) Adjust the gain, TGC (or STC/DGC), contrast, and brightness to their optimal settings.
(3) Set the focus adjustment to the depth corresponding to the lesion (or a depth close to it), or set it to a multi-zone or full-depth focus mode. (4) By performing the aforementioned adjustments, a backscatter image of the TM material—resembling a clinical diagnostic image—is obtained. Against this background, images of simulated lesions can be observed, characterized as follows:

a. Cyst: The interior appears as a "black hole" devoid of light spots; clinically, this is referred to as an "anechoic zone." The backscattered light spots located posterior to the cyst appear brighter than the surrounding tissue at the same depth; clinically, this is termed "posterior enhancement." If necessary, electronic calipers may be used to measure the longitudinal or transverse diameter (in mm) of the cyst; these measurements can then be compared against the design specifications to calculate the relative error (as a percentage).
b. Calculus (Stone): The image of the stone itself appears as a highly reflective cluster of light. The backscattered light spots posterior to the stone are obscured within a dark band; clinically, this is known as "posterior acoustic shadowing."
c. Tumor: The image appears as a region of light spots that are coarser and brighter than the surrounding background tissue, with a circular outline.

11. Upon completion of measurements, if adhesive tape was applied to the back of the phantom, please remove the tape before slowly withdrawing the intracavitary ultrasound probe used for scanning. If a large-container scanning setup was utilized—meaning no adhesive tape was applied to the back of the phantom—you may proceed directly to slowly withdraw the intracavitary probe. Collect the used ultrasound maintenance fluid for reuse during future scans. Wipe the surface of the phantom dry, and then securely seal both sides of the probe insertion port with adhesive tape to prevent internal fluid leakage.

Note: To prevent skin irritation caused by the ultrasound maintenance fluid (prolonged, extensive contact can strip natural oils from the skin, leading to dryness and roughness), it is recommended to wear thin latex gloves when handling the fluid frequently. The ultrasound maintenance fluid must never be ingested; in the event of accidental contact with the skin, promptly wash the affected area with clean water.