PH-31

MRI QA Phantom

Instruction Manual

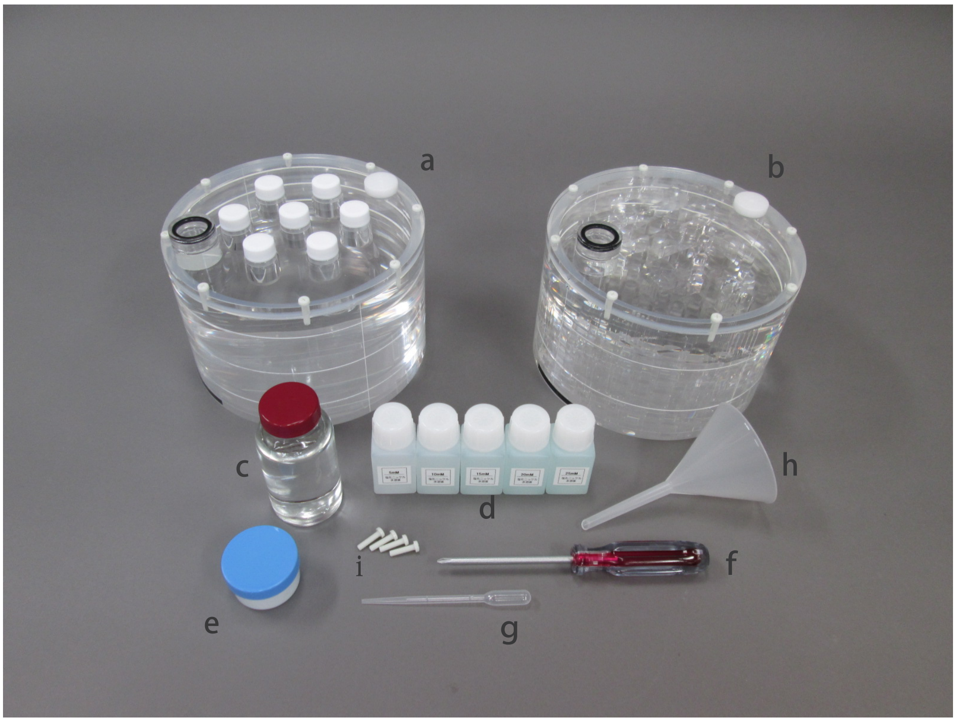
Contents

KYOTO KAGAKU co.,LTD

Product contents and warning

Product contents

Before your first use, ensure that your product includes all components listed below.



a	Phantom unit A	1	e	Petroleum jelly	1
b	Phantom unit B	1	f	Screwdriver	1
c	Liquid paraffin (suitable for 3T)	1	g	Dropper	1
d	MRI contrast solution (nickel dichloride) *5 levels of concentration, 50mL per bottle (5, 10, 15, 20, 25 millimole)	5	h	Funnel	1
			i	Extra screws	4
				Instruction manual	

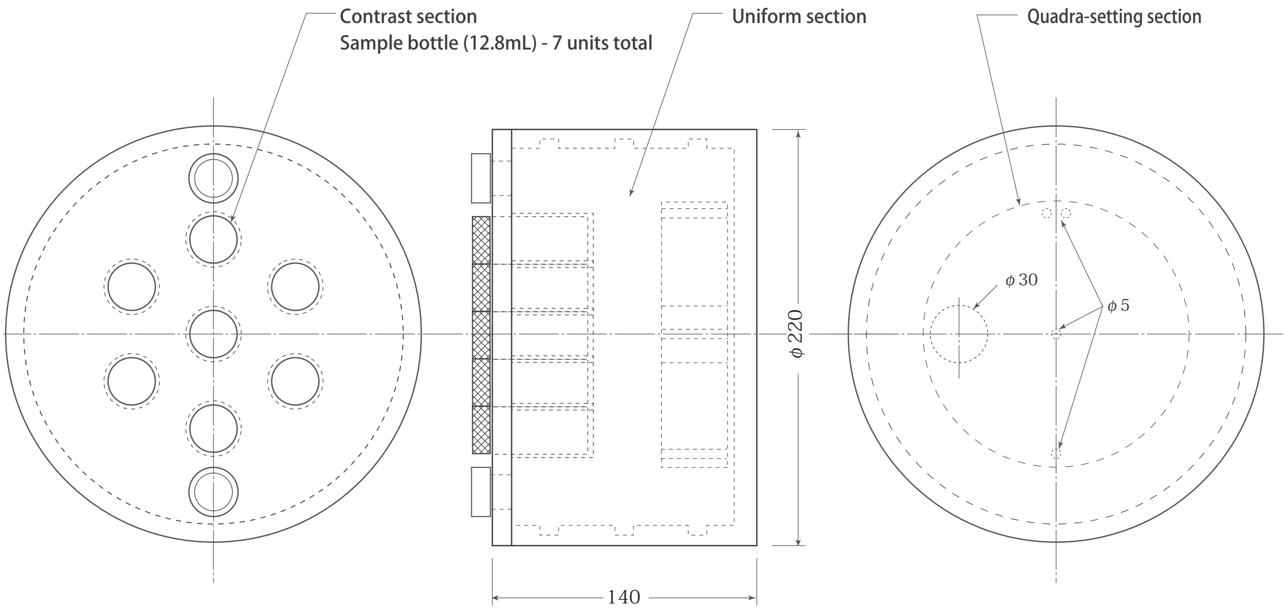
⚠ Warning

- Please handle with care.The phantom is made of hard resinous material; the phantom can be damaged if dropped or hit by a hard object.
- Please clean the phantom with water or pH neutral detergent. Please do not use organic detergent such as thinner.
- Please do not store in high temperatures, high humidity or in direct sunlight. It may lead to deformation or damages.
- Please do not write with a pen. Writing directly on the phantom with felt-tip pen or permanent marker will not wash off.

How to use the phantom

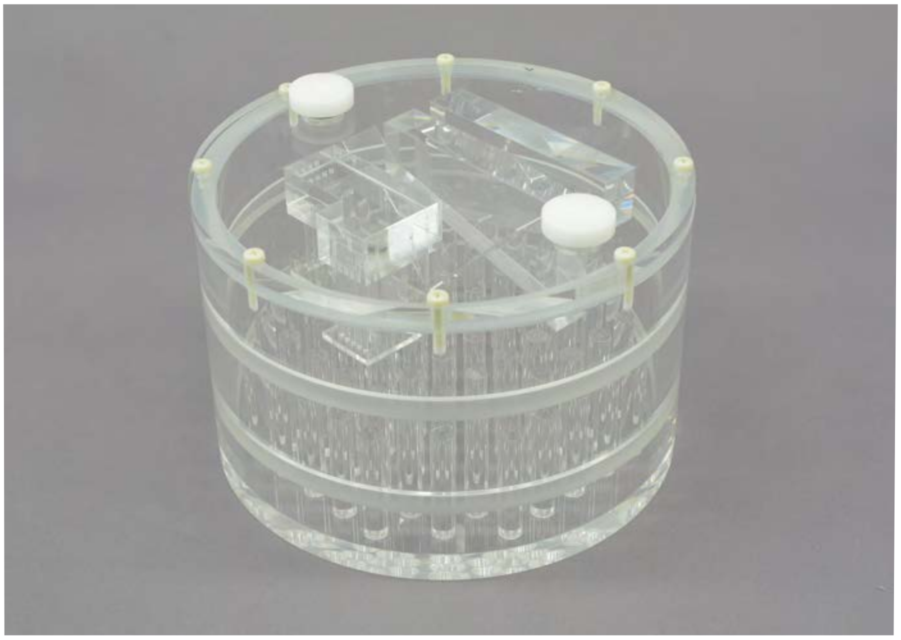
Phantom unit A	Liquid capacity 3180mL Acrylic materials, Outer diameter 220mm

Structural design

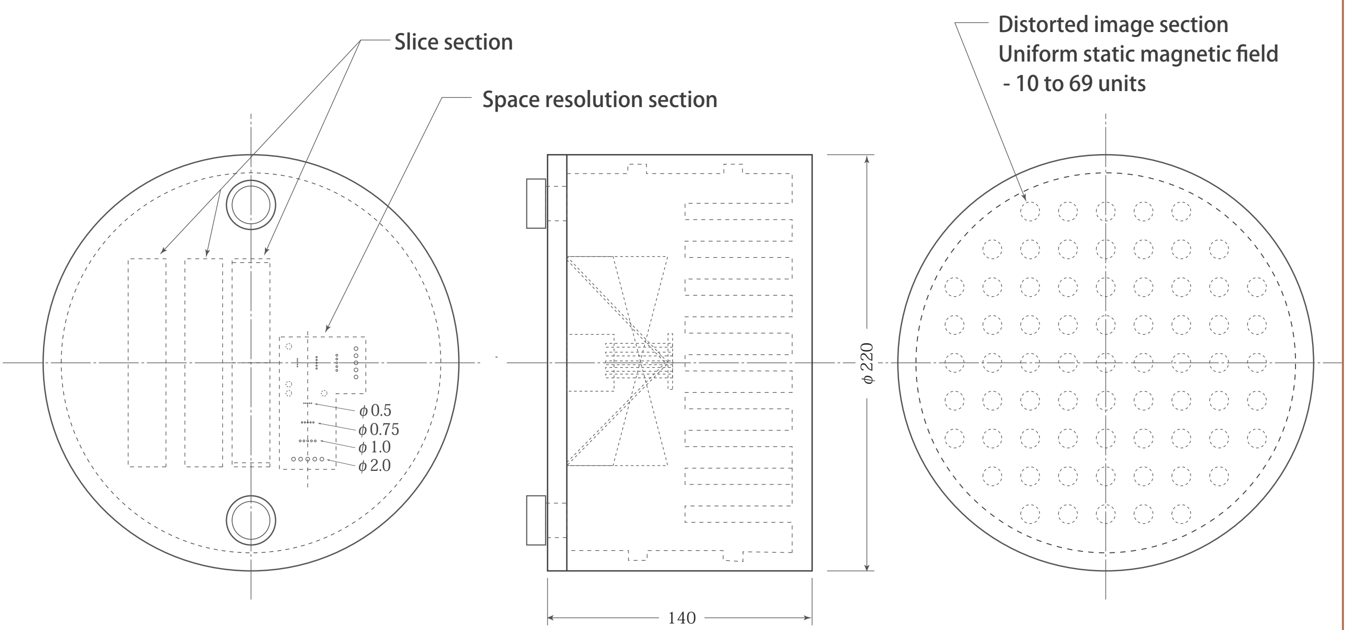


How to use the phantom

Phantom unit B	Liquid capacity 3300mL Acrylic materials, Outer diameter 220mm

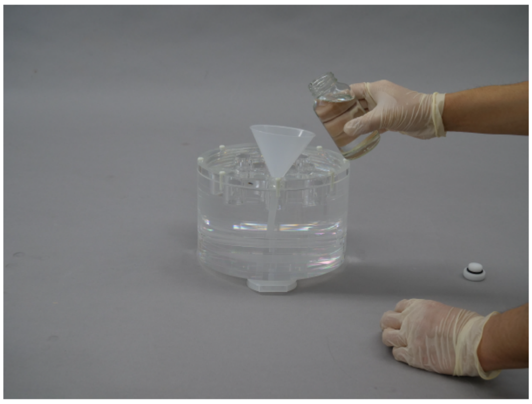


Structural design



1 How to fill with MRI solution

1. In order to avoid liquid leaks due to temperature changes, the phantom is not totally filled up with the solution at the time of delivery. First, remove one of the two plastic caps for the main unit of the phantom. Then insert the funnel into the hole to fill up the phantom pouring the paraffin solution (c) into the unit.



2. Fill up the rest of the unit using the dropper slowly without leaving air bubbles inside. Then close the unit again placing back the plastic cap.

※In order to avoid liquid leaks due to temperature changes, take out the paraffin solution and return it to its original liquid container (c) after using the phantom.

2 Warning

T1 and T2 values are heavily dependent on temperature change; please take extreme care in maintaining a consistent temperature when the phantom is in use. Leave the phantom with the contrast solution in room temperature for over 24 hours to retain a consistent temperature for the product. Raw materials used to manufacuture the provided nickel dichloride solution is manufactured in 23 degrees Celcius with relative humidity of 40%.

Setting Contrast Section

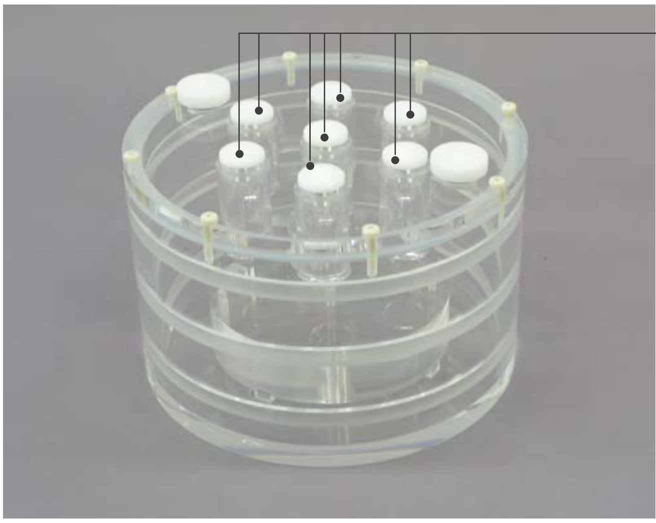
1 Setting

- First fill up the main body of the phantom with the liquid paraffin and close the cap tightly.
- The phantom shall be centered in the RF receiver coil, with its flat sides parallel to the designated scanning section.
- Use the lines on the wall of the phantom as landmarks for positioning.

2 Contrast Section

The section has seven holders to set the sample bottles. Fill the bottles with $NiCl_2$ solution with different concentration (5 variations of solution are included in the set) to evaluate the contrast.
Further study is possible by adding optional samples.

Select the most appropriate setting by adjusting the Pulse Parameter and the Image sequence.



7 Solution holders

3 Uniformity Section

This section is for measurement of the signal to noise ratio (S/N), the image uniformity, and the RF uniformity.

-Signal to Noise Ratio (S/N)

Set the slide thickness at 10mm or below, and scan the section with the spin echo method at $3T \leqq TR \leqq 5T1$ conditions.
Execute the first scan. Position the ROI on the center of the volume………(R1)
Immediately after the first scan, repeat the scan with the same settings to acquire the second data…………………………(R2)
Subtract (R2) from (R1) to obtain the difference of the images, and set the ROI in the same place as (R1)……(R3)

$$(R3) = (R1) - (R2)$$

Measure the signal intensity S of the ROI (R1), the standard deviation SD of (R3), and calculate the $S/N = \sqrt{2} \times S / SD$

NEMA defines Measurement Regions of Interest (MROI) as a centered regular geometric area enclosing at least 75% of the image of the signal producing volume of the phantom, while AAPM standards mention a minimum dimension in the image plane of at least 10cm or 80% of the image field of view, whichever is larger.

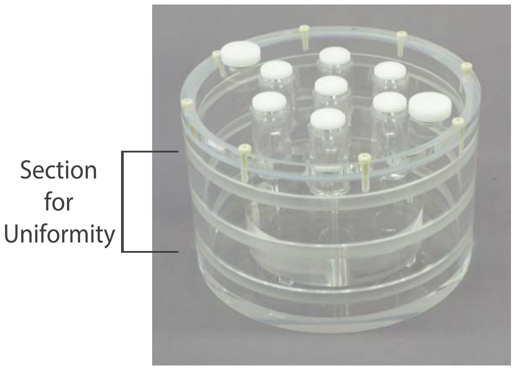
-Image Uniformity

Adjust the S/N at 80 or more by increasing the slide thickness, increasing the number of image additions, or using an appropriate filter.
Examine the signal from each pixel in the 75% to 80% of the central area of the image of the phantom.
Determine the maximum value as S MAX, and the minimum value as S MIN.
The image uniformity is calculated as follows:

$$\text{Uniformity} = \left(1 - \frac{S_{MAX} - S_{MIN}}{S_{MAX} + S_{MIN}}\right) \times 100$$

-RF Uniformity

After turning off all the coils for the magnetic field gradient, place the phantom in the center of the main magnet, and adjust the radio-frequency (RF) to acquire the maximum signal. (For more details contact the system manufacturer)



4 Quadrature Setting Section

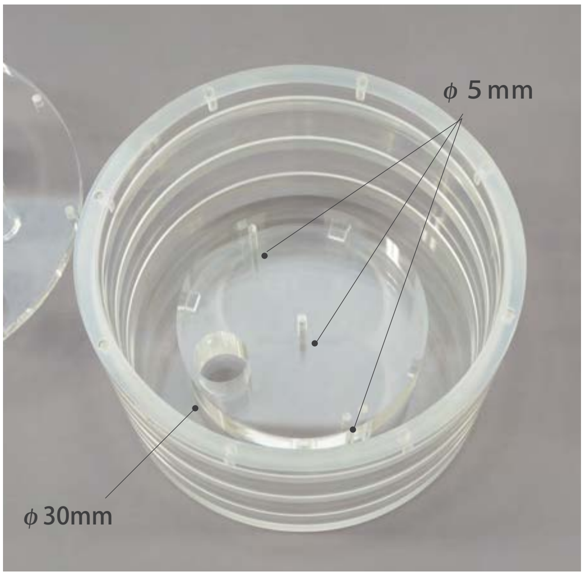
This section is used to detect irregularities in the quadrature setting.

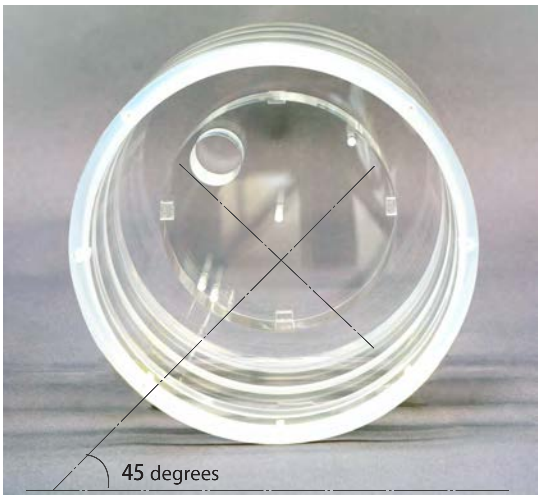
The section consists of a disc with a hole of 30mm diameter and 4 small marker holes which line across the center of the disc perpendicularly to the line from the 30mm hole.

When scanning the X-Y side, the phantom shall be placed so that the line that connects the maker holes makes 45 degrees to the X axis. (Y axis)

Then, using the matrix method, scan the section two times or more with a slice thickness of 10mm and the maximum matrix number. Use the image sequence and the pulse parameter on the same conditions as used in the common clinical settings.

Visually interpret the obtained images. In case that any irregularities of the quadrature setting arise, the Ø 30mm hole will appear as a ghost artifact in a symmetric position from the line formed by the marker holes.





5 Slice Thickness Section

The two wedge shaped planks in this section are to measure a slice thicknesses of 10mm or less. Both planks are of 15 degrees inclination angle and 20mm thickness. Scan the section with the maximum matrix number, in the conditions so that the TR represents more than three times T1.
Using the multi-slice method, make the measurements on an image taken from the center.
In the image, planks appear as black squares. Number them as first and second. Place the ROI at the center, along the central line of the first plank, and calculate the signal intensity of each pixel In.

$$D_n = I_n - I_{n-1}$$

n: pixel number
In: signal pixel intensity of n pixel

Obtain the slice profile by plotting the values of D_n obtained through the above formula along the pixel distribution.
Calculate the FWHM (full width at half maximum) of the earned slice profile (L1). In this case FWHM indicates the length of the line connecting the two points in which Dn is the half of the maximum value of change.
Repeat the same procedure with the second plank to calculate L2.
When L1 is equal to L2, the calculation for the slice thickness T is: $T = L1 \cdot \tan 15^\circ$
However, L1 and L2 usually vary because of measurement errors due to the rotation of the X, Y or Z axis during the setting of the phantom, or during the setting of the slice section.
Therefore, the below correction is necessary:
Assuming that L1 $<$ L2 due to a rotation of the angle α around the Y axis, the angle made up by the first plank and the slice side is:
$15^\circ + \alpha$
The angle made up by the second plank and the slice side is:
$15^\circ - \alpha$
The slice thickness T is calculated by using the values of L1,L2 and the above mentioned rotation error α.

$$L1 = T/\tan(15^\circ + \alpha) \quad \cdots\cdots\cdots\cdots\cdots \quad (1)$$

$$L2 = T/\tan(15^\circ - \alpha) \quad \cdots\cdots\cdots\cdots\cdots \quad (2)$$

$$\frac{L1-L2}{L1+L2} = \frac{\tan(15^\circ + \alpha) - \tan(15^\circ - \alpha)}{\tan(15^\circ + \alpha) + \tan(15^\circ - \alpha)} = \frac{\sin\{(15^\circ + \alpha) - (15^\circ - \alpha)\}}{\sin\{(15^\circ + \alpha) + (15^\circ - \alpha)\}}$$

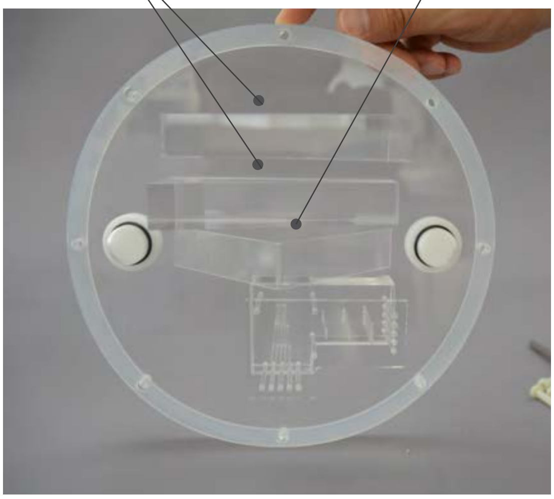
$$= \frac{\sin 2\alpha}{\sin 30^\circ} \quad \cdots\cdots\cdots\cdots\cdots \quad (3)$$

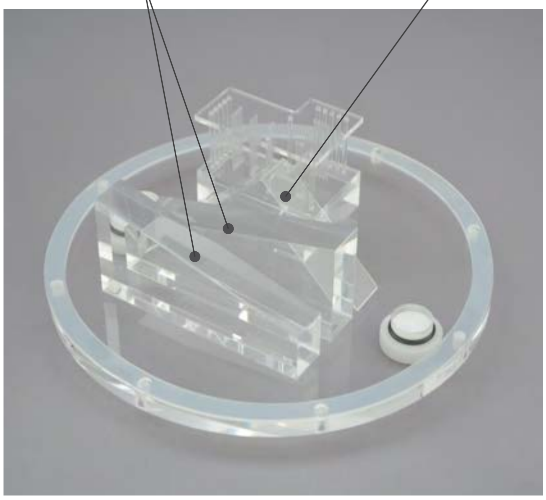
By substituting the α calculated by (3) in the formula (1) or (2) it is possible to calculate the right slice thickness T.

5 Slice Thickness Section

This target is to measure a slice thickness of 10mm or more. The target consists of two plates of 1mm thickness and 20mm width which make a right angle with each other.
Scan the section with the maximum matrix number, in the necessary conditions so that the TR represents more than three times T1.
By placing the ROI along the line that connects the center of the two gray areas, calculate the curve of the signal intensity.
Then, find the two parts in the curve where the intensity drops, and calculate the FWHM of this part to define L1 and L2. In this case, the FWHM is the length of the line connecting the two points in which the decrease amount is the half of the minimum values in the curve, while the slice thickness T is calculated by

$$T = (L1 \cdot L2)^{1/2}$$





5 Spatial Resolution

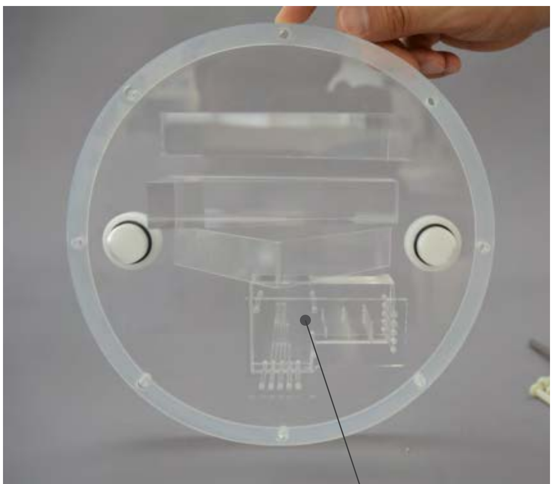
This target is to measure the spatial resolution.

The target consists of two blocks placed in right angle with each other. On each block, each five pins of different diameters (0.50, 0.75, 1.00, 2.00 mm) are placed. The spaces between the pins are the same as the pins' diameter.

There is no restriction for Pulse Parameter or Image Sequence. Using the matrix method, acquire two or more images at a slice thickness of 5 to 10mm at the maximum matrix number. Then visually inspect the acquired images. The spatial resolution is evaluated by judging whether it is possible to define the diameter of all five pins of each diameter.

The spatial resolution might vary considerably since there are cases in which the pins of the phantom and the collecting matrix match, and other cases in which don't match.

Compare the results of the phase encoding direction and in the frequency encoding direction, as they may possibly vary.



Spatial Resolution Section

Spatial Resolution Section

6 Image Distortion and Static Magnetic Uniformity Section

This section is to measure the image distortion and the static magnetic field uniformity. The phantom has 69 sticks of 10mm diameter with 10mm of space between each other placed in a grating pattern.

Scan the slice thickness at 10mm or below, and the matrix number at maximum. There is no restriction for Pulse Parameter or Image Sequence. NEMA standards recommend the spin echo method.
By measuring the diameter of the obtained image of the signal producing volume of the phantom, calculate the overall aspect ratio, and by measuring the rod diameter and their spacing, evaluate the level of image distortion at each part of the field of vision.
Sometimes image distortions may appear due to wrong adjustments of CRT, so beforehand ensure that the adjustments are properly made, and then evaluate the image distortion using the following formula:

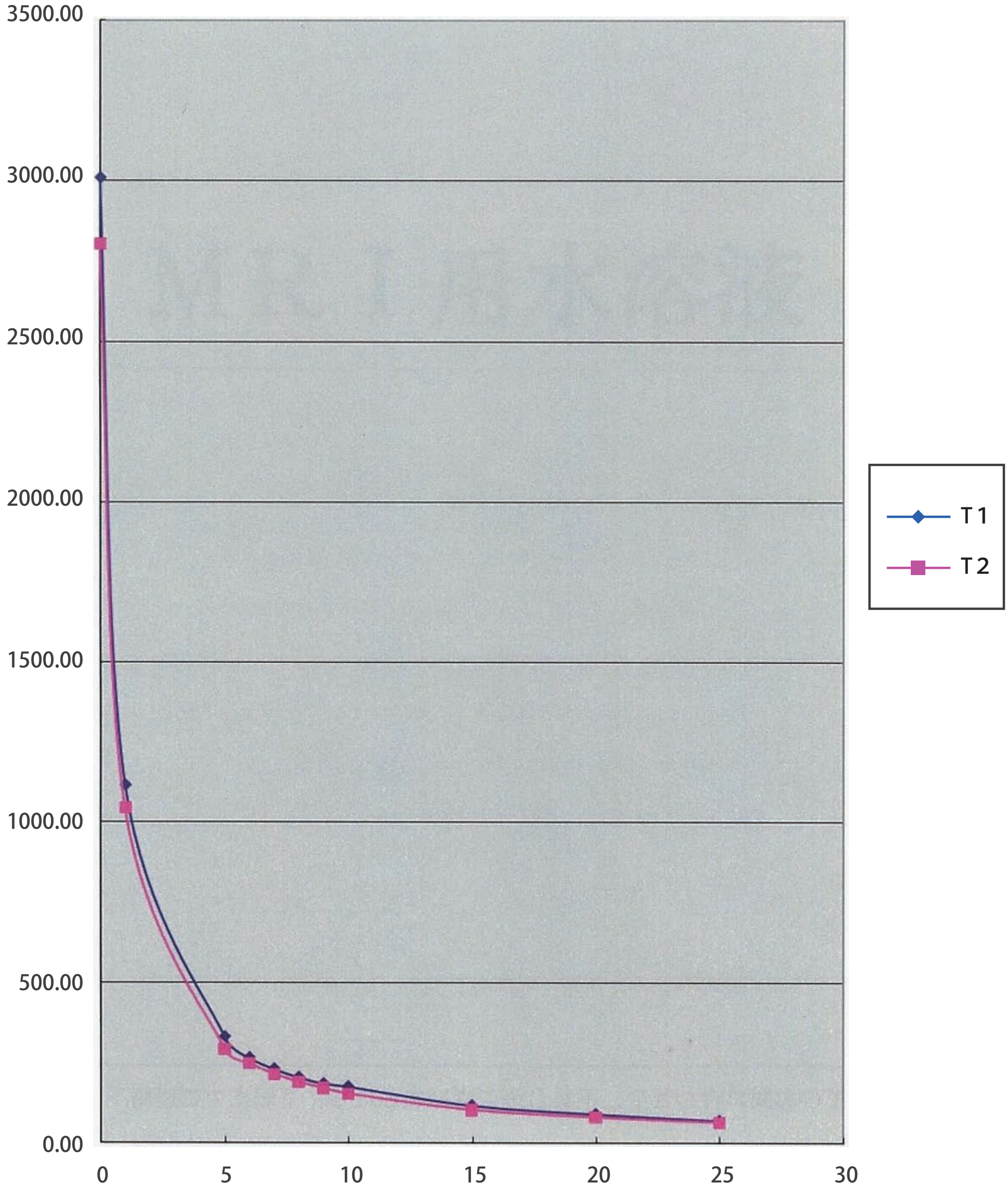
$$D = \frac{\text{real dimensions} - \text{measured dimensions}}{\text{real dimensions}} \times 100\%$$

Image Distortion, Static Magnetic Field Uniformity Section

$NiCl_2$ density (mM)	1	5	6	7	8
T1 value (msec)	1117	329	264	229	203
Standard deviation	23.53	5.54	10.11	4.5	3.02
T2 value (msec)	1044	291	246	213	189
Standard deviation	6.96	0.83	0.56	0.61	0.66
$NiCl_2$ density (mM)	9	10	15	20	25
T1 value (msec)	184	174	116	89	69
Standard deviation	4.28	2.11	1.27	1.03	0.71
T2 value (msec)	169	152	102	79	64
Standard deviation	0.51	0.65	0.5	0.11	0.4

T1 and T2 values of the magnetic resonance of varying nickel dichloride densities

*Data from room temperature 24 degree Celcius and magnetic field strength of 1.5 Tesla



T1 and T2 values of varying nickel dichloride densities

T1 and T2 values

Measurement method: value inversion recovery method for T1, and value multiecho methodfor T2.

1.5 Tesla	$NiCl_2$ solution	liquid paraffin
T1 value	161	206
T2 value	145	105

※1.5 Tesla, Room temperature 23℃ Unit: [msec]

Chart 1: T1 and T2 values for nickel dichloride solution and liquid paraffin on nuclear magnetic resonance

3 Tesla	$NiCl_2$ solution	liquid paraffin
T1 value	173	241
T2 value	121	89

※3 Tesla, Room temperature 23℃ Unit: [msec]

Chart 2: T1 and T2 values for nickel dichloride solution and liquid paraffin on nuclear magnetic resonance

※Utilized MRI device and scanning conditions
1.5 Tesla Siemens MAGETOM Avanto and 3 Tesla Philips Achiva dStream

T1 value(FSE-IR sequence) Temperature=23℃ TI=50～2500ms TR=3000ms TE=10ms NEX=1 FA=170° ScanTime=1:50 FOV=25×25cm Matrix size=256×192BW=180Hz/px Slice thickness=5.0mm Coil=Whole Body Coil
T2 value(SE Multi Echo) Temperature=23° TR=3000ms NEX=1 FA=180° ScanTime=9:41 TE=22～352ms FOV=25×25cm Matrix size=256×192 BW=130Hz/px Slice thickness=6.0mm Coil=Whole Body Coil

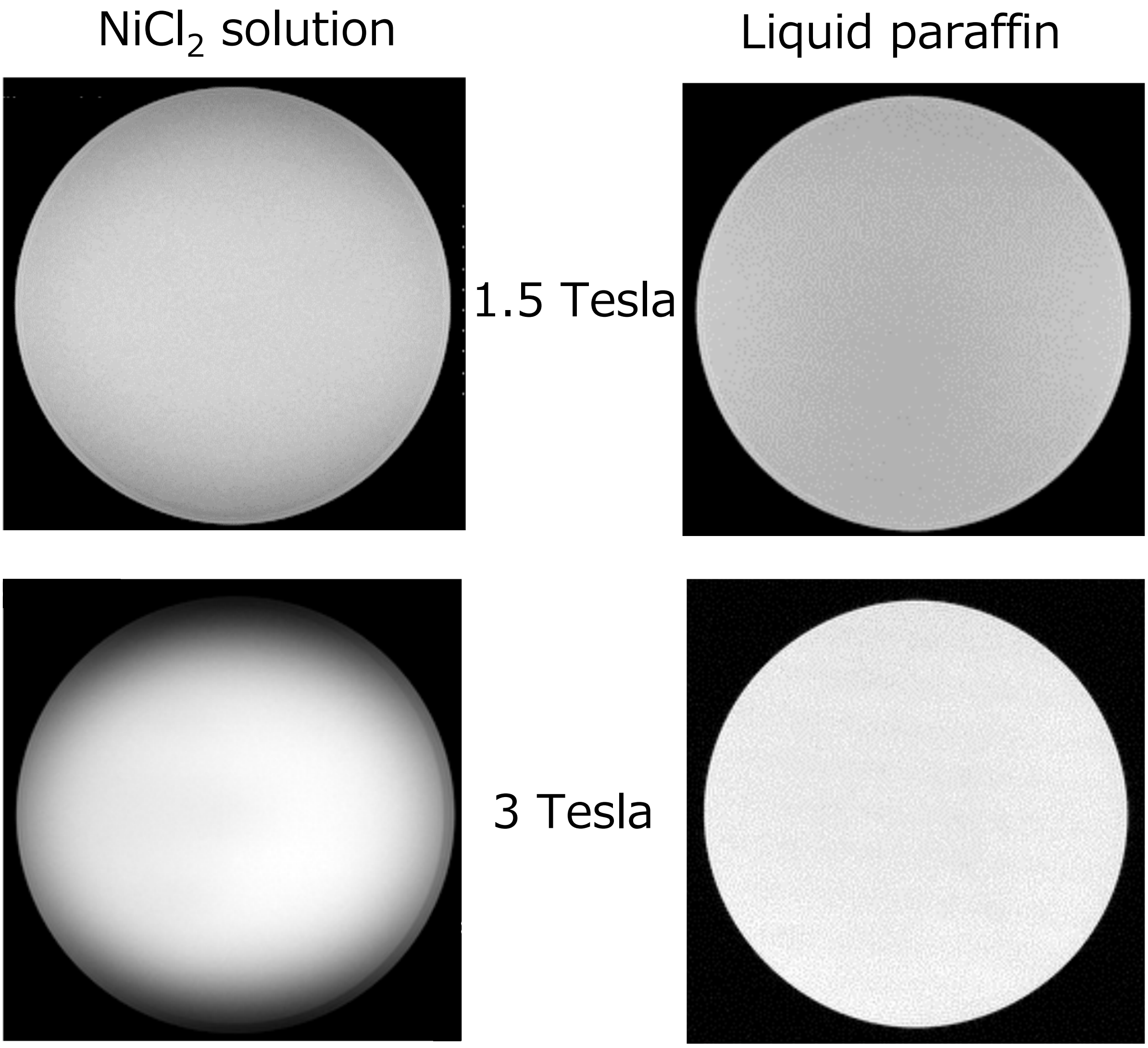
Uniformity

Measurement method : value inversion recovery method for T1, and value multiecho methodfor T2.

	$NiCl_2$ solution	liquid paraffin
1.5 Tesla	17.7	8.2
3 Tesla	49.6	7.4

※Room temperature 23℃ Unit : [%]

Chart 3: Uniformity of nickel dichloride solution and liquid paraffin on nuclear magnetic resonance



※Utilized MRI device and scanning conditions
1.5 Tesla Siemens MAGETOM Avanto and 3 Tesla Philips Achiva dStream

Spin Echo Temperature=23℃ TR=1500ms TE=14ms NEX=1 FA=75° ScanTime=6:26 FOV=25×25cm
Matrix size=256×256 BW=130Hz/px Slice thickness=6.0mm Coil=Whole Body Coil

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