US 20180140273A1

(19) United States

(12) Patent Application Publication (10) Pub. No.: US 2018/0140273 A1

TERADA et al. (43) Pub. Date: May 24, 2018

(54) ULTRASONIC SIGNAL PROCESSING APPARATUS, ULTRASONIC IMAGING APPARATUS USING SAME, AND CONTROL METHOD IN ULTRASONIC SIGNAL PROCESSING APPARATUS

(71) Applicant: **HITACHI, LTD.**, Tokyo (JP)

(72) Inventors: **Takahide TERADA**, Tokyo (JP); **Kenichi KAWABATA**, Tokyo (JP); **Atsurou SUZUKI**, Tokyo (JP); **Yushi TSUBOTA**, Tokyo (JP); **Wenjing WU**, Tokyo (JP); **Kazuhiro YAMANAKA**, Tokyo (JP)

(73) Assignee: **HITACHI, LTD.**, Tokyo (JP)

(21) Appl. No.: **15/819,856**

(22) Filed: **Nov. 21, 2017**

(30) **Foreign Application Priority Data**

Nov. 22, 2016 (JP) 2016-226402

Publication Classification

(51) **Int. Cl.**

A61B 8/00 (2006.01)
G01S 15/89 (2006.01)
A61B 8/08 (2006.01)

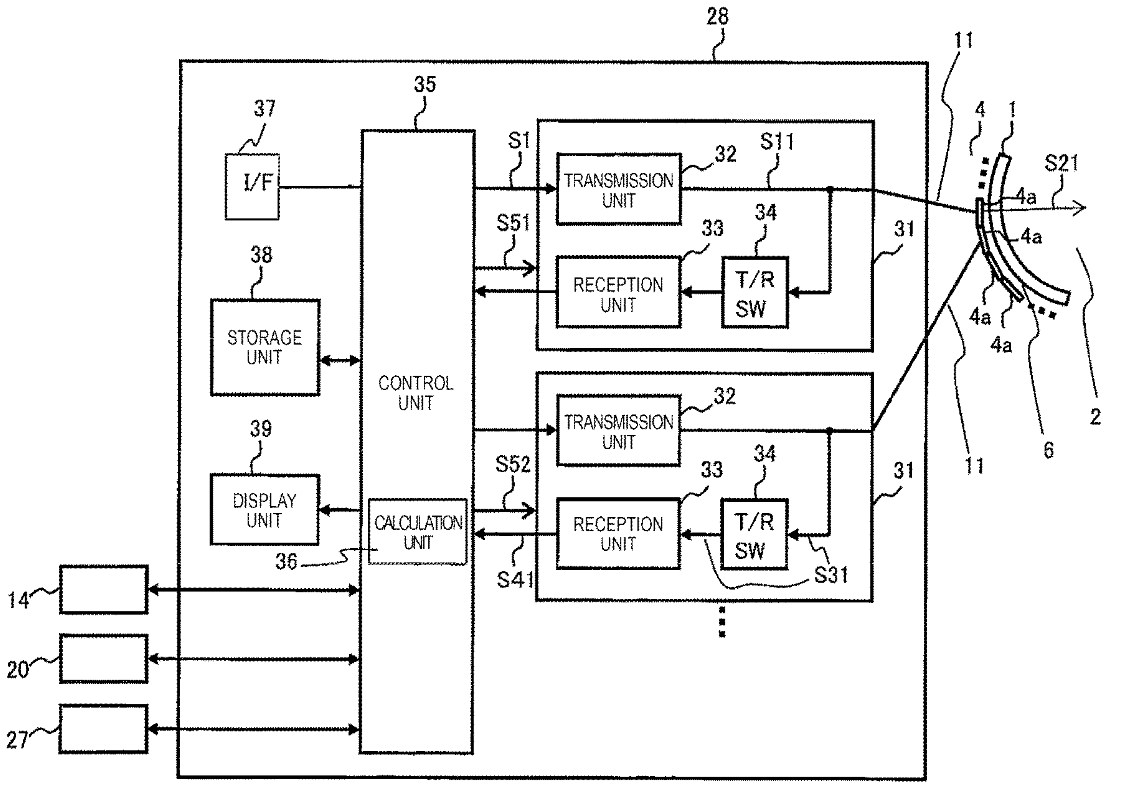
(52) **U.S. Cl.**

CPC ***A61B 8/4281*** (2013.01); ***G01S 15/8922*** (2013.01); ***A61B 8/4483*** (2013.01); ***A61B 8/406*** (2013.01); ***A61B 8/0825*** (2013.01)

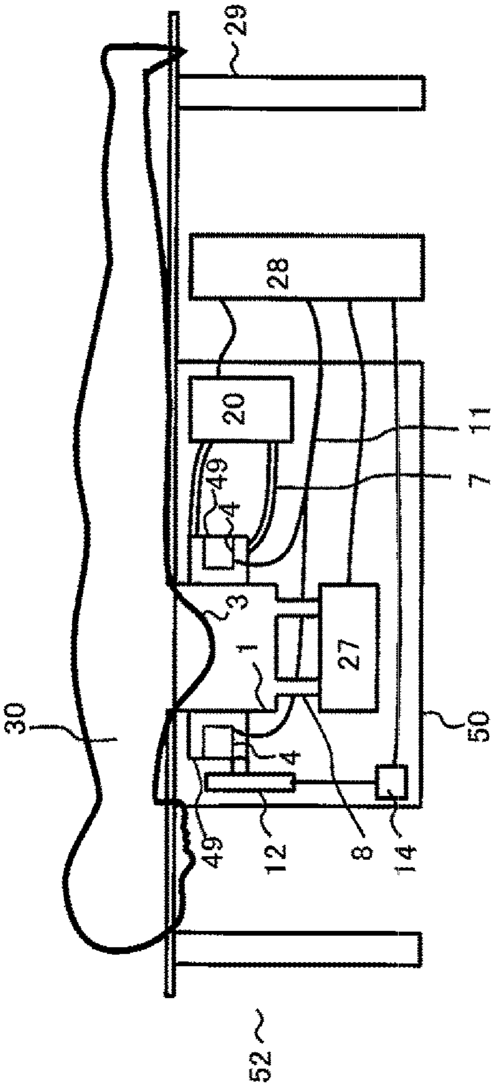
(57) **ABSTRACT**

There is provided an ultrasonic signal processing apparatus in which the amount of an ultrasonic propagation material in a measurement unit that stores a transducer array is reduced while the transducer array and a target are separated from each other, and thus maintenance of the ultrasonic propagation material is easily managed.

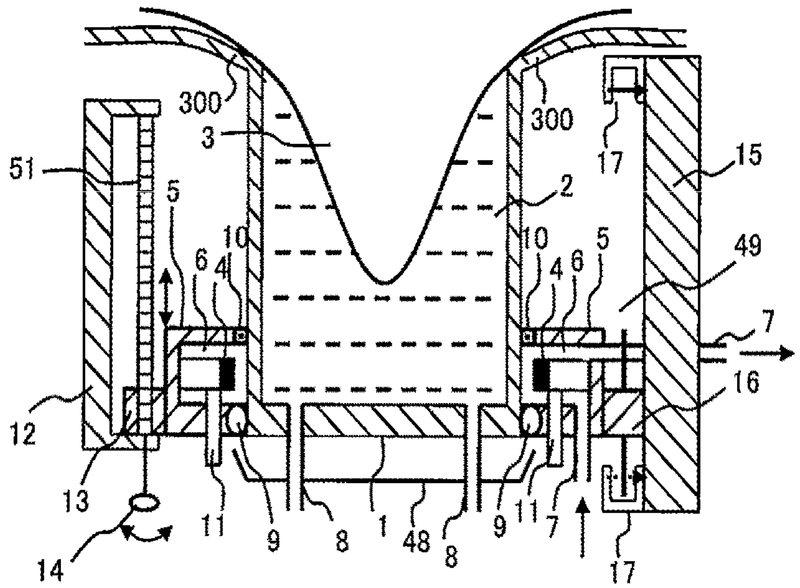
The ultrasonic signal processing apparatus includes a water tank having an opening portion, a measurement unit, and a moving unit. The measurement unit which is disposed on an outside of the water tank, includes a transducer array that transmits and receives an ultrasonic signal, and a space which is filled with a material for propagating the ultrasonic signal, and measures the ultrasonic signal. The moving unit is connected to the measurement unit, and moves the measurement unit between the opening portion and the bottom portion of the water tank, along a side wall thereof.



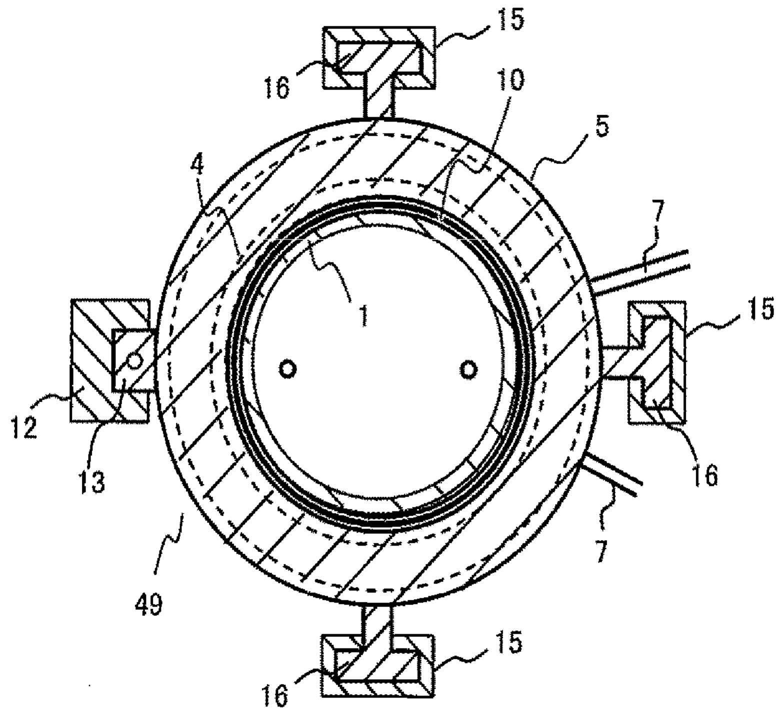
[Fig. 1]



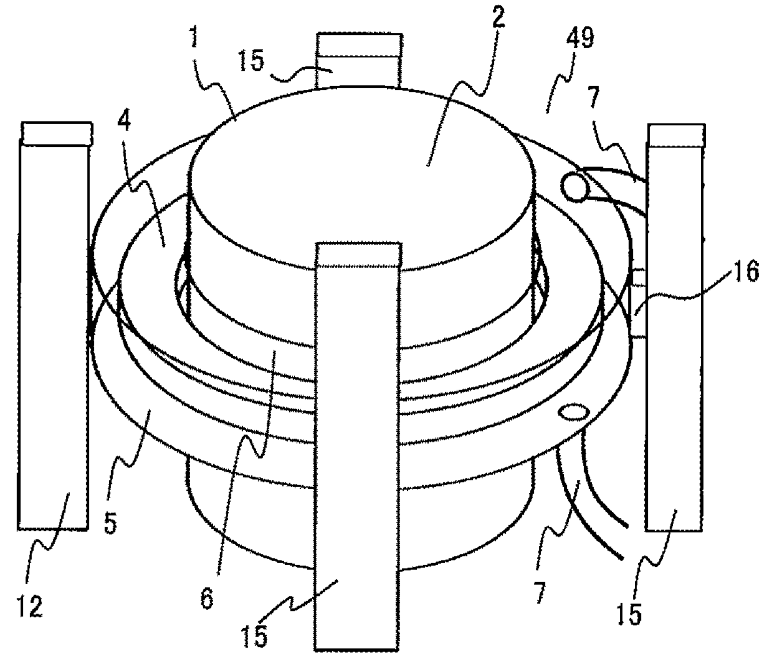
[Fig. 2A]


300
300
3
51
5
2
17
15
10
6
4
10
4
6
5
49
7
16
12
13
11
9
8
1
48
8
9
11
7
17
14

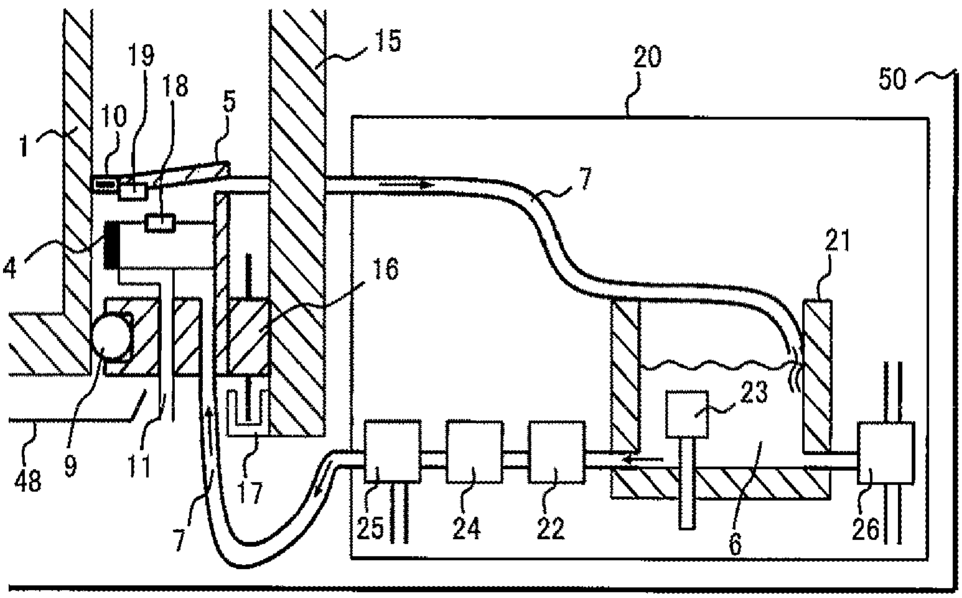
[Fig. 2B]


15
16
10
5
4
7
1
15
12
13
16
7
49
15
16

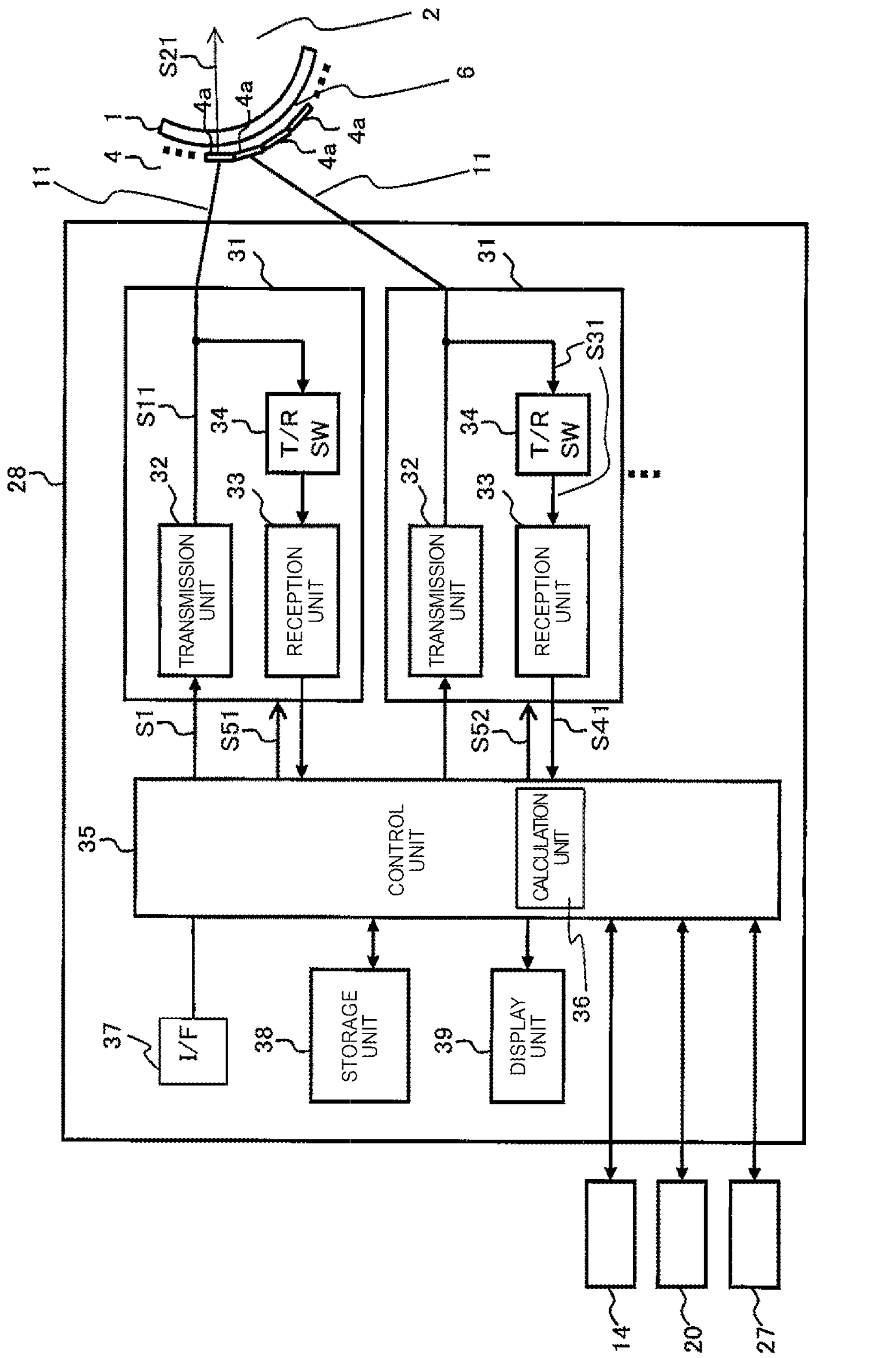
[Fig. 2C]


1
15
2
49
7
4
16
5
6
12
15
7
15

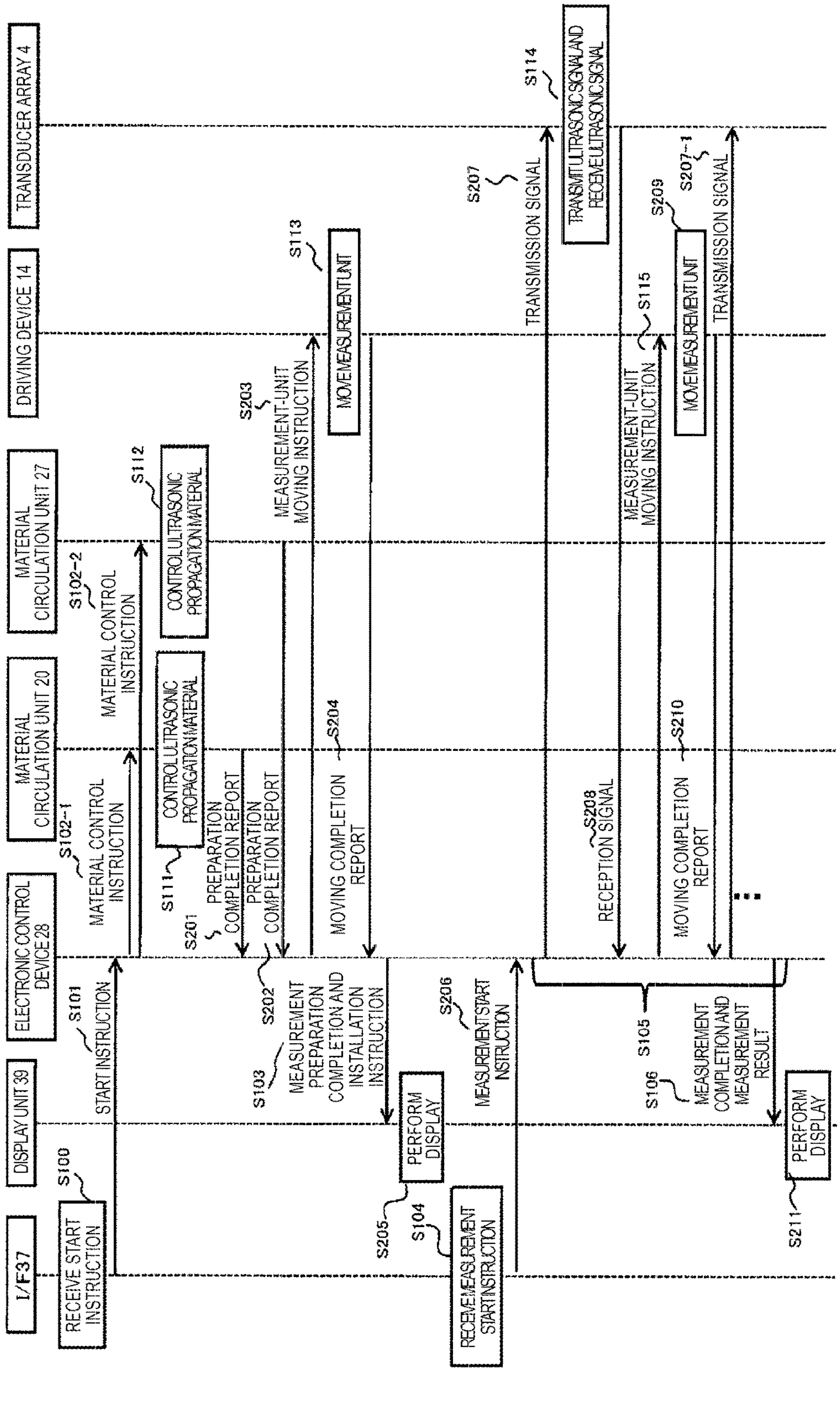
[Fig. 2D]


15
20
50
19
18
5
1
10
7
21
4
16
23
48
9
11
17
25
24
22
6
26
7

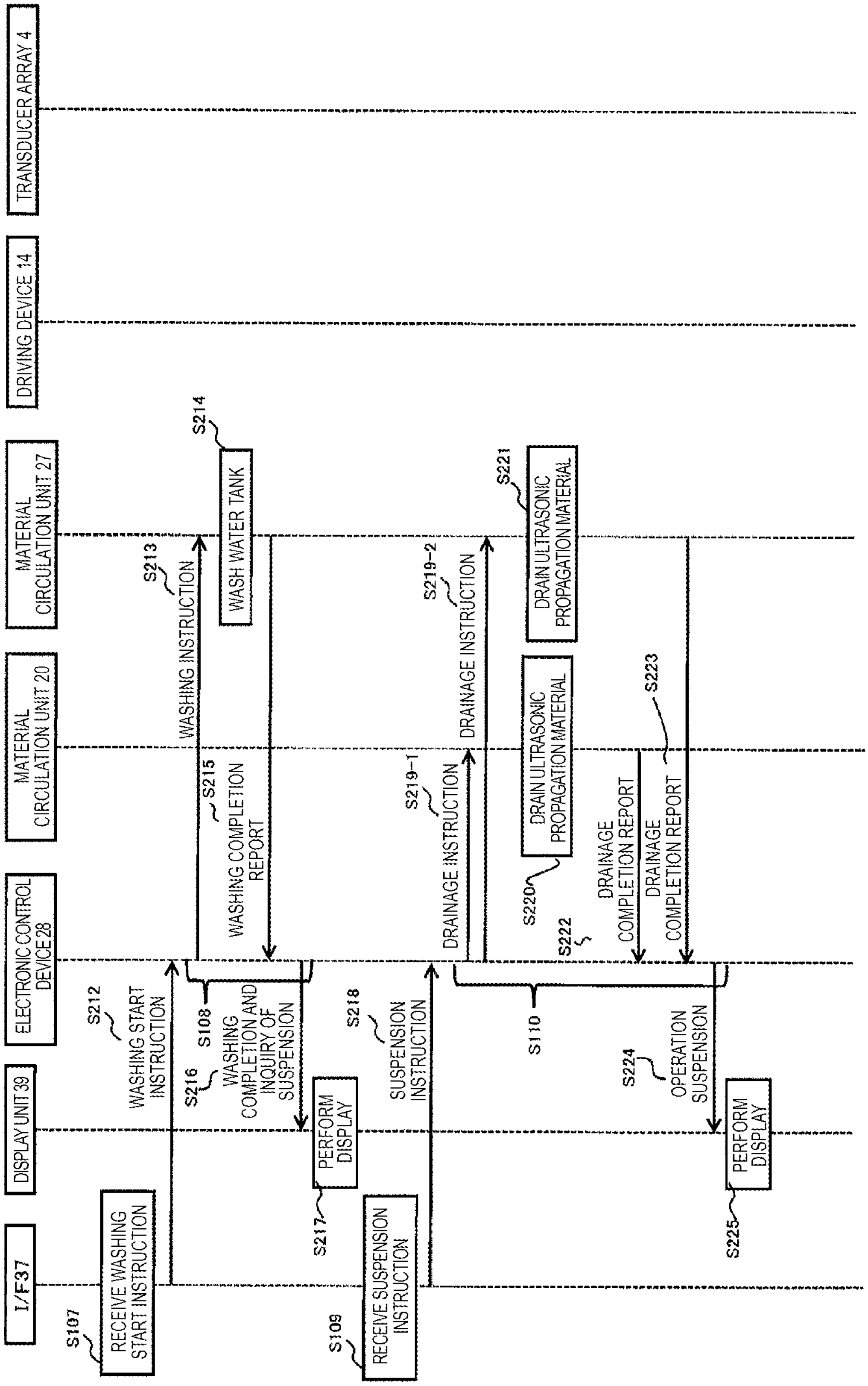
[Fig. 3]


2
S21
6
1
4
4a
4a
4a
4a
11
11
31
31
28
S11
S31
34
T/R SW
34
T/R SW
32
33
32
33
TRANSMISSION UNIT
RECEPTION UNIT
TRANSMISSION UNIT
RECEPTION UNIT
S1
S51
S52
S41
35
CONTROL UNIT
CALCULATION UNIT
36
37
I/F
38
STORAGE UNIT
39
DISPLAY UNIT
14
20
27

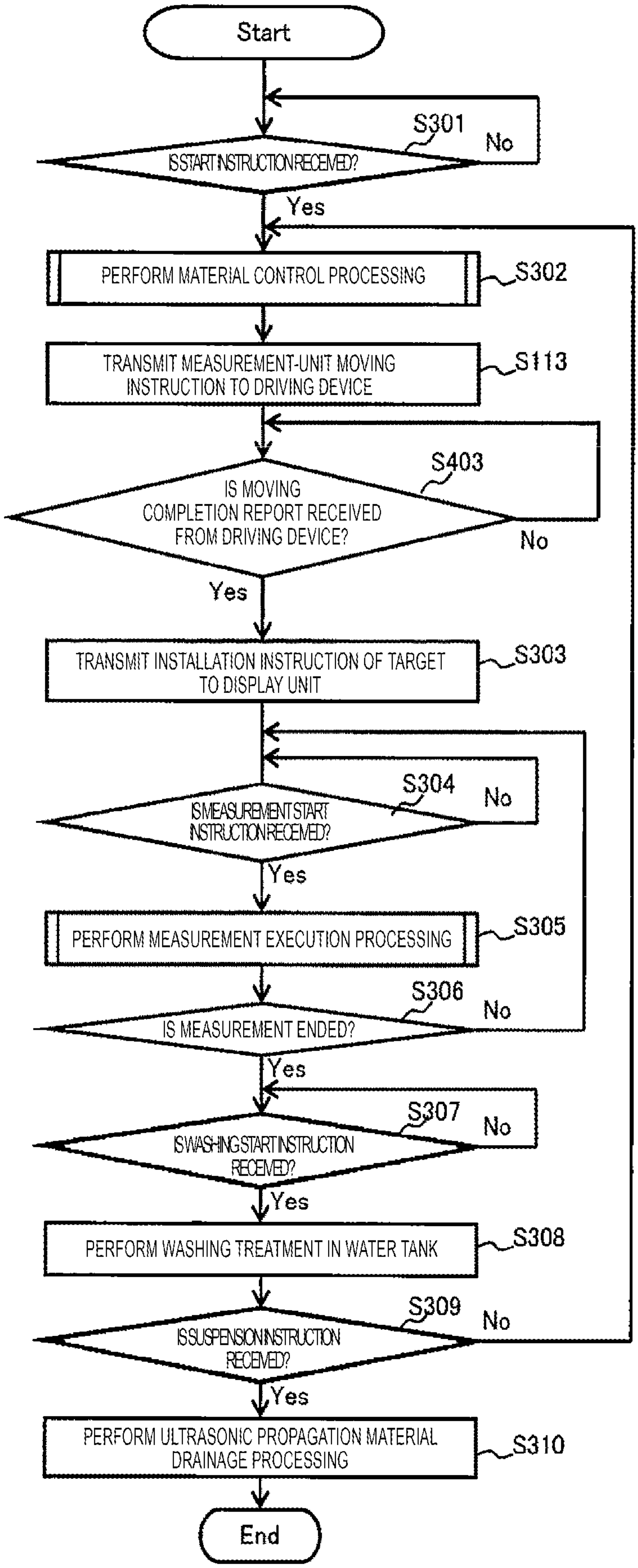
[Fig. 4A]


I/F37
DISPLAY UNIT 39
ELECTRONIC CONTROL DEVICE 28
MATERIAL CIRCULATION UNIT 20
MATERIAL CIRCULATION UNIT 27
DRIVING DEVICE 14
TRANSDUCER ARRAY 4
S100
RECEIVE START INSTRUCTION
S101
START INSTRUCTION
S102-1
MATERIAL CONTROL INSTRUCTION
S102-2
MATERIAL CONTROL INSTRUCTION
S111
CONTROL ULTRASONIC PROPAGATION MATERIAL
S112
CONTROL ULTRASONIC PROPAGATION MATERIAL
S201
PREPARATION COMPLETION REPORT
PREPARATION COMPLETION REPORT
S202
S203
MEASUREMENT-UNIT MOVING INSTRUCTION
S113
MOVE MEASUREMENT UNIT
S204
MOVING COMPLETION REPORT
S103
MEASUREMENT PREPARATION COMPLETION AND INSTALLATION INSTRUCTION
S205
PERFORM DISPLAY
S104
RECEIVE MEASUREMENT START INSTRUCTION
S206
MEASUREMENT START INSTRUCTION
S207
TRANSMISSION SIGNAL
S114
TRANSMIT ULTRASONIC SIGNAL AND RECEIVE ULTRASONIC SIGNAL
S208
RECEPTION SIGNAL
MEASUREMENT-UNIT MOVING INSTRUCTION
S115
S209
MOVE MEASUREMENT UNIT
S210
MOVING COMPLETION REPORT
S207-1
TRANSMISSION SIGNAL
S105
S106
MEASUREMENT COMPLETION AND MEASUREMENT RESULT
PERFORM DISPLAY
S211

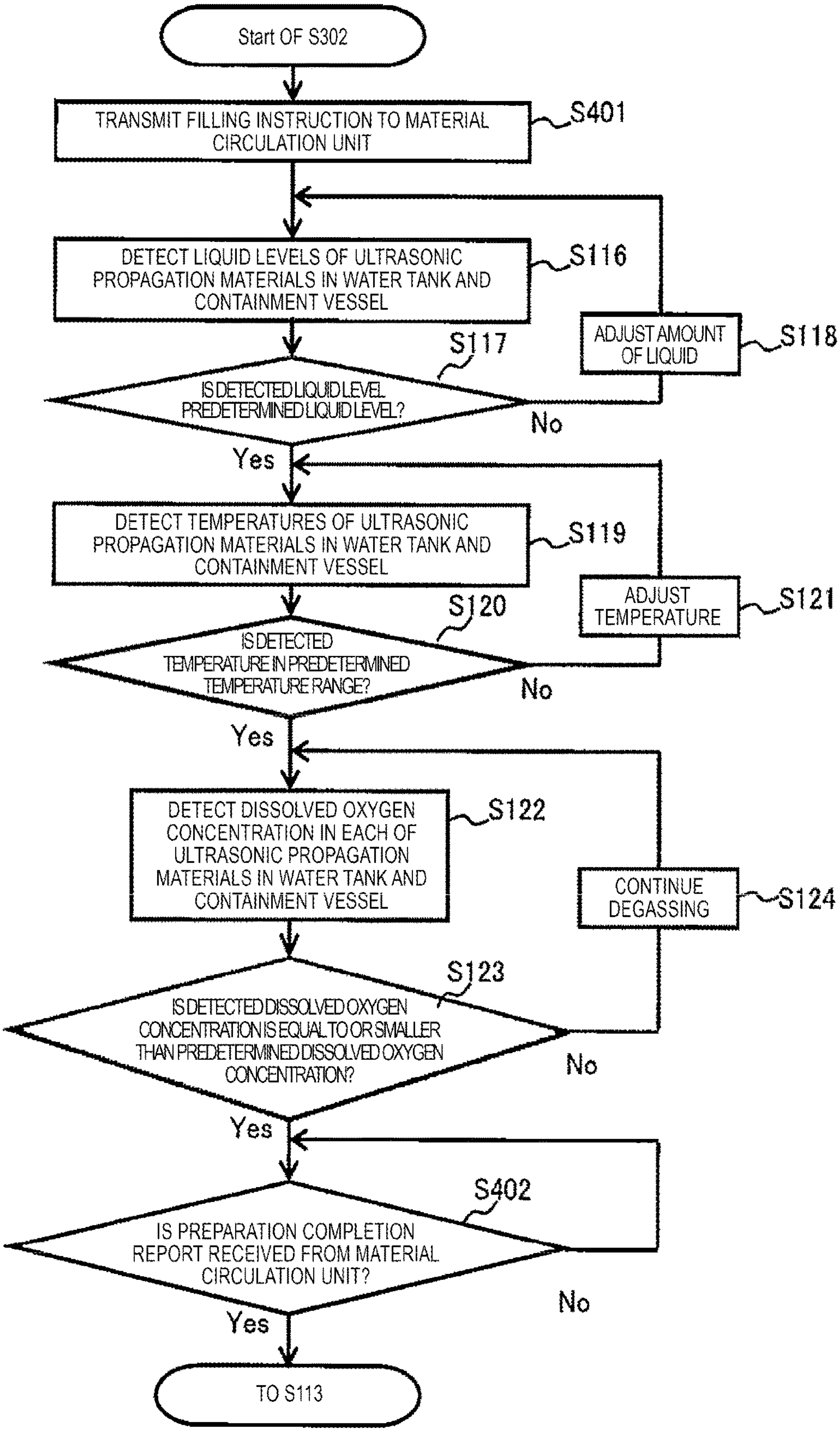
[Fig. 4B]


I/F37
DISPLAY UNIT 39
ELECTRONIC CONTROL DEVICE 28
MATERIAL CIRCULATION UNIT 20
MATERIAL CIRCULATION UNIT 27
DRIVING DEVICE 14
TRANSDUCER ARRAY 4
S107
RECEIVE WASHING START INSTRUCTION
S212
WASHING START INSTRUCTION
S213
WASHING INSTRUCTION
S214
WASH WATER TANK
S215
WASHING COMPLETION REPORT
S108
S216
WASHING COMPLETION AND INQUIRY OF SUSPENSION
PERFORM DISPLAY
S217
S109
RECEIVE SUSPENSION INSTRUCTION
S218
SUSPENSION INSTRUCTION
S219-1
DRAINAGE INSTRUCTION
S219-2
DRAINAGE INSTRUCTION
S220
DRAIN ULTRASONIC PROPAGATION MATERIAL
S221
DRAIN ULTRASONIC PROPAGATION MATERIAL
S222
DRAINAGE COMPLETION REPORT
S223
DRAINAGE COMPLETION REPORT
S110
S224
OPERATION SUSPENSION
PERFORM DISPLAY
S225

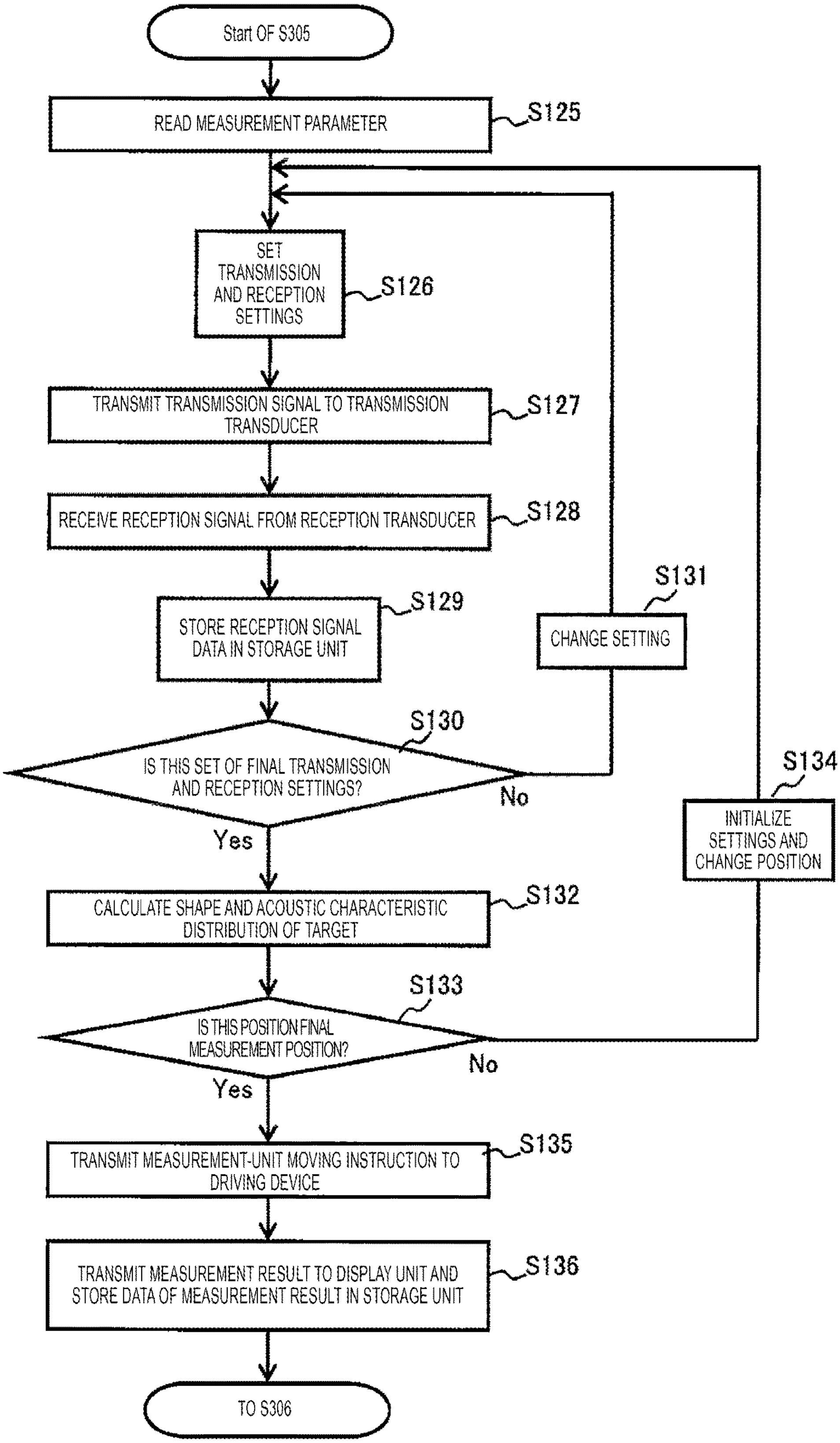
[Fig. 5]


Start
S301
IS START INSTRUCTION RECEIVED?
No
Yes
PERFORM MATERIAL CONTROL PROCESSING
S302
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION TO DRIVING DEVICE
S113
S403
IS MOVING COMPLETION REPORT RECEIVED FROM DRIVING DEVICE?
No
Yes
TRANSMIT INSTALLATION INSTRUCTION OF TARGET TO DISPLAY UNIT
S303
S304
IS MEASUREMENT START INSTRUCTION RECEIVED?
No
Yes
PERFORM MEASUREMENT EXECUTION PROCESSING
S305
S306
IS MEASUREMENT ENDED?
No
Yes
S307
IS WASHING START INSTRUCTION RECEIVED?
No
Yes
PERFORM WASHING TREATMENT IN WATER TANK
S308
S309
IS SUSPENSION INSTRUCTION RECEIVED?
No
Yes
PERFORM ULTRASONIC PROPAGATION MATERIAL DRAINAGE PROCESSING
S310
End

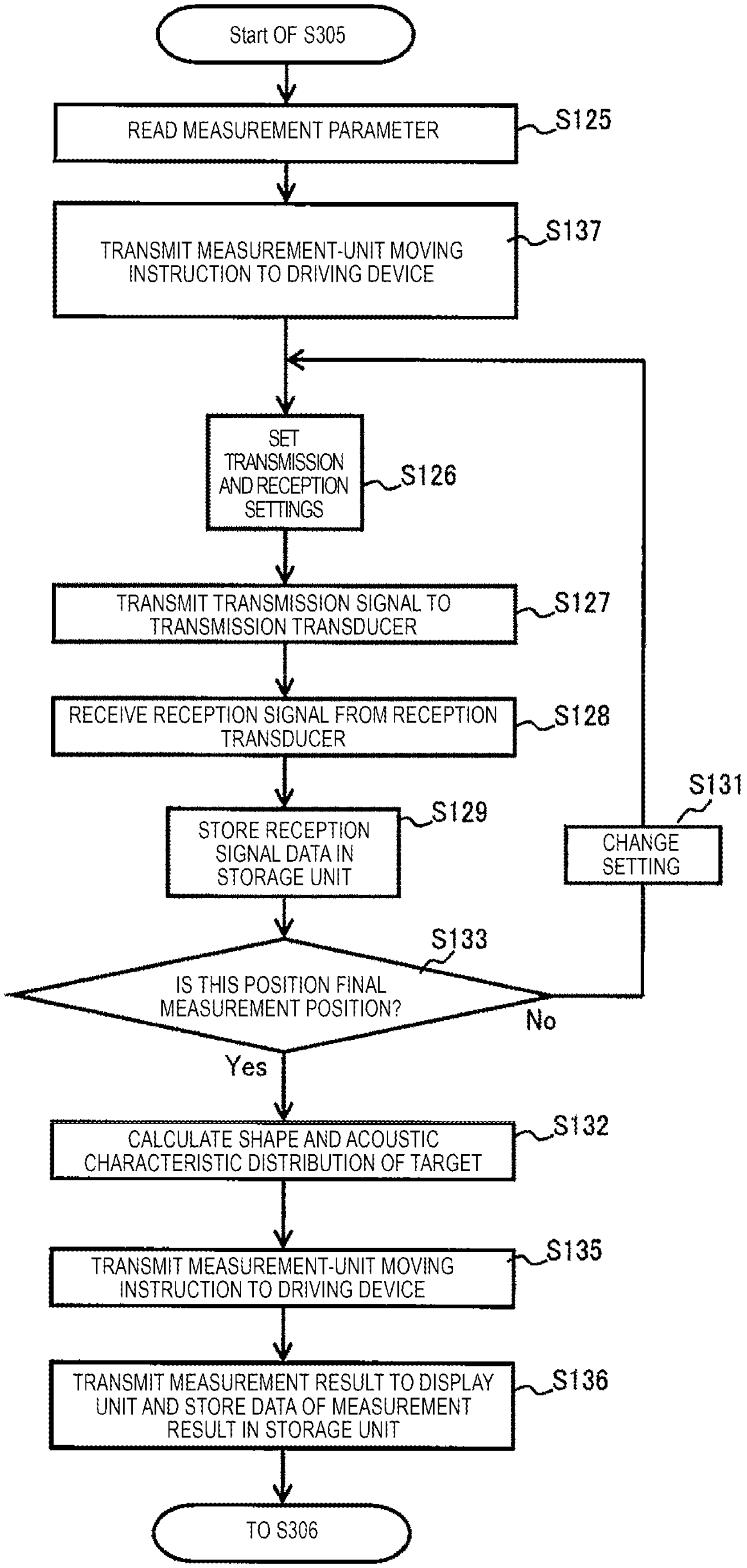
[Fig. 6]


Start OF S302
TRANSMIT FILLING INSTRUCTION TO MATERIAL CIRCULATION UNIT
S401
DETECT LIQUID LEVELS OF ULTRASONIC PROPAGATION MATERIALS IN WATER TANK AND CONTAINMENT VESSEL
S116
S117
IS DETECTED LIQUID LEVEL PREDETERMINED LIQUID LEVEL?
No
ADJUST AMOUNT OF LIQUID
S118
Yes
DETECT TEMPERATURES OF ULTRASONIC PROPAGATION MATERIALS IN WATER TANK AND CONTAINMENT VESSEL
S119
S120
IS DETECTED TEMPERATURE IN PREDETERMINED TEMPERATURE RANGE?
No
ADJUST TEMPERATURE
S121
Yes
DETECT DISSOLVED OXYGEN CONCENTRATION IN EACH OF ULTRASONIC PROPAGATION MATERIALS IN WATER TANK AND CONTAINMENT VESSEL
S122
CONTINUE DEGASSING
S124
S123
IS DETECTED DISSOLVED OXYGEN CONCENTRATION IS EQUAL TO OR SMALLER THAN PREDETERMINED DISSOLVED OXYGEN CONCENTRATION?
No
Yes
S402
IS PREPARATION COMPLETION REPORT RECEIVED FROM MATERIAL CIRCULATION UNIT?
No
Yes
TO S113

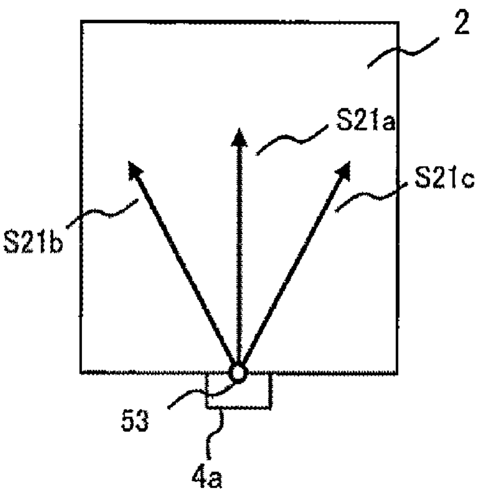
[Fig. 7A]


Start OF S305
READ MEASUREMENT PARAMETER
S125
SET TRANSMISSION AND RECEPTION SETTINGS
S126
TRANSMIT TRANSMISSION SIGNAL TO TRANSMISSION TRANSDUCER
S127
RECEIVE RECEPTION SIGNAL FROM RECEPTION TRANSDUCER
S128
STORE RECEPTION SIGNAL DATA IN STORAGE UNIT
S129
S131
CHANGE SETTING
S130
IS THIS SET OF FINAL TRANSMISSION AND RECEPTION SETTINGS?
No
Yes
S134
INITIALIZE SETTINGS AND CHANGE POSITION
CALCULATE SHAPE AND ACOUSTIC CHARACTERISTIC DISTRIBUTION OF TARGET
S132
S133
IS THIS POSITION FINAL MEASUREMENT POSITION?
No
Yes
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION TO DRIVING DEVICE
S135
TRANSMIT MEASUREMENT RESULT TO DISPLAY UNIT AND STORE DATA OF MEASUREMENT RESULT IN STORAGE UNIT
S136
TO S306

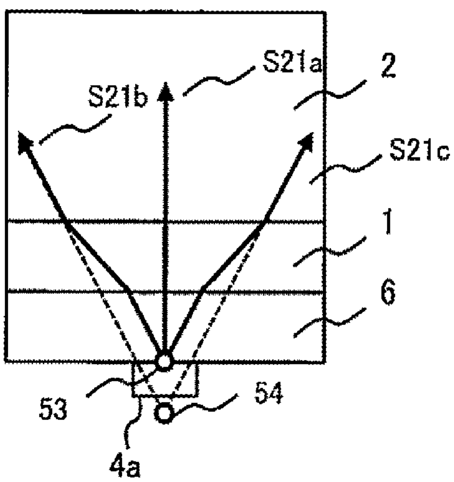
[Fig. 7B]


Start OF S305
READ MEASUREMENT PARAMETER
S125
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION TO DRIVING DEVICE
S137
SET TRANSMISSION AND RECEPTION SETTINGS
S126
TRANSMIT TRANSMISSION SIGNAL TO TRANSMISSION TRANSDUCER
S127
RECEIVE RECEPTION SIGNAL FROM RECEPTION TRANSDUCER
S128
STORE RECEPTION SIGNAL DATA IN STORAGE UNIT
S129
S131
CHANGE SETTING
S133
IS THIS POSITION FINAL MEASUREMENT POSITION?
No
Yes
CALCULATE SHAPE AND ACOUSTIC CHARACTERISTIC DISTRIBUTION OF TARGET
S132
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION TO DRIVING DEVICE
S135
TRANSMIT MEASUREMENT RESULT TO DISPLAY UNIT AND STORE DATA OF MEASUREMENT RESULT IN STORAGE UNIT
S136
TO S306

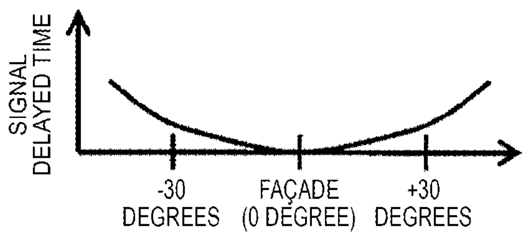
[Fig. 8A]



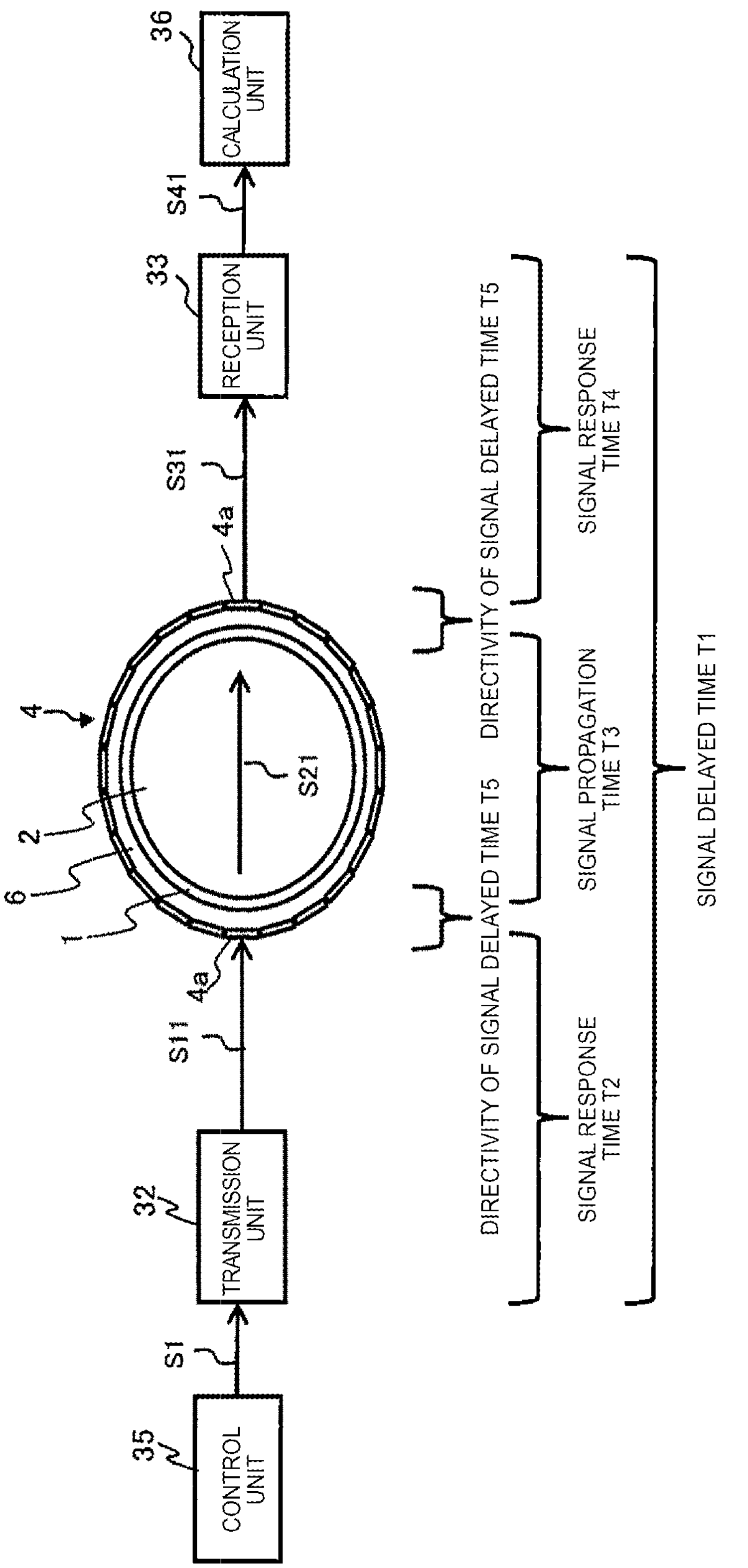
[Fig. 8B]



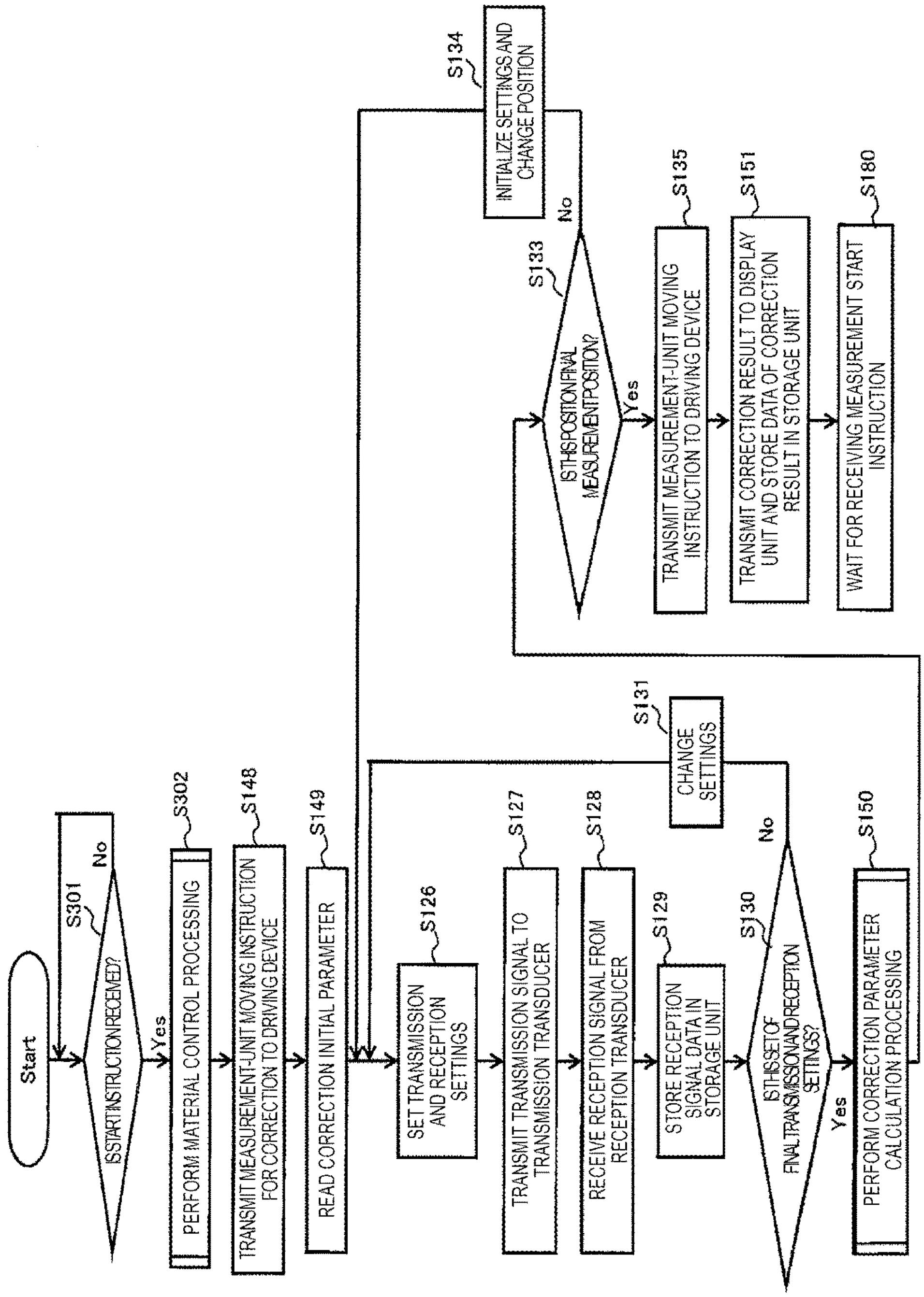
[Fig. 8C]



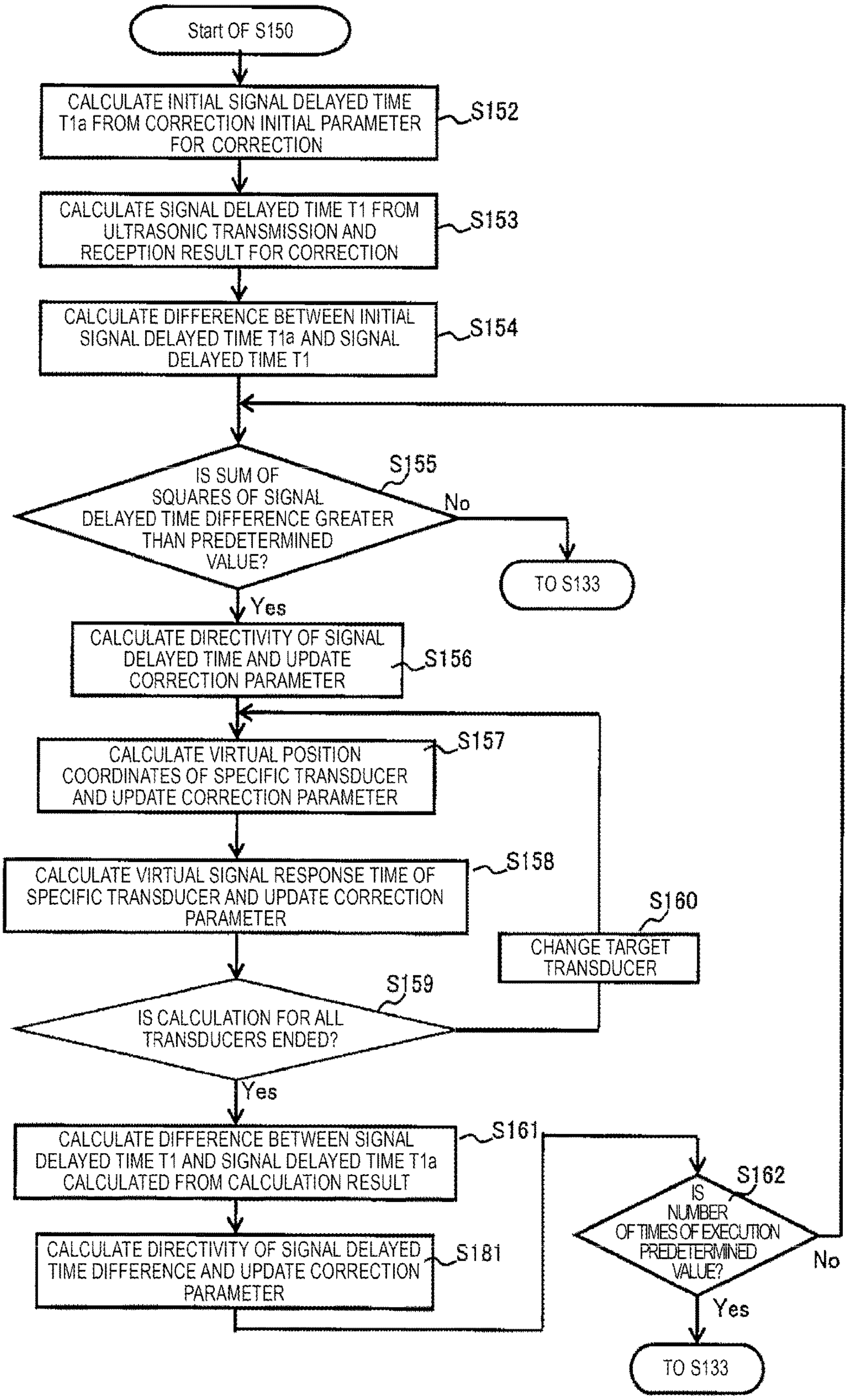
[Fig. 9]


35
CONTROL UNIT
S1
32
TRANSMISSION UNIT
S11
4a
1
6
2
4
S21
4a
S31
33
RECEPTION UNIT
S41
36
CALCULATION UNIT
DIRECTIVITY OF SIGNAL DELAYED TIME T5
SIGNAL RESPONSE TIME T2
SIGNAL PROPAGATION TIME T3
DIRECTIVITY OF SIGNAL DELAYED TIME T5
SIGNAL RESPONSE TIME T4
SIGNAL DELAYED TIME T1

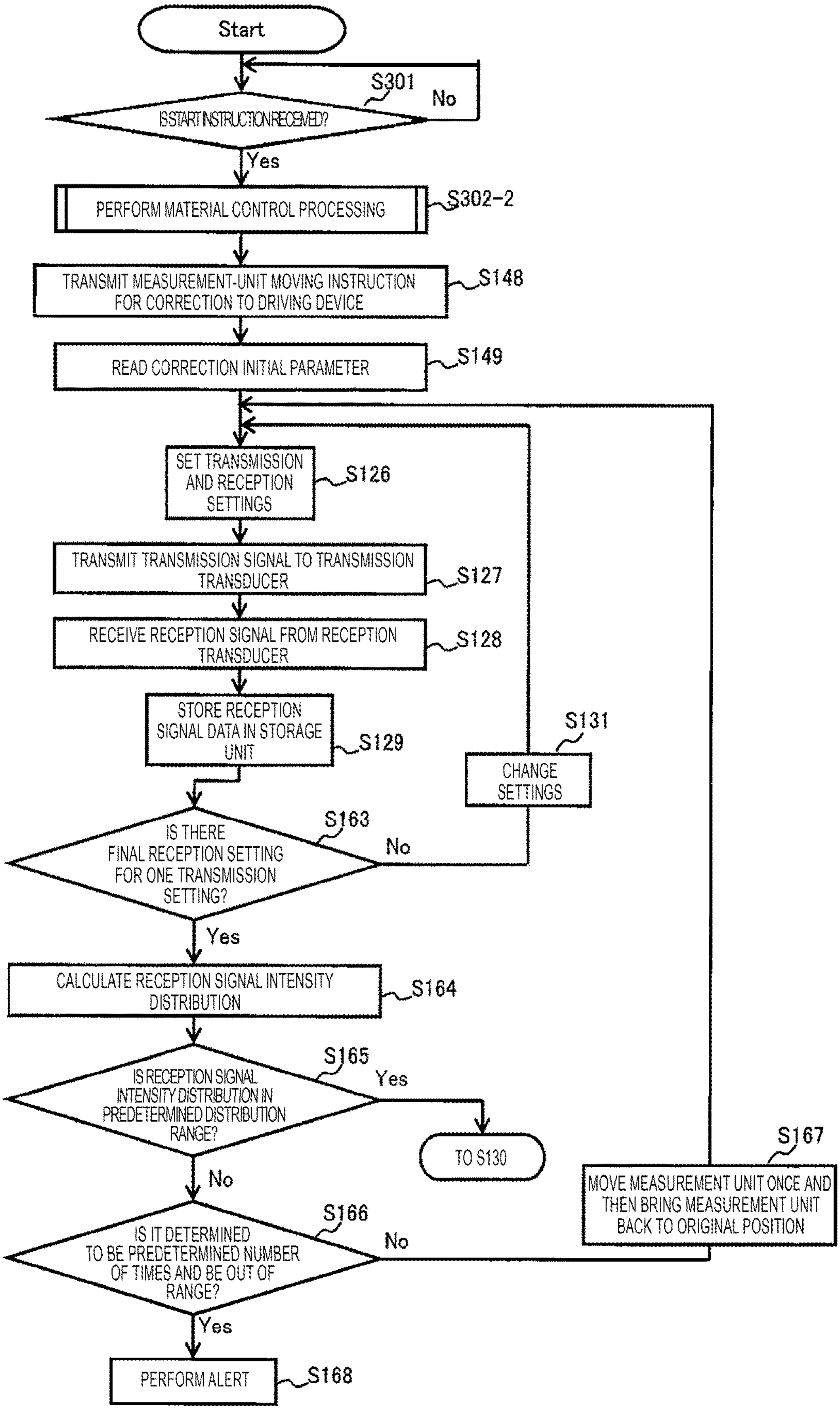
[Fig. 10]


Start
S301
IS START INSTRUCTION RECEIVED?
Yes
No
S302
PERFORM MATERIAL CONTROL PROCESSING
S148
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION FOR CORRECTION TO DRIVING DEVICE
S149
READ CORRECTION INITIAL PARAMETER
S126
SET TRANSMISSION AND RECEPTION SETTINGS
S127
TRANSMIT TRANSMISSION SIGNAL TO TRANSMISSION TRANSDUCER
S128
RECEIVE RECEPTION SIGNAL FROM RECEPTION TRANSDUCER
S129
STORE RECEPTION SIGNAL DATA IN STORAGE UNIT
S130
IS THIS SET OF FINAL TRANSMISSION AND RECEPTION SETTINGS?
Yes
No
S131
CHANGE SETTINGS
S150
PERFORM CORRECTION PARAMETER CALCULATION PROCESSING
S133
IS THIS POSITION FINAL MEASUREMENT POSITION?
Yes
No
S134
INITIALIZE SETTINGS AND CHANGE POSITION
S135
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION TO DRIVING DEVICE
S151
TRANSMIT CORRECTION RESULT TO DISPLAY UNIT AND STORE DATA OF CORRECTION RESULT IN STORAGE UNIT
S180
WAIT FOR RECEIVING MEASUREMENT START INSTRUCTION

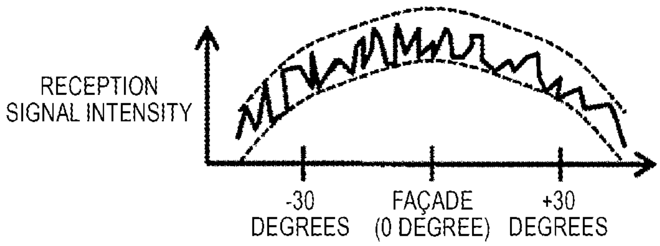
[Fig. 11]


Start OF S150
CALCULATE INITIAL SIGNAL DELAYED TIME T1a FROM CORRECTION INITIAL PARAMETER FOR CORRECTION
S152
CALCULATE SIGNAL DELAYED TIME T1 FROM ULTRASONIC TRANSMISSION AND RECEPTION RESULT FOR CORRECTION
S153
CALCULATE DIFFERENCE BETWEEN INITIAL SIGNAL DELAYED TIME T1a AND SIGNAL DELAYED TIME T1
S154
IS SUM OF SQUARES OF SIGNAL DELAYED TIME DIFFERENCE GREATER THAN PREDETERMINED VALUE?
S155
No
TO S133
Yes
CALCULATE DIRECTIVITY OF SIGNAL DELAYED TIME AND UPDATE CORRECTION PARAMETER
S156
CALCULATE VIRTUAL POSITION COORDINATES OF SPECIFIC TRANSDUCER AND UPDATE CORRECTION PARAMETER
S157
CALCULATE VIRTUAL SIGNAL RESPONSE TIME OF SPECIFIC TRANSDUCER AND UPDATE CORRECTION PARAMETER
S158
S160
CHANGE TARGET TRANSDUCER
IS CALCULATION FOR ALL TRANSDUCERS ENDED?
S159
Yes
CALCULATE DIFFERENCE BETWEEN SIGNAL DELAYED TIME T1 AND SIGNAL DELAYED TIME T1a CALCULATED FROM CALCULATION RESULT
S161
S162
IS NUMBER OF TIMES OF EXECUTION PREDETERMINED VALUE?
No
CALCULATE DIRECTIVITY OF SIGNAL DELAYED TIME DIFFERENCE AND UPDATE CORRECTION PARAMETER
S181
Yes
TO S133

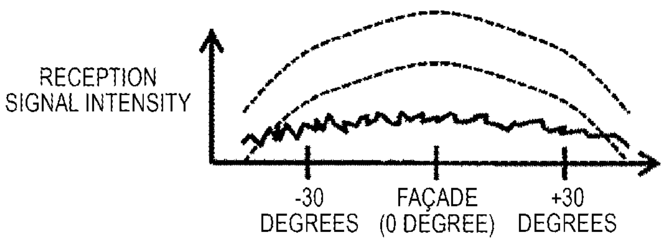
[Fig. 12]


Start
S301
IS START INSTRUCTION RECEIVED?
No
Yes
PERFORM MATERIAL CONTROL PROCESSING
S302-2
TRANSMIT MEASUREMENT-UNIT MOVING INSTRUCTION FOR CORRECTION TO DRIVING DEVICE
S148
READ CORRECTION INITIAL PARAMETER
S149
SET TRANSMISSION AND RECEPTION SETTINGS
S126
TRANSMIT TRANSMISSION SIGNAL TO TRANSMISSION TRANSDUCER
S127
RECEIVE RECEPTION SIGNAL FROM RECEPTION TRANSDUCER
S128
STORE RECEPTION SIGNAL DATA IN STORAGE UNIT
S129
S131
CHANGE SETTINGS
S163
IS THERE FINAL RECEPTION SETTING FOR ONE TRANSMISSION SETTING?
No
Yes
CALCULATE RECEPTION SIGNAL INTENSITY DISTRIBUTION
S164
S165
IS RECEPTION SIGNAL INTENSITY DISTRIBUTION IN PREDETERMINED DISTRIBUTION RANGE?
Yes
TO S130
No
S167
MOVE MEASUREMENT UNIT ONCE AND THEN BRING MEASUREMENT UNIT BACK TO ORIGINAL POSITION
S166
IS IT DETERMINED TO BE PREDETERMINED NUMBER OF TIMES AND BE OUT OF RANGE?
No
Yes
PERFORM ALERT
S168

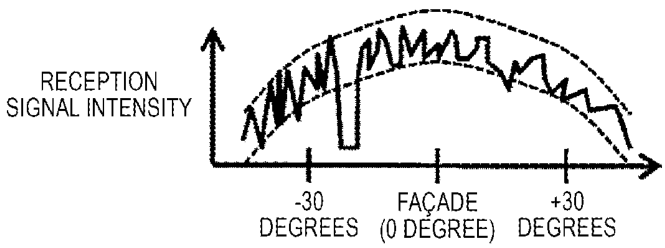
[Fig. 13A]



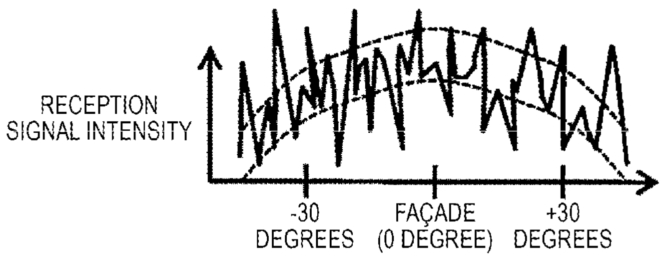
[Fig. 13B]



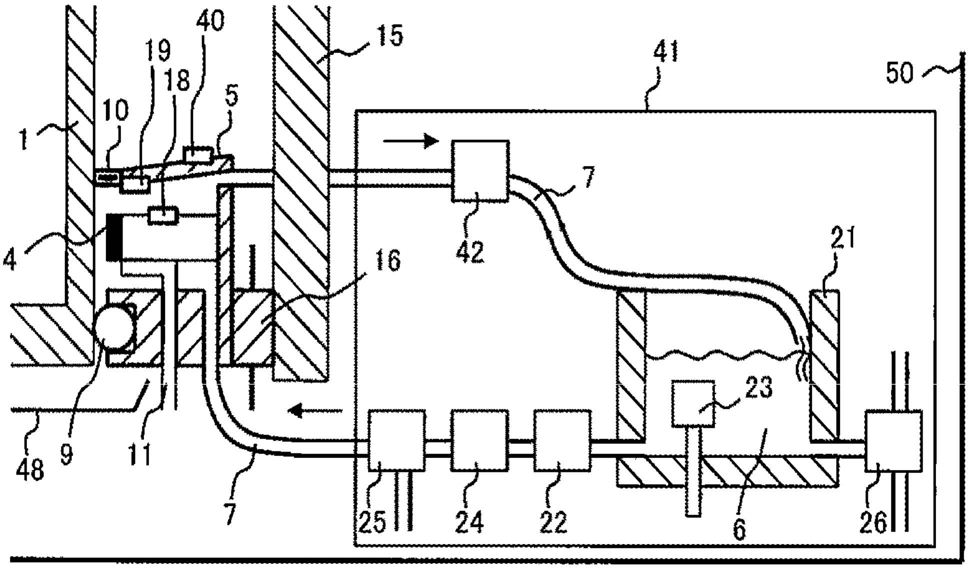
[Fig. 13C]



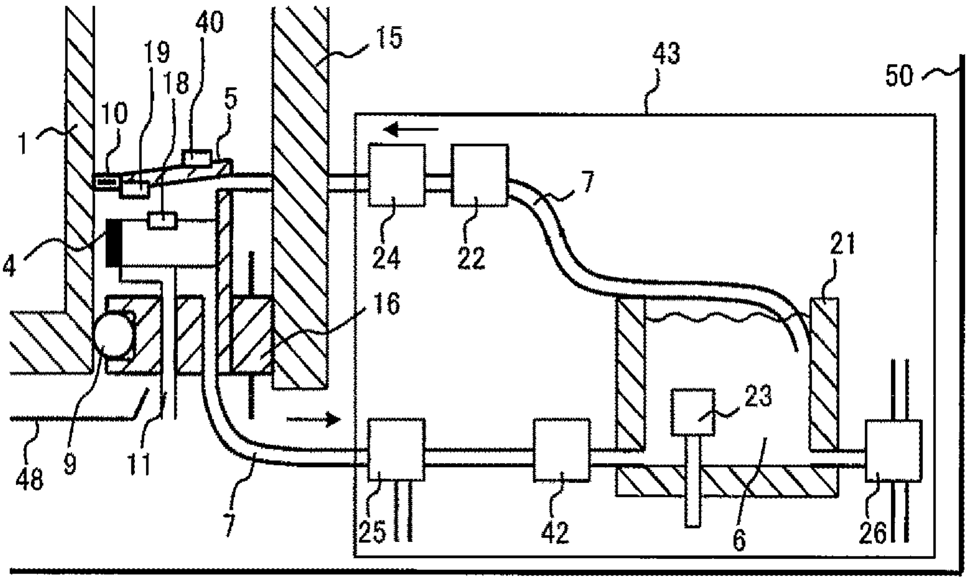
[Fig. 13D]



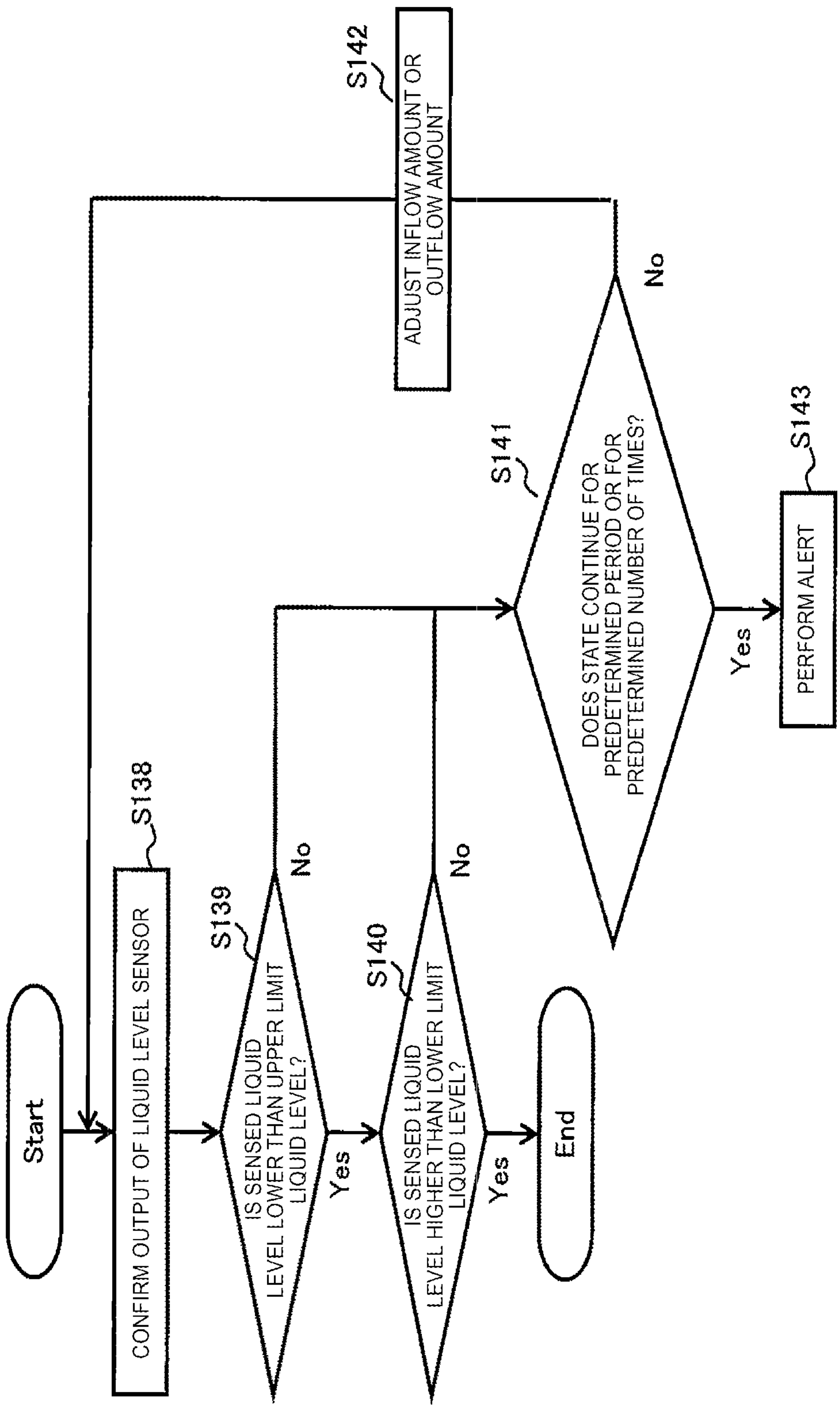
[Fig. 14A]



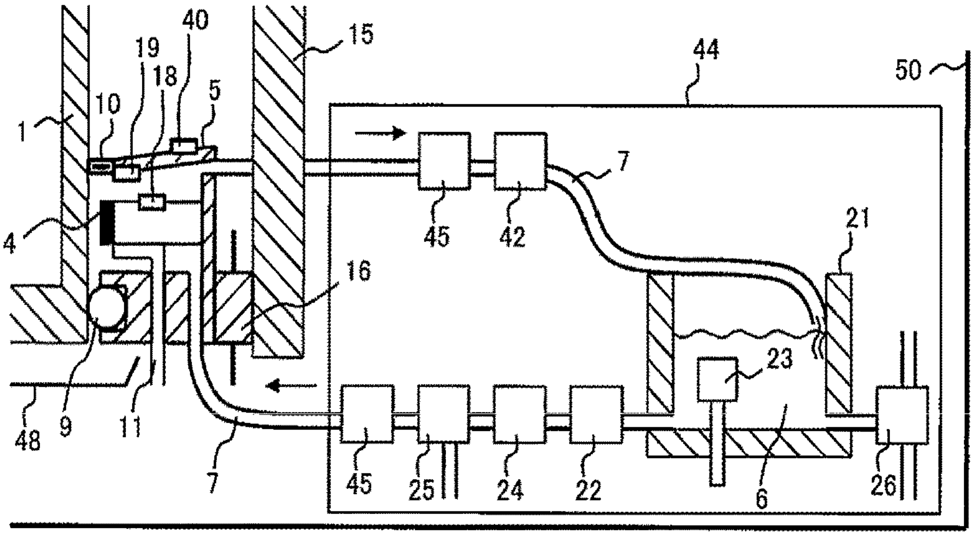
[Fig. 14B]



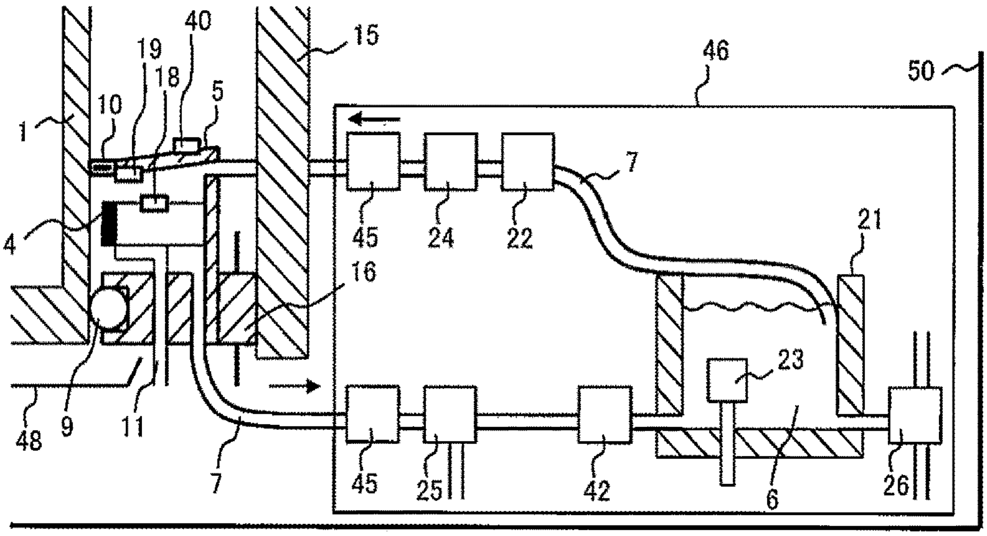
[Fig. 15]


Start
S138
CONFIRM OUTPUT OF LIQUID LEVEL SENSOR
S139
IS SENSED LIQUID LEVEL LOWER THAN UPPER LIMIT LIQUID LEVEL?
Yes
No
S140
IS SENSED LIQUID LEVEL HIGHER THAN LOWER LIMIT LIQUID LEVEL?
Yes
No
End
S141
DOES STATE CONTINUE FOR PREDETERMINED PERIOD OR FOR PREDETERMINED NUMBER OF TIMES?
Yes
No
S142
ADJUST INFLOW AMOUNT OR OUTFLOW AMOUNT
S143
PERFORM ALERT

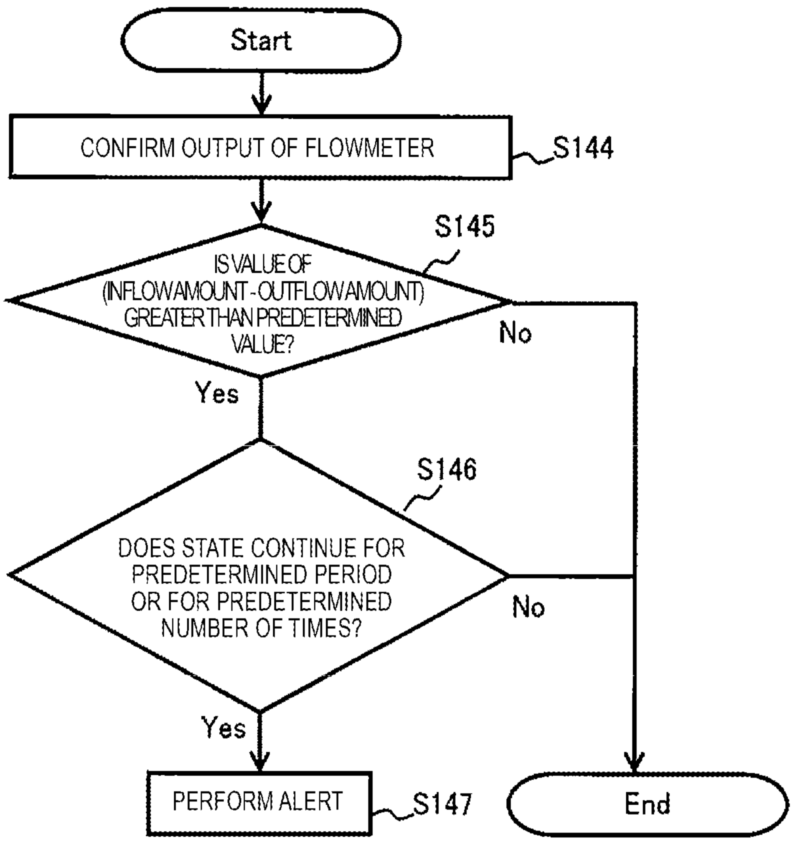
[Fig. 16A]



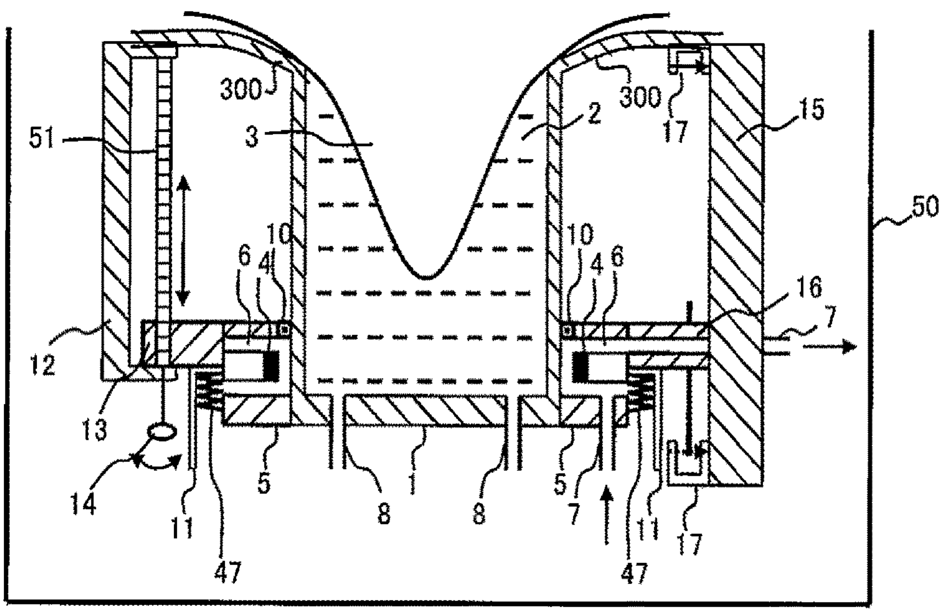
[Fig. 16B]



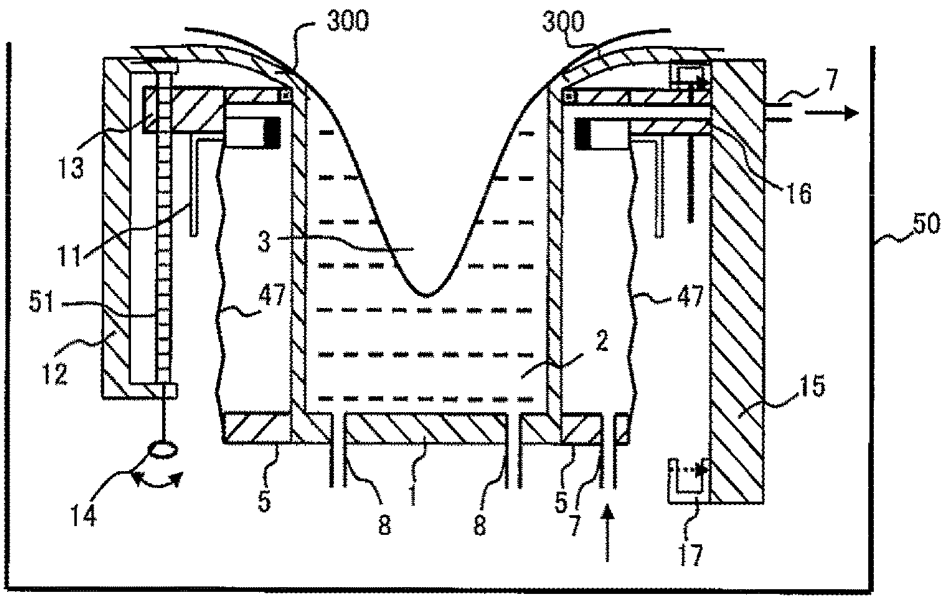
[Fig. 17]


Start
CONFIRM OUTPUT OF FLOWMETER
S144
S145
IS VALUE OF (INFLOW AMOUNT - OUTFLOW AMOUNT) GREATER THAN PREDETERMINED VALUE?
No
Yes
S146
DOES STATE CONTINUE FOR PREDETERMINED PERIOD OR FOR PREDETERMINED NUMBER OF TIMES?
No
Yes
PERFORM ALERT
S147
End

[Fig. 18A]



[Fig. 18B]



ULTRASONIC SIGNAL PROCESSING APPARATUS, ULTRASONIC IMAGING APPARATUS USING SAME, AND CONTROL METHOD IN ULTRASONIC SIGNAL PROCESSING APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to an ultrasonic signal processing apparatus, an ultrasonic imaging apparatus using the same, and a control method in the ultrasonic signal processing apparatus.

BACKGROUND ART

[0002] As an ultrasonic computed tomography (CT) apparatus, there is an ultrasonic imaging apparatus as follows. The ultrasonic imaging apparatus transmits an ultrasonic wave to an inside of a target disposed in an ultrasonic propagation material (water and the like) which is a medium for propagating an ultrasonic wave. The apparatus receives an ultrasonic wave passing through the inside of the target on each of a plurality of paths, and measures a propagation time and the like from the transmission of the ultrasonic wave until being received. The apparatus calculates distribution (acoustic characteristic distribution) of physical property values (sound speed, attenuation of ultrasonic wave, or the like) which reflect acoustic characteristics of the target, based on the propagation time, the length (propagation distance) of propagation path, and the like, and thus generates a tomographic image of the target. That is, the ultrasonic CT apparatus obtains a tomographic image of a target regarding predetermined physical property values, by using an ultrasonic tomography method.

[0003] PTL 1 discloses an ultrasonic CT apparatus having a configuration in which an oil tank that encircles a water tank in which a breast is put is disposed, and a ring-like transducer array is disposed in the oil tank. PTL 1 discloses that the transducer array is movable up and down in the oil tank.

CITATION LIST

Patent Literature

[0004] PTL 1: U.S. Pat. No. 5,305,752

SUMMARY OF INVENTION

Technical Problem

[0005] The temperature of an ultrasonic propagation material causes a propagation speed of an ultrasonic wave to be changed. Thus, in a case where temperature distribution of an ultrasonic propagation material is not sufficiently uniform, a propagation time of an ultrasonic wave changes and thus it is not possible to calculate acoustic characteristic distribution of a target with high accuracy. In addition, an ultrasonic wave transmitted from a transducer array is scattered by bubbles in the ultrasonic propagation material. Thus, in a case where it is not possible to sufficiently remove the bubbles in the ultrasonic propagation material, a propagation path of an ultrasonic wave changes, and thus it is not possible to calculate acoustic characteristic distribution of the target with high accuracy.

[0006] As described above, since the ultrasonic propagation material much largely influences propagation of an ultrasonic wave, special managements regarding material temperature adjustment for holding temperature distribution to be uniform, a degassing treatment of removing bubbles in the ultrasonic propagation material, and the like are required. Therefore, in an ultrasonic imaging apparatus for medical purposes (for example, for breast cancer screening), the amount of an ultrasonic propagation material is preferably small from a viewpoint of, for example, maintenance management of the ultrasonic propagation material.

[0007] As in PTL 1, if a target and a transducer array are disposed in tanks different from each other and are separated from each other, an ultrasonic propagation material with which the outer tank in which the transducer array is stored is filled is required in addition to an ultrasonic propagation material with which the inner tank into which the target is put is filled. Since the transducer array moves up and down in the outer tank, a large amount of the ultrasonic propagation material is required for the outer tank, and thus the amount of the ultrasonic propagation material required by the ultrasonic imaging apparatus is more increased.

[0008] An object of the present invention is to provide an ultrasonic signal processing apparatus in which the amount of an ultrasonic propagation material in a measurement unit that stores a transducer array is reduced while the transducer array and a target are separated from each other, and thus maintenance of the ultrasonic propagation material is easily managed.

Solution to Problem

[0009] To solve the above problem, according to the present invention, there is provided an ultrasonic signal processing apparatus as follows. That is, the ultrasonic signal processing apparatus includes a water tank having an opening portion, a measurement unit, and a moving unit. The measurement unit includes a transducer array that transmits and receives an ultrasonic signal, and a space which is filled with a material for propagating the ultrasonic signal, is disposed on the outside of the water tank, and measures the ultrasonic signal. The moving unit is connected to the measurement unit, and moves the measurement unit between the opening portion and the bottom portion of the water tank, along a side wall thereof .

Advantageous Effects of Invention

[0010] According to the present invention, it is possible to provide an ultrasonic signal processing apparatus in which the amount of an ultrasonic propagation material in a measurement unit that stores a transducer array is reduced while the transducer array and a target are separated from each other, and thus maintenance of the ultrasonic propagation material is easily managed.

BRIEF DESCRIPTION OF DRAWINGS

[0011] [FIG. **1**] FIG. **1** is a diagram illustrating an overall configuration example of an ultrasonic imaging apparatus.

[0012] [FIG. **2**A] FIG. **2**A is a diagram illustrating an example of a peripheral structure of a measurement unit and a water tank.

[0013] [FIG. **2**B] FIG. **2**B is a diagram illustrating an example when the peripheral structure of the measurement unit and the water tank is viewed from the top.

[0014] [FIG. **2**C] FIG. **2**C is a perspective view illustrating an example of the peripheral structure of the measurement unit and the water tank.

[0015] [FIG. **2**D] FIG. **2**D is a diagram illustrating an example of the measurement unit and a material circulation unit that circulates an ultrasonic propagation material in the measurement unit.

[0016] [FIG. **3**] FIG. **3** is a block diagram illustrating an example of an electronic control device of the ultrasonic imaging apparatus.

[0017] [FIG. **4**A] FIG. **4**A is a sequence diagram illustrating an operation example of the ultrasonic imaging apparatus.

[0018] [FIG. **4**B] FIG. **4**B is a sequence diagram illustrating an operation example of the ultrasonic imaging apparatus.

[0019] [FIG. **5**] FIG. **5** is a flowchart illustrating an example of an overall flow of an operation of a control unit.

[0020] [FIG. **6**] FIG. **6** is a flowchart illustrating an example of details of material control processing by the control unit.

[0021] [FIG. **7**A] FIG. **7**A is a flowchart illustrating an example of details of measurement execution processing by the control unit.

[0022] [FIG. **7**B] FIG. **7**B is a flowchart illustrating a modification example of details of the measurement execution processing by the control unit.

[0023] [FIG. **8**A] FIG. **8**A is a diagram illustrating an ultrasonic wave propagation path in a case where a transducer array is installed in the water tank

[0024] [FIG. **8**B] FIG. **8**B is a diagram illustrating an ultrasonic wave propagation path through the water tank, the ultrasonic propagation material in water tank, and an ultrasonic propagation material in a containment vessel.

[0025] [FIG. **8**C] FIG. **8**C is a diagram illustrating directivity of a signal delayed time of an ultrasonic signal.

[0026] [FIG. **9**] FIG. **9** is a diagram illustrating a signal propagation path in an ultrasonic imaging apparatus.

[0027] [FIG. **10**] FIG. **10** is a flowchart illustrating an example of a correction parameter calculation operation of the measurement unit which includes the ultrasonic propagation material between a wall of the water tank and the containment vessel, the correction parameter calculation operation being performed by the control unit.

[0028] [FIG. **11**] FIG. **11** is a flowchart illustrating an example of details of correction parameter calculation processing by the control unit.

[0029] [FIG. **12**] FIG. **12** is a flowchart illustrating a modification example of the correction parameter calculation operation of the measurement unit which includes the wall of the water tank and the ultrasonic propagation material in the containment vessel, the correction parameter calculation operation being performed by the control unit.

[0030] [FIG. **13**A] FIG. **13**A is an example of predetermined distribution in S**165** in FIG. **12**.

[0031] [FIG. **13**B] FIG. **13**B is another example of predetermined distribution in S**165** in FIG. **12**.

[0032] [FIG. **13**C] FIG. **13**C is still another example of predetermined distribution in S**165** in FIG. **12**.

[0033] [FIG. **13**D] FIG. **13**D is still another example of predetermined distribution in S**165** in FIG. **12**.

[0034] [FIG. **14**A] FIG. **14**A is a diagram illustrating a modification example of the measurement unit and the material circulation unit that circulates the ultrasonic propagation material in the measurement unit.

[0035] [FIG. **14**B] FIG. **14**B is a diagram illustrating a modification example of the measurement unit and the material circulation unit that circulates the ultrasonic propagation material in the measurement unit.

[0036] [FIG. **15**] FIG. **15** is a flowchart illustrating an operation example of the control unit, in which control is performed so as to cause the ultrasonic propagation material which remains on an upper surface of the containment vessel not to overflow, in the configuration illustrated in FIG. **14**.

[0037] [FIG. **16**A] FIG. **16**A is a diagram illustrating another modification example of the measurement unit and the material circulation unit that circulates the ultrasonic propagation material in the measurement unit.

[0038] [FIG. **16**B] FIG. **16**B is a diagram illustrating another modification example of the measurement unit and the material circulation unit that circulates the ultrasonic propagation material in the measurement unit.

[0039] [FIG. **17**] FIG. **17** is a flowchart illustrating an operation example of the control unit, in which it is detected whether or not liquid leakage of the ultrasonic propagation material occurs in the containment vessel or a hose, in the configuration illustrated in FIG. **16**.

[0040] [FIG. **18**A] FIG. **18**A is a diagram illustrating a modification example of the containment vessel.

[0041] [FIG. **18**B] FIG. **18**B is a diagram illustrating a modification example of the containment vessel.

DESCRIPTION OF EMBODIMENTS

[0042] Hereinafter, an embodiment of the present invention will be described with respect to the drawings. In the drawings for describing the embodiment, components having the same function are denoted by the same names and the same reference signs, and descriptions thereof will not be repeated.

[0043] FIG. **1** is a diagram illustrating an overall configuration example of an ultrasonic imaging apparatus and is a diagram illustrating an example in which measurement is performed on the breast of a person as a measurement target.

[0044] An ultrasonic imaging apparatus (ultrasonic CT apparatus) **52** includes a bed **29** on which a measurement subject **30** rides, a main apparatus (ultrasonic signal processing apparatus) **50**, and an electronic control device **28**. The main apparatus **50** transmits and receives an ultrasonic wave (ultrasonic signal) so as to perform ultrasonic wave imaging on a measurement target. The electronic control device **28** controls the main apparatus **50**. The main apparatus **50** includes a water tank **1**, a measurement unit **49**, and a stage **12**. In the water tank **1**, an opening portion is provided, and a target **3** is inserted into the opening portion. The measurement unit **49** measures an ultrasonic signal (transmits and receives an ultrasonic wave). The stage **12** is a support unit that supports the measurement unit **49**.

[0045] The water tank **1** is filled with an ultrasonic propagation material which is a material for propagating an ultrasonic wave. The measurement unit **49** includes a transducer array **4** configured to transmit and receive an ultrasonic wave. The measurement unit **49** is filled with an ultrasonic propagation material which is different from the ultrasonic propagation material in the water tank **1**.

[0046] The main apparatus **50** further includes a material circulation unit **20**, a driving device **14**, and a material circulation unit **27**. The material circulation unit **20** circulates the ultrasonic propagation material in the measurement unit **49** through a hose **7**. The driving device **14** moves the measurement unit **49** (vertically moves) along the wall surface (side wall surface) in the water tank **1** on the stage **12**. The material circulation unit **27** circulates the ultrasonic propagation material in the water tank **1** through a hose **8**. In this example, the opening portion side of the water tank **1** is referred to as an upper portion, and the bottom side of the water tank **1** is referred to as a lower portion. Movement of the measurement unit **49** moving between the opening portion and the bottom portion is referred to as vertical movement.

[0047] The ultrasonic propagation material in the water tank **1** is circulated by the material circulation unit **27** and the temperature and the like thereof are managed to be in a state which is suitable for ultrasonic wave imaging. The ultrasonic propagation material in the measurement unit **49** is circulated by the material circulation unit **20** and the temperature and the like thereof are managed to be in a state which is suitable for ultrasonic wave imaging.

[0048] The electronic control device **28** is connected to each unit of the main apparatus **50** via each signal wiring **11**, and controls the units. Specifically, the electronic control device **28** controls the material circulation unit **20**, the material circulation unit **27**, and the driving device **14**. Thus, the electronic control device **28** outputs a transmission signal for transmission of an ultrasonic wave to the transducer array **4** and receives a reception signal which is input as a result of receiving the ultrasonic wave, from the transducer array **4**. Practical devices are not required to have a positional relationship illustrated in FIG. **1**. Electric wirings are provided between the electronic control device **28**, and the material circulation unit **20**, the material circulation unit **27**, the driving device **14**, and the transducer array **4**. However, components may be connected in a manner of wireless communication.

[0049] As illustrated in FIG. **1**, the measurement subject **30** lies his/her face downward on the bed **29**, and thus the breast as a target **3** to be measured is inserted into the water tank **1** through the opening Portion. The transducer array **4** in the measurement unit **49** disposed on the outside of the water tank **1** transmits and receives an ultrasonic wave to and from the target **3** in the water tank **1**.

[0050] FIG. **2** is a diagram illustrating the measurement unit, the water tank, and the material circulation unit configured to circulate the ultrasonic propagation material in the measurement unit. FIG. **2**A is a diagram illustrating an example of a peripheral structure of the measurement unit and the water tank. FIG. **2**B is a diagram illustrating an example when the peripheral structure of the measurement unit and the water tank is viewed from the upper Portion. FIG. **2**C is a perspective view illustrating an example of the peripheral structure of the measurement unit and the water tank. FIG. **2**D is a diagram illustrating an example of the measurement unit and the material circulation unit configured to circulate the ultrasonic propagation material in the measurement unit.

[0051] As illustrated in FIGS. **2**A to **2**C, the measurement unit **49** includes the transducer array **4**, a containment vessel **5** configured to accommodate the transducer array **4**, and an ultrasonic propagation material **6** with which the containment vessel **5** is filled. The transducer array **4** is a piezoelectric element configured to transmit and receive an ultrasonic wave. A transmission and reception surface of an ultrasonic wave is directed toward the water tank **1**. The transducer array **4** is not necessarily limited to an annular shape of covering the entirety of the surroundings of the water tank **1** and a portion of the ring may be cut. In order to simplify a manufacturing process, a plurality of arc sub-transducer arrays may be assembled so as to form an annular transducer array **4**.

[0052] The water tank **1** or the transducer array **4** are not necessarily columnar or annular. The water tank or the transducer array may have a polygonal cylinder shape or a ring shape. A material which is suitable from a viewpoint of propagation characteristics of an ultrasonic wave, manufacturing cost, or the like can be selected as the material of the water tank **1**. For example, resins such as polyethylene, ABS, and polyethylene terephthalate are provided. The wall of the water tank **1** is preferably thin from a viewpoint of the propagation characteristics of an ultrasonic wave. The ultrasonic propagation materials **2** and **6** are acoustic matching materials which are liquids in which an ultrasonic wave is easily transmitted, and are liquids (acoustic matching liquids) for matching with acoustic impedance of a propagation path of an ultrasonic wave. A material which is suitable from a viewpoint of, for example, propagation characteristics of an ultrasonic wave, or manufacturing or treatment cost can be selected as the ultrasonic propagation material. For example, water (degassed water) or a physiological salt solution is provided as the ultrasonic propagation material. The ultrasonic propagation material may be sol, gel, or the like. The ultrasonic propagation materials **2** and **6** may be the same materials or may be materials different from each other.

[0053] In order to prevent an occurrence of a situation in which the ultrasonic propagation material **6** is leaked out from the containment vessel **5**, a liquid-tight structure **9** is provided on a contact surface between the wall of the containment vessel **5** on a lower surface and the wall of the water tank **1**. Since the containment vessel **5** moves up and down along the wall surface of the water tank **1**, the liquid-tight structure **9** preferably has a structure having low sliding resistance and high liquid tightness. For example, an O-ring, an X-ring, an U packing, or the like made of synthetic rubber is provided.

[0054] The following is considered. When the containment vessel **5** moves up and down, a small gap is formed between the liquid-tight structure **9** and the wall surface of the water tank **1**, and thus the ultrasonic propagation material **6** is leaked. In particular, when the containment vessel **5** turns to fall after rising up to the top or the containment vessel **5** turns to rise after falling up to the bottom, the liquid-tight structure **9** may be twisted, and thus there is a probability of forming a gap. In a case where the water tank **1** is made of a resin and the wall surface is thin, the water tank is slightly deformed by pressure which is generated by the liquid-tight structure **9**, and the liquid-tight property is totally or locally decreased. Thus, there is a probability of the ultrasonic propagation material **6** being easily leaked. A material receiving tray **48** is provided under the liquid-tight mechanism **9**. Thus, the leaked ultrasonic propagation material **6** is collected and drained or is brought back into the material circulation unit **20**.

[0055] A hole structure **10** is provided on a contact surface between the wall of the containment vessel **5** on an upper surface and the wall of the water tank **1**. The hole structure **10** is provided in order to escape an air in the containment vessel **5** and prevent an occurrence of a situation in which bubbles adhere to the wall of the water tank **1** when the containment vessel **5** moves up and down. The hole structure **10** is a ventilation structure of causing an air in the containment vessel **5** to pass. As the hole structure **10**, a structure in which the ultrasonic propagation material **6** is permeated and which has elasticity for suppressing wear of the wall surface of the water tank **1**. For example, a foam structure or a brush structure made of rubber, a resin, urethane, or the like is provided. The ultrasonic propagation material **6** is permeated into the hole structure **10**, and thus it is possible to decrease sliding resistance between the hole structure **10** and the water tank **1**.

[0056] The hole structure **10** is set to be in contact with a liquid surface of the ultrasonic propagation material **6** or the liquid level of the ultrasonic propagation material **6** is set to be higher than the hole structure **10**. Thus, it is possible to prevent an occurrence of a situation in which, when the containment vessel **5** moves up and down, the liquid level of the ultrasonic propagation material **6** coming into contact with the wall of the water tank **1** is changed in the containment vessel **5** by surface tension of the ultrasonic propagation material **6** or bubbles adhere to the liquid surface of the ultrasonic propagation material **6** by foreign matters adhering to the wall of the water tank **1**, minute scratches, or the like. In addition, when the containment vessel **5** moves up and down, the liquid-tight structure **9** removes foreign matters on the surface, which adhere to the wall of the water tank **1**, and thus it is possible to prevent bubbles from being generated.

[0057] It is also considered that a structure which is similar to the liquid-tight structure **9** is provided instead of the hole structure **10**, and a hole for escaping an air is provided at a place which is different from the wall of the containment vessel **5** on the upper surface. However, in this case, the wall of the containment vessel **5** on the upper surface becomes thick and measurement in the vicinity of the opening portion of the water tank **1** is not possible, and a blind area which is an area of which measurement is not possible is largely formed. Generally, if the diameter of the water tank **1** is set to be about 200 mm, the thickness of the liquid-tight structure **9** provided on the wall of the containment vessel **5** on the upper surface thereof is set to be about 10 mm. This is not suitable in a case where the breast is measured as the target **3** in order to detect a breast cancer. On the contrary, in a case where the hole structure **10** is provided, the thickness of the wall of the containment vessel **5** on the upper surface thereof may be set to be about 1 mm and thin. The reason is because a function of escaping an air in the containment vessel **5**, a function of permeating the ultrasonic propagation material **6** into the hole structure **10**, or a function of preventing adhering of bubbles by being brought into contact with the wall of the water tank **1** is hardly impaired without depending on the thickness of the hole structure **10**. The measurement unit **49** which includes the hole structure **10** can move until the hole structure **10** is brought into contact with an upper wall **300** in the vicinity of the opening portion of the water tank **1**.

[0058] The signal wiring **11** is drawn outwardly from the inside of the containment vessel **5** in order to input a transmission signal to the transducer array **4** or output a reception signal from the transducer array **4**. Since the transducer array **4** and the containment vessel **5** are fixed to each other, the signal wiring **11** and the containment vessel **5** are also fixed to each other. Therefore, liquid tightness between the signal wiring **11** and the containment vessel **5** can be easily realized by burying an adhesive, silicon rubber, or the like in the gap.

[0059] The signal wiring **11** on at least an outside of the containment vessel **5** is configured by a flexible printed board or a multi-core coaxial cable having flexibility, so as not to disturb vertical movement of the containment vessel **5**. The signal wiring **11** has a sufficient length in consideration of the vertical movement of the containment vessel **5**, and is connected to the electronic control device **28** (see FIGS. **1** and **3**).

[0060] The measurement unit **49** is supported by fitting portions **13** and **16** which are connected (fixed) to the containment vessel **5**, the stage **12** which is the support unit, and a guide rail **15**, and moves up and down along the wall surface of the water tank **1**. The fitting portions **13** and **16** are moving units configured to move (vertically move) the measurement unit **49** between the opening portion and the bottom portion of the water tank **1**, along the side wall of the water tank **1**. The stage **12** and the fitting portion **13** are connected by, for example, a screw structure **51** which is a vertical movement mechanism of moving the measurement unit **49** up and down. The screw structure **51** is rotated by the driving device **14**, and thus a relative positional relationship between the stage **12** and the fitting portion **13** changes. The guide rail **15** is fit with the fitting portion **16** such that the measurement unit **49** is held to be vertical to the wall surface of the water tank **1**. If three sets or more of stages **12** and guide rails **15** are provided, the measurement unit **49** can move up and down without being inclined from the water tank **1**. If the measurement unit **49** is inclined from the water tank **1**, pressure on the liquid-tight structure **9** becomes ununiform, and thus the liquid-tight property is deteriorated.

[0061] With a structure of moving the measurement unit **49** up and down, the fitting portions **13** and **16** can be provided in a transverse direction of the containment vessel **5**, and a space which is provided at the lower portion of the containment vessel **5** for vertical movement can be reduced. Thus, it is possible to accommodate the water tank **1**, the measurement unit **49**, the stage **12**, the guide rail **15**, and the like in a space having a small volume. In addition, in a case where a thermostatic tank is provided in the main apparatus **50** in order to hold states of the water tank **1**, the ultrasonic propagation materials **2** and **6**, and the like under constant conditions, it is possible to reduce the volume of the thermostatic tank.

[0062] The guide rail **15** includes a position detection sensor **17**, and detects the position of the fitting portion **16**. For example, an infrared sensor is used as the position detection sensor **17** and a protrusion for blocking an infrared ray is provided at the fitting portion **16**. If the protrusion of the fitting portion **16** is applied to the position detection sensor **17** installed at the lower portion of the guide rail **15**, and an infrared ray is blocked, the position detection sensor **17** detects this situation. Since the position detection sensor **17** detects blocking of an infrared ray, it is detected that the fitting portion **16** reaches the bottom portion, that is, that the measurement unit **49** reaches the bottom portion. Similarly, if the protrusion of the fitting portion **16** is applied to the position detection sensor **17** installed at the upper portion of the guide rail **15**, and an infrared ray is blocked, the position detection sensor **17** detects this situation. Thus, the position detection sensor **17** detects that the fitting portion **16** reaches the top portion, that is, that the measurement unit **49** reaches the top portion. The position detection sensor **17** is not limited to an infrared sensor, and may be a sensor by using visible light, an electromagnetic wave, a sound wave, an electric signal, or the like.

[0063] The installation place of the position detection sensor **17** is not limited to the guide rail **15**. The position detection sensor **17** may be installed on the stage **12**, in the main apparatus **50**, the thermostatic tank, or at another fixable place. A protrusion shape or the like corresponding to any place of the measurement unit **49** may be disposed in accordance with the installation place of the position detection sensor **17**. However, the position detection sensor **17** is not installed at a place at which measurement of the target **3** is hindered.

[0064] The water tank **1** is joined to the material circulation unit **27** through a hose **8**. The containment vessel **5** is joined to the material circulation unit **20** through a hose **7**. The hose **7** has a length which is sufficient for causing the vertical movement and measurement accuracy of the measurement unit **49** not to be restricted.

[0065] Next, the material circulation unit **20** will be described. As illustrated in FIG. **2**D, the material circulation unit **20** includes a material reservoir (material tank) **21**, a pump **22**, a temperature control device **23**, a degassing device **24**, a draining device **25**, and a feeding and draining device **26**. The material circulation unit circulates the ultrasonic propagation material **6** and appropriately manages the temperature and the like of the ultrasonic propagation material **6**.

[0066] The ultrasonic propagation material **6** is circulated between the containment vessel **5** and the material circulation unit **20** by pressure of the pump **22**. The sufficient amount of the ultrasonic propagation material **6** is stored in the material reservoir **21** by the feeding and draining device **26**. In a case where the amount of the ultrasonic propagation material **6** is reduced, the ultrasonic propagation material **6** is replenished by the feeding and draining device **26**. In order to manage ultrasonic characteristics of the ultrasonic propagation material **6** to be in a desired range, the temperature control device **23** controls the temperature of the ultrasonic propagation material **6** and the degassing device **24** performs degassing by removing a gas (air and the like) included in the ultrasonic propagation material **6**.

[0067] In a case where the target **3** is a human body, stable measurement is possible if the temperature is controlled to be about 37 degrees which is close to the body temperature. Thus, the temperature control device **23** is realized by, for example, a heater. A heat insulating material may be wound around the hose **7** so as not to change the temperature when the ultrasonic propagation material passes in the hose **7**. A thermostatic tank (not illustrated) maybe installed to surround the measurement unit **49**, the hose **7**, and the material circulation unit **20** through which the ultrasonic propagation material **6** is circulated, and the internal temperature may be set to be substantially equal to a desired temperature of the ultrasonic propagation material **6**.

[0068] The degassing device **24** is configured by, for example, a filter and a vacuum pump. The filter is configured by a hollow fiber membrane. Since the ultrasonic propagation material **6** passes in the hollow fiber membrane and an outside of the hollow fiber membrane is decompressed by a vacuum pump, a gas or bubbles dissolved in the ultrasonic propagation material **6** are moved to the outside of the hollow fiber membrane. When the ultrasonic propagation material is drained, the ultrasonic propagation material **6** in the containment vessel **5** and the ultrasonic propagation material **6** in the material reservoir **21** are drained by the draining device **25** and the feeding and draining device **26**.

[0069] Although not illustrated, the ultrasonic propagation material **2** in the water tank **1** is also similarly joined to the material circulation unit **27** (see FIG. **1**) through the hose **8**. The material circulation unit **27** circulates the ultrasonic propagation material **2** and appropriately manages the temperature and the like of the ultrasonic propagation material **2**.

[0070] The temperature and the liquid level of the ultrasonic propagation material **6** in the containment vessel **5** are managed by a temperature sensor **18** and a liquid level sensor **19**. The temperature sensor **18** detects the temperature of the ultrasonic propagation material **6**. Preferably, the temperature sensor **18** is disposed at a position which is close to an ultrasonic transmission and reception surface of the transducer array **4**, in a range without an influence on measurement of the target **3**. The liquid level sensor **19** detects the liquid level of the ultrasonic propagation material **6**, that is, detects whether or not the containment vessel **5** is filled with the ultrasonic propagation material **6** having an amount as much as not influencing ultrasonic transmission and reception characteristics of the transducer array **4**.

[0071] As described above, the liquid level of the ultrasonic propagation material **6** is set to be the height which is equal to or higher than the bottom surface of the hole structure **10**. If the ultrasonic propagation material **6** flows in from the hose **7** connected to the lower portion of the containment vessel **5**, and the ultrasonic propagation material **6** flows from the hose **7** connected to the upper portion of the containment vessel **5** out to the material reservoir **21**, the height of the hose **7** connected to the upper portion of the containment vessel **5** corresponds to the height of the liquid level of the ultrasonic propagation material **6** in the containment vessel **5**. If the wall of the containment vessel **5** on the upper surface thereof has a configuration in which the height of the wall thereof is reduced as the wall thereof is closer to the water tank **1** and the height of the wall of the containment vessel **5** on the upper surface thereof becomes higher as the wall thereof is farther from the water tank **1** (closer to the hose **7**) , an effect of preventing an occurrence of a situation in which the hole structure **10** is submerged in the ultrasonic propagation material **6** or bubbles adhere to the wall of the water tank **1** by the hole structure **10** is easily obtained.

[0072] With the above-described configuration, the transducer array **4** is disposed on the outside of the water tank **1**, and the measurement unit **49** which includes the transducer array **4** and the ultrasonic propagation material **6** moves up and down along the side wall of the water tank **1**. Accordingly, it is possible to three-dimensionally measure a target. The state of the ultrasonic propagation material **6** around the transducer array **4** is suitably managed and thus measurement with high accuracy is possible. The wall of the containment vessel **5** on the upper surface is set to be thin, and thus it is possible to perform measurement up to a position close to the opening portion of the water tank **1**, that is, to measure acoustic characteristics of the target **3** in a wide range. With the hole structure **10**, forming of bubbles by vertical movement of the measurement unit **49** is suppressed, and thus it is possible to process the ultrasonic propagation material **6** in the containment vessel **5** with higher accuracy. Accordingly, measurement with high accuracy is possible. The support for moving the transducer array **4** up and down may have a shape which protrudes from the bottom surface of the containment vessel **5**. However, since the stage **12** and the guide rail **15** are arranged in a transverse direction of the containment vessel **5**, an effect in that a large space at the lower portion of the containment vessel **5** is not required and it is possible to reduce the volume of the main apparatus **50** is exhibited in addition to the above-described effect. In a case where a thermostatic tank is provided in the main apparatus **50**, it is possible to manage the temperature state of the ultrasonic propagation material **6** by the thermostatic tank with higher accuracy, and thus measurement with high accuracy is possible.

[0073] FIG. **3** is a block diagram illustrating an example of the electronic control device in the ultrasonic imaging apparatus.

[0074] The electronic control device **28** includes transmission and reception units **31**, a control unit **35**, an interface (I/F) **37**, a storage unit **38**, and a display unit **39**. The transmission and reception units **31** are respectively connected to transducers **4***a* in the transducer array **4** by the signal wirings **11**.

[0075] The transmission and reception unit **31** includes a transmission unit **32**, a reception unit **33**, and a transmission and reception switch (T/R SW) **34** that performs switching between transmission and reception. The transmission and reception unit **31** transmits and receives an ultrasonic wave through the transducer array **4**. One transmission and reception unit **31** is connected to one transducer **4***a*. Each of the transmission and reception units **31** may independently output a transmission signal to the corresponding transducer **4***a*. In a case where many transducers **4***a* are provided and all transducers **4***a* are not used for one time (ultrasonic signal is not transmitted and received), a connection relationship between the transducer **4***a* and the transmission and reception unit **31** may be switched by an analog switch (not illustrated) or the like, and thus only a transducer **4***a* to be used may be connected to the transmission and reception unit **31**. On and OFF of the analog switch may be switched by the control unit **35**.

[0076] The control unit **35** controls the main apparatus **50** and the units in the electronic control device **28**. The control unit **35** includes a calculation unit **36** that performs various calculations for calculating the shape or acoustic characteristics of a target **3**, based on an electric signal S**41** received from the transmission and reception unit **31**. The control unit **35** includes a processor (for example, central processing unit (CPU) or a graphics processing unit (GPU)) and a memory in which a program is previously stored. The processor reads and executes the program, and thus realizes the function of the control unit **35**. In a case where the control unit **35** is realized by hardware, circuit design may be performed by using a custom IC such as an application specific integrated circuit (ASIC) or a programmable IC such as a field-programmable gate array (FPGA), so as to realize an operation of the control unit **35**.

[0077] The control unit **35** may perform different controls, for example, control signals S**51** and S**52**, on the transmission and reception units **31**. For example, the control unit **35** controls the transmission and reception unit **31** to which the control signal S**51** is input, to perform a transmission operation, and controls the transmission and reception unit **31** to which the control signal S**52** is input, to perform a reception operation.

[0078] The transmission unit **32** is configured by, for example, an amplifier. The transmission unit **32** amplifies an electric signal **51** input from the control unit **35** to have a desired amplitude, and then outputs the amplified signal to the transducer **4***a*. Acoustic pressure and a transmission timing of an ultrasonic signal S**21** transmitted from the transducer **4***a* are changed in accordance with a transmission timing and a voltage of an electric signal S**11** applied to the transducer **4***a*. Therefore, acoustic pressure and a transmission timing of the ultrasonic signal S**21** is controlled in accordance with the amplitude and the transmission timing of the electric signal S**1**. Alternatively, a gain of the amplifier constituting the transmission unit **32** and a signal response time may be controlled in accordance with the control signal S**51**, and the voltage and the transmission timing of the electric signal S**11** may be controlled.

[0079] The reception unit **33** is configured by, for example, a low noise amplifier, a filter, a variable gain amplifier, an analog-digital converter, and the like. An electric signal S**31** which is input from the transducer **4***a* via the transmission and reception switch **34** is amplified by the low noise amplifier. Noise other than a desired frequency band is reduced by the filter, and the resultant is amplified to have an appropriate amplitude by the variable gain amplifier. Then, the resultant signal is converted into a digital signal by the analog-digital converter. An electric signal S**41** obtained by conversion into a digital signal is input to the control unit **35**. Settings of a circuit constituting the reception unit **33** are controlled in accordance with a control signal S**52**. An amplitude value (quantized binary number) and a reception timing of the electric signal S**41** are changed in accordance with the acoustic pressure and a reception timing of the ultrasonic signal S**21**. A relationship between the amplitude value and the reception timing of the electric signal S**41** and the acoustic pressure and the reception timing of the ultrasonic signal S**21** are changed in accordance with the settings of the circuit constituting the reception unit **33**. Thus, the relationship thereof may be controlled by the control signal S**52** so as to obtain a desired relationship.

[0080] The transmission and reception switch **34** cuts off a connection between the reception unit **33** and the transducer **4***a* during a transmission operation, and has a short circuit between the reception unit **33** and the transducer **4***a* during a reception operation. Generally, the transmission unit **32** is configured by a high breakdown-voltage transistor in order to output a transmission signal having a high voltage. However, the reception unit **33** is configured by a low breakdown-voltage transistor because amplifying a reception signal having a low voltage. The transmission and reception switch **34** cuts off the connection between the reception unit **33** and the transducer **4***a* during the transmission operation, such that a high-voltage transmission signal output from the transmission unit **32** is applied to the reception unit **33** configured by a low breakdown-voltage transistor, and thus the reception unit **33** is broken down.

[0081] The control unit **35** calculates a transmission and reception result of the ultrasonic signal S**21** and calculates the shape or acoustic characteristics of the target **3**, with controlling transmission and reception of the ultrasonic signal S**21**. An ultrasonic signal S**21** which has been transmitted from a certain transmission and reception unit **31** via the transducer **4***a* propagates in the ultrasonic propagation material **6**, the water tank **1**, the ultrasonic propagation material **2**, and the target **3** with being scattered. The ultrasonic signal S**21** which has propagated in the above members is received via the same or a different transducer **4***a*. The shape of the target **3** is calculated by delaying and adding the reception result. A physical property value (sound speed and/or attenuation rate (attenuation amount)) which reflects acoustic characteristics of the target **3** is calculated by using an ultrasonic tomography method.

[0082] The control unit **35** stores data indicating the shape of the target **3** and the sound speed and/or the attenuation rate which have been calculated, in the storage unit **38**. Various settings such as setting of the transmission unit **32** and setting of the reception unit **33**, which are measurement parameters are also stored in the storage unit **38**. The control unit **35** reads the various settings from the storage unit **38** and controls the transmission and reception units **31**. Further, the control unit **35** performs output of a control command and acquirement of information regarding each of a state of the ultrasonic propagation material **6** and a state of the ultrasonic propagation material **2**, for the driving device **14** that moves the measurement unit **49** up and down, the material circulation unit **20** that manages the state of the ultrasonic propagation material **6** in the containment vessel **5**, and the material circulation unit **27** that manages the state of the ultrasonic propagation material **2** in the water tank **1**.

[0083] An operator of the ultrasonic imaging apparatus **52** performs an input and the like of a command via the interface **37**. The operator confirms a measurement result of the target **3** by the display unit **39** or confirms various states (setting state, operation state, and the like) of the ultrasonic imaging apparatus **52**. The operator may perform communication of information with another device via the interface **37**.

[0084] Next, an operation of the ultrasonic imaging apparatus **52**, particularly, an operation of the control unit **35** will be specifically described with reference to FIGS. **4** to **7**. FIGS. **4**A and **4**B are sequence diagrams illustrating an operation example of the ultrasonic imaging apparatus.

[0085] Firstly, if a start instruction is received from the operator (S**100**), the interface **37** transmits the start instruction to the electronic control device **28** (S**101**). The electronic control device **28** which has received the start instruction starts an operation as measurement preparation processing. The electronic control device **28** transmits a material unit control instruction to each of the material circulation unit **20** and the material circulation unit **27**. The material unit control instruction is a preparation instruction for the ultrasonic propagation material and is provided for controlling filling with the ultrasonic propagation materials **6** and **2**, and states (such as the temperature, filling conditions and the like) of the ultrasonic propagation materials **6** and **2** (S**102**-**1** and S**102**-**2**). The material circulation unit **20** and the material circulation unit **27** which have received the material unit control instruction fill the water tank **1** and the containment vessel **5** with the ultrasonic propagation materials **6** and **2**, respectively. The material circulation unit **20** and the material circulation unit **27** respectively control (manage) the ultrasonic propagation materials **6** and **2** under control of the control unit **35**, such that the ultrasonic propagation materials **6** and **2** are in a state suitable for imaging (S**111** and S**112**).

[0086] The material unit control instruction includes, for example, a liquid quantity control instruction, a temperature control instruction, and the degassing instruction. The liquid quantity control instruction is an instruction that the control unit **35** respectively instructs the material circulation units **27** and **20** to control the liquid quantities of the ultrasonic propagation materials **2** and **6**. The temperature control instruction is an instruction that the control unit **35** respectively instructs the material circulation units **27** and **20** to control the temperature of the ultrasonic propagation materials **2** and **6**. The degassing instruction is an instruction that the control unit **35** respectively instructs the material circulation units **27** and **20** to degas oxygen dissolved in the ultrasonic propagation materials **2** and **6**.

[0087] If the control of filling and the states of the ultrasonic propagation materials **6** and **2** is completed, each of the material circulation unit **20** and the material circulation unit **27** transmits a preparation completion report (S**201** and S**202**). The preparation completion report is used for reporting completion of preparation of the ultrasonic propagation material to the electronic control device **28**. Then, the material circulation unit **20** and the material circulation unit **27** continue the control to cause the ultrasonic propagation materials **6** and **2** to respectively maintain the appropriate state, until the ultrasonic imaging apparatus **52** is suspended.

[0088] The electronic control device **28** which has received the completion report from both the material circulation unit **20** and the material circulation unit **27** transmits a measurement-unit moving instruction to move the measurement unit **49** to a measurement position, to the driving device **14** (S**203**). The driving device **14** which has received the measurement-unit moving instruction moves the measurement unit **49** to the measurement position (S**113**). In a case of the first measurement-unit moving instruction, a moving destination of the measurement unit **49** is a measurement initial position. If the process of S**113** is completed, the driving device **14** transmits a moving completion report for reporting completion of moving the measurement unit **49**, to the electronic control device **28** (S**204**).

[0089] The electronic control device **28** which has received the moving completion report from the driving device **14** transmits a message indicating that measurement preparation is completed, and an installation instruction to promote installation of a target **3**, to the display unit **39** (S**103**). Then, the display unit **39** displays the message and the installation instruction (S**205**).

[0090] Then, if the target **3** is installed in the water tank **1**, the interface **37** receives a measurement start instruction from the operator (S**104**), and outputs the measurement start instruction to the electronic control device **28** (S**206**). The electronic control device **28** which has received the measurement start instruction performs control of performing measurement, as measurement execution processing (S**105**). The electronic control device **28** performs transmission and reception settings for each of the transmission and reception units **31**. The electronic control device **28** transmits a transmission signal which is an electric signal for transmitting an ultrasonic wave to the transducer array **4**, via each of the transmission and reception units **31** (S**207**). The transducer array **4** converts the electric signal into an ultrasonic signal, and transmits the ultrasonic signal into the transducer array **4**. The transducer array **4** receives an ultrasonic signal from the transducer array **4** (S**114**).

[0091] The transducer array **4** converts the received ultrasonic signal into a reception signal which is an electric signal, and transmits the reception signal to the electronic control device **28** via each of the transmission and reception units **31** (S**208**).

[0092] The electronic control device **28** stores the received reception signal in the storage unit **38**. If transmission and reception of the ultrasonic signal in predetermined transmission and reception settings are completed, the electronic control device **28** transmits a measurement-unit moving instruction of moving the measurement unit **49** to the next measurement position, to the driving device **14** (S**115**). The driving device **14** which has received the measurement-unit moving instruction moves the measurement unit **49** to the next measurement position (S**209**). If the process of S**209** is completed, the driving device **14** transmits a moving completion report to the electronic control device **28** (S**210**).

[0093] The electronic control device **28** which has received the moving completion report transmits a transmission signal to the transducer array **4** via each of the transmission and reception units **31** (S**207-1**). The electronic control device **28** transmits and receives an ultrasonic wave to the next measurement position at which the measurement unit **49** has moved in S**209**.

[0094] The ultrasonic imaging apparatus **52** repeats transmission and reception (S**207**, S**208**, and S**114**) of an ultrasonic wave and moving (S**115**, S**209**, and S**210**) of the measurement unit **49** until measurement unit **49** reaches the final measurement position. When the measurement unit **49** moves after the measurement unit **49** reaches the final measurement position and performs transmission and reception of an ultrasonic wave, the electronic control device **28** moves the measurement unit **49** to the measurement initial position. Then, the electronic control device **28** transmits a message indicating that the measurement is completed, and a measurement result based on the reception signal stored in the storage unit **38** to the display unit **39** (S**106**). The display unit **39** displays the message and the measurement result (S**211**). The electronic control device **28** stores a measurement result in the storage unit **38**, and then completes the measurement execution processing.

[0095] The operator confirms measurement completion and the measurement result by the display unit **39**. Then, the interface **37** receives a washing start instruction by the operator (S**107**), and outputs the washing start instruction to the electronic control device **28** (S**212**). The electronic control device **28** which has received the washing start instruction controls the material circulation unit **27** to wash the inside of the water tank **1** (S**108**). The electronic control device **28** transmits a washing instruction to the material circulation unit **27** (S**213**). The material circulation unit **27** which has received the washing instruction washes the water tank **1** (S**214**). Specifically, the material circulation unit **27** drains the ultrasonic propagation material **2** and rinses the inside of the water tank **1** with a new ultrasonic propagation material **2**. The material circulation unit **27** cause the ultrasonic propagation material **2** to pass through a filter configured to remove dirt, bacteria, and the like, and thus makes the ultrasonic propagation material **2** be clean. If necessary, the material circulation unit **27** injects a washing liquid into the water tank **1**, and thus performs washing. If washing of the water tank **1** is completed, the material circulation unit **27** transmits a washing completion report for reporting completion of washing of the water tank **1** to the electronic control device **28** (S**215**). The electronic control device **28** which has received the washing completion report transmits a message indicating that washing is completed, and an inquiry of whether or not the ultrasonic imaging apparatus **52** is suspended, to the display unit **39** (S**216**). The display unit **39** displays the message and the inquiry (S**217**).

[0096] The operator confirms a display of the display unit **39**. In a case where the operator suspends the ultrasonic imaging apparatus **52**, the interface **37** receives a suspension instruction by the operator (S**109**). Then, the interface **37** outputs the suspension instruction to the electronic control device **28** (S**218**). In a case where the ultrasonic imaging apparatus **52** is not to be suspended and measurement of another target **3** continues, the interface **37** receives an execution instruction for instructing execution of the process of S**102**, by the operator. Then, the interface **37** outputs the execution instruction to the electronic control device **28**.

[0097] The electronic control device **28** which has received the suspension instruction controls the material circulation unit **20** and the material circulation unit **27** to drain the ultrasonic propagation material **2** in the water tank **1** and the ultrasonic propagation material **6** in the containment vessel **5**, as operation suspension processing (S**110**). The electronic control device **28** transmits a drainage instruction for instructing drainage of the ultrasonic propagation materials **6** and **2**, to each of the material circulation unit **20** and the material circulation unit **27** (S**219-1** and S**219-2**).

[0098] The material circulation unit **20** and the material circulation unit **27** which have received the drainage instruction perform drainage of the ultrasonic propagation materials **6** and **2**, respectively (S**220** and S**221**). If the drainage is completed, each of the material circulation unit **20** and the material circulation unit **27** transmits a drainage completion report to the electronic control device **28** (S**222** and S**223**). The electronic control device **28** which has received the drainage completion report transmits a message indicating an operation of the ultrasonic imaging apparatus **52** is suspended, to the display unit **39** (S**224**). The display unit **39** displays the message (S**225**), and the processing is ended.

[0099] FIG. **5** is a flowchart illustrating an example of an overall flow of an operation of the control unit. The control unit **35** determines whether or not the start instruction is provided, based on a determination of whether the start instruction is received from the interface **37** (S**301**). The control unit **35** may determine that the start instruction is provided, by applying power to the ultrasonic imaging apparatus **52**. In a case where the start instruction is not provided (No in S**301**), the control unit **35** determines whether or not the start instruction is provided, again. In a case where the start instruction is provided (Yes in S**301**), the control unit **35** performs measurement preparation processing (S**302** and S**303**).

[0100] The control unit **35** performs material control processing in which the material circulation units **27** and **20** are filled with the ultrasonic propagation materials **2** and **6** and the states (such as the temperature, filling conditions and the like) of the ultrasonic propagation materials **2** and **6** are controlled (S**302**). Details of S**302** will be described later with reference to FIG. **6**. The control unit **35** transmits a measurement-unit moving instruction to the driving device **14** and moves the measurement unit **49** to the measurement initial position (S**113**). The control unit **35** determines whether or not a moving completion report is provided, based on a determination of whether the moving completion report is received from the driving device **14** (S**403**). In a case where the moving completion report is not provided (No in S**403**), the control unit **35** determines whether or not the moving completion report is provided, again. In a case where the moving completion report is provided (Yes in S**403**), the control unit **35** transmits an installation instruction of the target **3** to the display unit **39** (S**303**).

[0101] Then, the control unit **35** determines whether or not a measurement start instruction is provided, based on a determination of whether the measurement start instruction is received from the interface **37** (S**304**). In a case where the measurement start instruction is not provided (No in S**304**), the control unit **35** determines whether or not the measurement start instruction is provided, again. In a case where the measurement start instruction is provided (Yes in S**304**), the control unit **35** performs measurement execution processing (S**305**). Details of S**305** will be described later with reference to FIG. **7**.

[0102] The control unit **35** determines whether or not the measurement is ended, based on a determination of whether a remeasurement instruction is received from the interface **37** (S**306**). In a case where the remeasurement instruction is provided (No in S**304**), the control unit **35** performs the process of S**304** again. In a case where the remeasurement instruction is not provided (Yes in S**304**), the control unit **35** determines whether or not a washing start instruction is provided, based on a determination of whether the washing start instruction is received from the interface **37** (S**307**). In a case where the washing start instruction is not provided (No in S**307**), the control unit **35** determines whether or not the washing start instruction is provided, again. In a case where the washing start instruction is provided (Yes in S**307**), the control unit **35** performs washing processing of the inside of the water tank (S**308**). Specifically, corresponding to the process of S**108** in FIG. **4**, the control unit **35** transmits a washing instruction to the material circulation unit **27**. After washing of the water tank **1** is completed by the material circulation unit **27**, the control unit **35** receives a washing completion report from the material circulation unit **27** and transmits a message indicating washing is completed, and an inquiry of whether or not the ultrasonic imaging apparatus **52** is suspended, to the display unit **39**.

[0103] The control unit **35** determines whether or not a suspension instruction is provided, based on a determination of whether the suspension instruction is received from the interface **37** (S**309**). In a case where the suspension instruction is not provided (No in S**309**), the control unit **35** performs the process of S**302** again. In a case where the suspension instruction is provided (Yes in S**309**), the control unit **35** performs drainage processing of the ultrasonic propagation material (S**310**). Specifically, corresponding to the process of S**110** in FIG. **4**, the control unit **35** transmits a drainage instruction to the material circulation units **20** and **27**. After drainage of the ultrasonic propagation materials **6** and **2** is respectively completed by the material circulation units **20** and **27**, the control unit **35** receives a drainage completion report from each of the material circulation units **20** and **27**, and transmits a message indicating that an operation of the ultrasonic imaging apparatus **52** is suspended, to the display unit **39**.

[0104] FIG. **6** is a flowchart illustrating an example of details of the material control processing by the control unit.

[0105] Firstly, the control unit **35** transmits filling instructions as material unit control instructions to the material circulation units **27** and **20**, respectively (S**401**). The filling instructions are an instruction to fill the water tank **1** with the ultrasonic propagation material **2** and an instruction to fill the containment vessel **5** with the ultrasonic propagation material **6**.

[0106] Then, the control unit **35** detects a liquid level of the ultrasonic propagation material **2** in the water tank **1** and a liquid level of the ultrasonic propagation material **6** in the containment vessel **5** (S**116**). That is, the control unit **35** detects whether or not there are the liquid levels of the ultrasonic propagation materials **2** and **6**.

[0107] Regarding the ultrasonic propagation material **2**, the control unit **35** detects the liquid level of the ultrasonic propagation material **2** by using a liquid level sensor which is installed in the vicinity of the opening portion of the water tank **1** although not illustrated. Regarding the ultrasonic propagation material **6**, the control unit **35** detects the liquid level of the ultrasonic propagation material **6** by using the liquid level sensor **19**. The amounts of the ultrasonic propagation materials **2** and **6** which have been respectively injected into the water tank **1** and the containment vessel **5** may be recognized by using a flowmeter and the recognized amount may be compared to the amount corresponding to a desired liquid level.

[0108] Then, the control unit **35** determines whether or not a detection result of each of the liquid levels corresponds to a predetermined liquid level (S**117**). Ina case where the liquid level is not detected in S**116**, this case means that the liquid level of the material does not reach the predetermined liquid level. In this case (No in S**117**), the control unit **35** controls the liquid quantity (S**118**). Specifically, the control unit **35** transmits a liquid quantity control instruction as a material unit control instruction to the material circulation unit **27** or the material circulation unit **20**, and continues injection of the ultrasonic propagation material **2** or **6** (S**118**). In a case where detection of the liquid level of the ultrasonic propagation material **6** is not possible even though a predetermined time waits, there is a probability of the liquid-tight structure **9** having a problem or the like. Thus, the control unit **35** may notify the operator of the message indicating that there is a probability of the liquid-tight structure **9** having a problem, by using an alert or the like.

[0109] In a case where the liquid level is detected in S**116**, this case means that the liquid level reaches a predetermined liquid level. In this case (Yes in S**117**), then, the control unit **35** detects the temperature of each of the ultrasonic propagation materials **2** and **6** (S**119**). A temperature sensor (not illustrated) or the like is provided on the bottom surface of the water tank **1**, and thus the control unit **35** detects the temperature of the ultrasonic propagation material **2** in the water tank **1**. The control unit **35** detects the temperature of the ultrasonic propagation material **6** in the containment vessel **5** by the temperature sensor **18**.

[0110] Then, the control unit **35** determines whether or not the detected temperature is in a predetermined temperature range (S**120**). In a case where the detected temperature is not in the predetermined temperature range (No in S**120**), temperature control is performed (S**121**) . Specifically, the control unit **35** transmits a temperature control instruction as the material unit control instruction to the material circulation unit **20**, and controls the temperature control device **23** to heat or cool the ultrasonic propagation material **6**. The above descriptions are similarly applied to a case of the ultrasonic propagation material **2**. The control unit **35** transmits a temperature control instruction as the material unit control instruction to the material circulation unit **27**, and controls a temperature control device (not illustrated) in the material circulation unit **27** to heat or cool the ultrasonic propagation material **2**.

[0111] For example, in a case where the temperature of the ultrasonic propagation material **2** in the containment vessel **5** is held to be 37 degrees which is substantially equal to the body temperature of a person, the temperature is controlled as follows. Heat of the ultrasonic propagation material **2** in the containment vessel **5** propagates to the containment vessel **5**, the water tank **1**, the hose **7**, and the like and is diffused to the peripherals. In a case where the measurement target is a person, since the ultrasonic imaging apparatus **52** is installed in a space having a temperature (for example, pleasant temperature of about 25 degrees) which is lower than 37 degrees, the temperature of the ultrasonic propagation material **2** in the containment vessel **5** is decreased over time.

[0112] The temperature control device **23** continuously heats the ultrasonic propagation material **2** in the material reservoir **21** to be about 37 degrees, such that the temperature of the ultrasonic propagation material **2**, which is detected by the temperature sensor **18** is decreased from 37 degrees by a predetermined value or greater. If the temperature of the ultrasonic propagation material **2** is increased from 37 degrees by a predetermined value or greater, due to a certain cause, the ultrasonic propagation material **2** in the material reservoir **21** is cooled to be about 37 degrees by the temperature control device **23**. The above descriptions are similarly applied to a case of the ultrasonic propagation material **2** in the water tank **1**. The ultrasonic propagation material **2** in the material circulation unit **27** is continuously heated to be about 37 degrees by the temperature control device which is provided in the material circulation unit **27** although not illustrated, so as to compensate for heat which propagates to the opening portion at the upper portion of the water tank **1** or the wall thereof, the hose **8**, the target **3**, and the like.

[0113] In a case where the detected temperature is in the predetermined temperature range (Yes in S**120**), then, the control unit **35** detects dissolved oxygen concentration in the ultrasonic propagation material for each of the ultrasonic propagation materials **2** and **6** (S**122**). The control unit **35** detects the dissolved oxygen concentration for each of the ultrasonic motorized members **2** and **6** by using a dissolved oxygen concentration meter (not illustrated) disposed at a position which is similar to that of the temperature sensor. Then, the control unit **35** determines whether or not the detected dissolved oxygen concentration is equal to or smaller than predetermined dissolved oxygen concentration (S**123**). In a case where the detected dissolved oxygen concentration is higher than the predetermined dissolved oxygen concentration (No in S**123**), degassing continues (S**124**).

[0114] Specifically, the control unit **35** transmits a degassing instruction as the material unit control instruction to the material circulation unit **20**. The control unit **35** performs degassing of the ultrasonic propagation material **6** by causing the ultrasonic propagation material **6** to pass through the degassing device **24**. The above descriptions are similarly applied to a case of the ultrasonic propagation material **2**. The control unit **35** transmits the degassing instruction as the material unit control instruction to the material circulation unit **27**. The control unit **35** performs degassing of the ultrasonic propagation material **2** by causing the ultrasonic propagation material **2** to pass through a degassing device (not illustrated) in the material circulation unit **27**.

[0115] In a case where the detected dissolved oxygen concentration is equal to or smaller than the predetermined dissolved oxygen concentration (Yes in S**123**), since each of the ultrasonic propagation materials **2** and **6** is managed to be in a predetermined state, measurement can start. Therefore, the control unit **35** determines whether or not a preparation completion report is provided, based on a determination of whether the preparation completion report is received from each of the material circulation units **20** and **27** (S**402**). In a case where the preparation completion report is not provided (No in S**402**), the control unit **35** determines whether or not the preparation completion report is provided, again. In a case where the preparation completion report is provided (Yes in S**402**), the control unit **35** ends the material control processing and causes the process to proceed to S**113**.

[0116] FIG. **6** illustrates a flow of sequentially performing liquid level position detection (S**116**), temperature detection (S**119**), and dissolved oxygen concentration detection (S**122**). However, in practice, the processes may be performed in parallel with each other. Even if the detected value is a predetermined value once, detection and control may be continuously performed until the ultrasonic imaging apparatus **52** is suspended. The measurement unit **49** is moved to the measurement initial position for the first time, and then the liquid level position, the temperature, and the dissolved oxygen concentration may be detected and controlled.

[0117] FIG. **7**A is a flowchart illustrating an example of details of the measurement execution processing by the control unit. Firstly, the control unit **35** reads the collected measurement parameters which are transmission and reception settings such as the setting of the transmission and reception unit **31** and position coordinates of the transducer **4***a,* from the storage unit **38** (S**125**). Then, the control unit **35** performs transmission setting regarding transmission of an ultrasonic wave, in the transmission and reception unit **31** which is connected to the transducer (transmission transducer) **4***a* that transmits the ultrasonic wave, and performs reception setting regarding reception of an ultrasonic wave, in the transmission and reception unit **31** which is connected to the transducer (reception transducer) **4***a* that receives the ultrasonic wave (S**126**). The settings are performed based on the measurement parameters which have been read. The control unit **35** transmits a transmission signal to the transmission transducer **4***a* via the transmission and reception unit **31** in which the transmission setting is performed in S**126**, and cause an ultrasonic signal to be transmitted from this transmission transducer **4***a* (S**127**). The control unit **35** causes the reception transducer **4***a* connected to the transmission and reception unit **31** in which the reception setting is performed in S**126**, to receive an ultrasonic signal. A reception signal is received from this reception transducer **4***a* (S**128**). The control unit **35** stores the received reception signal as reception signal data, in the storage unit **38** (S**129**).

[0118] The transmission and reception unit **31** in which the transmission setting is performed in S**126** and the transmission transducer **4***a* can transmit an ultrasonic signal, and then can receive an ultrasonic signal based on the reception setting.

[0119] Then, the control unit **35** determines whether all sets of transmission and reception settings which have been collectively read are performed, that is, whether or not the current set of the transmission and reception settings is a final set of the transmission and reception settings (S**130**). In a case where a set of the transmission and reception settings remains (No in S**130**), the control unit **35** changes the current set of the transmission and reception settings to the next set of the transmission and reception settings (S**131**). The process returns to S**126**. The control unit **35** performs the process subsequent to the process of S**126** based on the changed set of the transmission and reception settings, and thus performs transmission and reception of an ultrasonic signal.

[0120] In a case where all sets of the transmission and reception settings are performed (Yes in S**130**), the calculation unit **36** of the control unit **35** calculates the shape of the target **3** and acoustic characteristic distribution based on the reception signal data in each set of the transmission and reception settings, which has been recorded in S**129** (S**132**). At this time, the control unit **35** may store a calculation result in the storage unit **38**. The calculation of the shape and the acoustic characteristic distribution of the target **3** means, for example, that the shape is calculated by delaying and adding the reception signal data of the ultrasonic signal, and means that the acoustic characteristic distribution is calculated by using a tomography method.

[0121] After the process of S**132**, the control unit **35** determines whether or not the measurement unit **49** reaches predetermined final measurement position (S**133**). In a case where the measurement unit **49** does not reach the final measurement position (No in S**133**), the control unit **35** initializes the set of the transmission and reception settings and changes the position of the measurement unit **49** (S**134**). Specifically, the control unit **35** brings the set of the transmission and reception settings back to the first settings. The control unit **35** transmits a measurement-unit moving instruction to the driving device **14**. The control unit **35** moves the measurement unit **49** to the next measurement position by changing the position of the measurement unit **49** by a predetermined step width. The process returns to S**126**, and the processes subsequent to the process of S**126** are performed. The control unit **35** repeats transmission and reception of an ultrasonic signal by using all sets of the transmission and reception settings in the next measurement position.

[0122] In a case where the measurement unit **49** reaches the final measurement position (Yes in S**133**), this means that measurement of the target **3** is completed. Thus, the control unit **35** prepares the next measurement in a manner that the control unit **35** transmits a measurement-unit moving instruction to the driving device **14** and moves the measurement unit **49** to the measurement initial position (S**135**). The control unit **35** transmits all measurement results to the display unit **39** and causes all of the measurement results to be displayed in the display unit **39**. The control unit **35** stores data of the final measurement result in the storage unit **38** (S**136**), and ends the measurement execution processing. Then, the control unit **35** causes the process to proceed to S**306**. As the final measurement result, the three-dimensional shape of the target **3**, three-dimensional acoustic characteristic distribution, and the like are provided.

[0123] FIG. **7**B is a flowchart illustrating a modification example of the details of the measurement execution processing by the control unit. FIG. **7**A illustrates an operation example in which transmission and reception of an ultrasonic wave and moving of the measurement unit **49** are alternately performed. However, FIG. **7**B illustrates an operation example in which transmission and reception of an ultrasonic wave and moving of the measurement unit **49** are simultaneously performed. Descriptions will be made focusing on a difference from FIG. **7**A. The same part is denoted by the same reference sign in FIG. **7**A and descriptions thereof will not be repeated.

[0124] After the process of S**125**, the control unit **35** transmits a measurement-unit moving instruction to the driving device **14** and starts moving of the measurement unit **49** (S**137**).

[0125] The moving of the measurement unit **49** is performed sufficiently slow and continuously. Thus, similar to helical scanning which is performed by an X-ray CT apparatus, it is possible to obtain a spiral ultrasonic transmission and reception result for the target **3**. Since transmission and reception of an ultrasonic wave and moving of the measurement unit **49** are simultaneously performed, it is possible to reduce a time required for measurement.

[0126] After the process of S**129**, the control unit **35** determines whether or not the measurement unit **49** reaches the final measurement position (S**133**). In a case where the measurement unit **49** does not reach the final measurement position (No in S**133**), the control unit **35** changes the current set of the transmission and reception settings to the next set of the transmission and reception settings (S**131**) and causes the process to return to S**126**. In a case where the measurement unit **49** reaches the final measurement position (Yes in S**133**), t e calculation unit **36** of the control unit **35** performs the process of S**132** so as to calculate the shape of the target **3** and acoustic characteristic distribution. After the process of S**132**, the control unit **35** performs the processes of S**135** and S**136**, and ends the measurement execution processing.

[0127] Then, calculation of the shape of the target **3** and acoustic characteristics in consideration of an ultrasonic wave propagation path of an ultrasonic signal will be described with reference to FIGS. **8** to **13**.

[0128] FIG. **8** is a diagram illustrating an ultrasonic wave propagation path of an ultrasonic signal. FIG. **8**A is a diagram illustrating an ultrasonic wave propagation path in a case where the transducer array is installed in the water tank. FIG. **8**B is a diagram illustrating an ultrasonic wave propagation path through the water tank, the ultrasonic propagation material in the water tank, and the ultrasonic propagation material in the containment vessel. FIG. **8**C is a diagram illustrating directivity of a signal delayed time of an ultrasonic signal.

[0129] In the related art, a signal delayed time from transmission until reception by using a pair of transducers **4***a* is measured. A propagation distance is calculated from a propagation speed of an ultrasonic wave, and thus position coordinates of the transducers **4***a* are estimated and corrected. If the water tank **1** into which the target **3** is inserted and the containment vessel **5** which stores the transducer array **4** are separated from each other, the ultrasonic propagation material **2** in the water tank **1**, the wall of the water tank **1**, and the ultrasonic propagation material **6** in the containment vessel **5** are provided during a period from transmission until reception by using a pair of transducers **4***a*. Thus, in the related art, it is not possible to correct the position coordinates of the transducer **4***a* with high accuracy. As a result, it is not possible to calculate the shape of the target **3** and the acoustic characteristic distribution with high accuracy. This is because an ultrasonic wave is refracted by a difference of an ultrasonic wave propagation speed or density thereof or a relationship between a propagation time and a propagation distance varies depending on a transmission angle of an ultrasonic wave.

[0130] In the configuration in FIG. **8**A, an ultrasonic signal S**21** transmitted from the transducer **4***a* installed in the water tank **1** straightly propagates in the ultrasonic propagation material **2** which has a constant sound speed and uniform density. Therefore, it can be considered that the position of the transducer **4***a* corresponds to the position of a wave source **53**.

[0131] On the contrary, in the configuration in FIG. **8**B which is the configuration of this example, an ultrasonic signal S**21** transmitted from the transducer **4***a* installed in the containment vessel **5** propagates in media having three types of sound speeds and density, that is, the ultrasonic propagation material **6**, the wall of the water tank **1**, and the ultrasonic propagation material **2**.

[0132] The ultrasonic propagation material **2** and the ultrasonic propagation material **6** can have the same composition and the same condition. However, the water tank **1** has a sound speed and density which are different from those of the ultrasonic propagation materials **2** and **6**. Accordingly, an ultrasonic signal S**21** transmitted from the transducer **4***a* is refracted and propagates at an interface between the ultrasonic propagation material **6** and the wall of the water tank **1** and at an interface between the wail of the water tank **1** and the ultrasonic propagation material **2**. The water tank **1** has a sound speed which is different from those of the ultrasonic propagation materials **2** and **6**. Thus, a propagation distance of an ultrasonic signal S**21***a* is different from propagation distances of ultrasonic signals S**21***b* and S**21***c* at the same time point. Therefore, it is necessary that it is considered that the position of the transducer **4***a* corresponds to the position of a virtual wave source **54** not the position of the wave source **53**.

[0133] Further, a distance when an ultrasonic signal S**21** passes through the wall of the water tank **1** varies depending on a propagation direction of the ultrasonic signal S**21**. Thus, the ultrasonic signal S**21** has directivity of a signal delayed time as illustrated in FIG. **8**C.

[0134] FIG. **9** is a diagram illustrating a signal propagation path of the ultrasonic imaging apparatus.

[0135] The calculation unit **36** detects a signal delayed time T**1** which is a difference between an output timing of an electric signal S**1** by the control unit **35** and an input timing of an electric signal S**41** from the reception unit **33**.

[0136] The electric signal S**1** is transmitted as the ultrasonic signal S**21** from the transducer **4***a* after a signal response time T**2** elapses after being input to the transmission unit **32**. The signal response time T**2** is determined in accordance with electric characteristics of the transmission unit **32** and electric-ultrasonic conversion characteristics of the transducer **4***a*. The ultrasonic signal S**21** transmitted from a transmission side transducer **4***a* is received in a reception side transducer **4***a* after a time elapses. The time satisfies a signal propagation time T**3** taken to propagate in the ultrasonic propagation materials **2** and **6** and the wall of the water tank **1** (propagation time on the assumption of the virtual wave source **54** and the ultrasonic propagation materials **2** and **6**) and directivity (signal delayed time based on the propagation direction of the ultrasonic signal S**21**) T**5** of the signal delayed time illustrated in FIG. **8**C.

[0137] The directivity T**5** of the signal delayed time also similarly occurs in the reception side transducer **4***a* in addition to the transmission side transducer **4***a*. The ultrasonic signal S**21** received in the reception side transducer **4***a* is output as an electric signal S**41** from the reception unit **33** to the calculation unit **36** after a signal response time T**4** elapses. The signal response time T**4** is determined in accordance with ultrasonic-electric conversion characteristics of the transducer **4***a* and electric characteristics of the reception unit **33**.

[0138] From the above descriptions, in order to accurately measure a signal propagation time T**3** and to calculate the shape of the target **3** and acoustic characteristics with high accuracy, it is necessary that a correction parameter is required. The correction parameter relates to position coordinates of the virtual transducer **4***a*, the directivity T**5** of the signal delayed time, the signal response time T**2** of the transmission unit **32**, and the signal response time T**4** of the reception unit **33**. The typical value of the correction parameter is obtained by typical electric characteristics, typical dimensions, or the like of the transmission and reception unit **31**, the transducer array **4** and the water tank **1**. However, manufacturing variations occur in the above factors. Thus, in order to calculate the shape of the target **3** and the acoustic characteristics with higher accuracy, it is necessary that a correction parameter calculation operation of the measurement unit **49** illustrated in FIG. **10** is performed in a state where the target **3** is not installed.

[0139] FIG. **10** is a flowchart illustrating an example of the correction parameter calculation operation of the measurement unit, which is performed by the control unit and in which the wall of the water tank and the ultrasonic propagation material in the containment vessel are provided. Parts which are the same as those in FIGS. **5** to **7** are denoted by the same reference signs and descriptions thereof will not be repeated.

[0140] In S302, a preparation completion report is received from each of the material circulation units **20** and **27** (Yes in S**402**), and preparation of the ultrasonic propagation material **2** in the water tank **1** and the ultrasonic propagation material **6** in the containment vessel **5** is finished. Then, the control unit **35** transmits a measurement-unit moving instruction for correction, which is used for movement to an correction initial position, to the driving device **14**, and moves the measurement unit **49** to the correction initial position (S**148**).

[0141] Then, the control unit **35** reads a correction initial parameter from the storage unit **38** (S**149**). The correction initial parameter is set to be a typical value which relates to the position coordinates of the virtual transducer **4***a*, the directivity T**5** of the signal delayed time, the signal response time T**2** of the transmission unit **32**, and the signal response time T**4** of the reception unit **33**.

[0142] Then, the control unit **35** sequentially transmits and receives an ultrasonic signal S**21** for all preset pairs of transducers **4***a*, and acquires reception signal data to be used when the signal delayed time T1 is calculated (S126 to S131). The calculation unit 36 in the control unit 35 performs correction parameter calculation processing based on the acquired reception signal data by using a least-square method or the like. In the correction parameter calculation processing, the signal delayed time T1 and the correction parameter which relates to the position coordinates of the virtual transducer 4*a*, the directivity T5 of the signal delayed time, the signal response time T2 of the transmission unit 32, and the signal response time T4 of the reception unit 33 are calculated (S150). Details of S150 will be described later with reference to FIG. 11.

[0143] After the process of S150, the control unit 35 determines whether or not the measurement unit 49 reaches the predetermined final measurement position (S133). In a case where the measurement unit 49 does not reach the final measurement position (No in S133), the control unit 35 initializes the set of the transmission and reception settings and changes the position of the measurement unit 49 (S134). The control unit 35 performs a series of operations from S126 to S150 in all measurement positions of the measurement unit 49, for all sets of transmission and reception settings.

[0144] If the calculation of the correction parameter is completed for all measurement positions of the measurement unit 49 (Yes in S133), the control unit 35 transmits a measurement-unit moving instruction to the driving device 14 and thus moves the measurement unit 49 to the measurement initial position (S135). The control unit 35 transmits the final correction result to the display unit 39, causes the final correction result to be displayed in the display unit 39, and stores data of the final correction result in the storage unit 38 (S151). The control unit 35 is in a state of waiting for reception of a measurement start instruction from the interface 37. If the control unit 35 receives the measurement start instruction, the control unit 35 performs, for example, the processes subsequent to the process of S304 (S180).

[0145] The correction parameter other than the directivity T5 of the signal delayed time is constant regardless of the position of the measurement unit 49. Thus, in S151, the position coordinates of the virtual transducer 4*a* and the signal response times T2 and T4 which are most reliable may be calculated based on correction results at all positions of the measurement unit 49 by using the least-square method in a manner similar to that in S150. Then, the position coordinates and the signal response times T2 and T4 which have been calculated may be set as the final correction parameter along with the directivity T5 of the signal delayed time.

[0146] FIG. 11 is a flowchart illustrating an example of details of the correction parameter calculation processing by the control unit . Firstly, the calculation unit 36 in the control unit 35 calculates an initial signal delayed time T1*a* by using the correction initial parameter which has been read in S149 (S152). Then, the calculation unit 36 calculates the signal delayed time T1 by using reception signal data which is an ultrasonic wave transmission and reception result for correction which has been acquired in S126 to S131 (S153). The calculation unit 36 calculates a difference between the initial signal delayed time T1*a* and the calculated signal delayed time T1 (S154). Then, the calculation unit 36 determines whether or not the square sum of the signal delayed time difference is greater than a predetermined value (S155).

[0147] In a case where the square sum is smaller than the predetermined value (No in S155), the correction initial parameter has accuracy which is sufficient as the correction parameter. Thus, the calculation unit 36 employs the correction initial parameter as the correction parameter, and ends calculation of the correction parameter. Then, the process proceeds to S133. In a case where the square sum is greater than the predetermined value (Yes in S155), the correction initial parameter does not have accuracy which is sufficient as the correction parameter. Thus, the calculation unit 36 causes the process to proceed to steps subsequent to the process of S156. Thus, the calculation unit 36 calculates a more suitable parameter, and updates the calculated parameter as the correction parameter.

[0148] Firstly, in S156, the calculation unit 36 obtains an average value of differences between the initial signal delayed time T1*a* and the calculated signal delayed time T1 for pairs of transducers 4*a*. The calculation unit 36 calculates the directivity T5 of the signal delayed time as a tendency of the entirety of the transducer array 4, and updates the calculated directivity T5 as the correction Parameter (S156). The calculation unit 36 calculates the signal delayed time T1*a* by using the updated correction parameter instead of the correction initial parameter, and thus obtains a difference between the signal delayed time T1*a* and the calculated signal delayed time T1. The calculation unit 36 calculates virtual position coordinates of a specific transducer 4*a*, which cause the square sum of the difference between the signal delayed time T1 and the signal delayed time T1*a* calculated by using the updated correction parameter to be smallest. Then, the calculation unit 36 updates the correction parameter (S157). Then, the calculation unit 36 calculates the signal delayed time T1*a* again by using the updated correction parameter. The calculation unit 36 calculates virtual signal response times T2 and T4 for the same transducer 4*a*, which cause the square sum of the difference between the signal delayed time T1*a* and the signal delayed time T1 to be smallest. Then, the calculation unit 36 updates the correction parameter (S158).

[0149] The calculation unit 36 performs calculations in S157 and S158 and update of the correction parameter for all transducers 4*a*. The calculation unit 36 determines whether or not the calculation is ended (S159). In a case where there is a transducer 4*a* for which the above processes are not performed yet (No in S159), the calculation unit 36 changes a transducer 4*a* as the target (S160) and causes the process to return to S157. Then, the calculation unit 36 performs the processes of S157 and S158.

[0150] In a case where the calculation for all of the transducers is ended (Yes in S159), the calculation unit 36 calculates a difference between the signal delayed time T1*a* calculated from a calculation result, and the calculated signal delayed time T1 (S161). Similar to S156, the calculation unit 36 calculates the directivity T5 of the signal delayed time as the tendency of the entirety of the transducer array 4, and updates the calculated directivity T5 as the correction parameter (S181).

[0151] The calculation unit 36 determines whether or not the calculation in S181 and update of the correction parameter are performed a predetermined number of times (S162). In a case where the above processes are not performed the predetermined number of times (No in S162), the process returns to S155 and the processes subsequent to S155 are performed. In a case where the above processes are performed the predetermined number of times (Yes in S**162**), the calculation unit **36** ends the calculation of the correction parameter and causes the process to proceed to S**133**. As described above, even in a case where the transducer array **4** is disposed on the outside of the water tank **1**, it is possible to calculate the shape of the target **3** and the acoustic characteristic distribution with higher accuracy by calculating and updating the correction parameter.

[0152] FIG. **12** is an example of a flowchart illustrating a modification example of the correction parameter calculation operation of the measurement unit which includes the wall of the water tank and the ultrasonic propagation material in the containment vessel. The correction parameter calculation operation is performed by the control unit. In this flowchart, another operation and determination are added to the operations of S**126** to S**129** in FIG. **10**, and thus it is detected whether or not bubbles are provided in the ultrasonic propagation material **6** in the containment vessel **5** or on the wall surface of the water tank **1**. In a case where bubbles are detected, the bubbles are removed and then correction is performed again. Descriptions will be made focusing on a difference from FIG. **10**.

[0153] After the process of S**149**, the calculation unit **36** determines whether or not the final reception setting is completed for one transmission setting which has been performed in the previous processes of S**126** to S**129**, that is, whether or not all reception settings are completed for one transmission setting (S**163**). After all of the reception settings are completed for one transmission setting (Yes in S**163**), the calculation unit **36** calculates reception signal intensity distribution for the transmission setting (S**164**). Here, all of the reception settings for one transmission setting means, for example, a case where one specific transducer **4***a* is set as the transmission side transducer **4***a* and all the remaining transducers **4***a* are set as the reception side transducers **4***a*.

[0154] The calculation unit **36** determines whether or not the calculated reception signal intensity distribution is in a range of predetermined distribution (S**165**). In a case where the calculated reception signal intensity distribution is in the range of predetermined distribution (Yes in S**165**), the process proceeds to S**130** in FIG. **10**. In a case where the reception signal intensity distribution is not in the range of the predetermined distribution (No in S**165**), the calculation unit **36** determines whether this state is repeated a predetermined number of times, that is, the reception signal intensity distribution is not in the range of the predetermined distribution for the predetermined number of times (S**166**). In a case where it is determined that this state is repeated the predetermined number of times (Yes in S**166**), the transducer array **4** or the water tank **1** is broken or a situation in which bubbles of which removal is not possible are provided occurs. Thus, the calculation unit **36** displays an alert in the display unit **39** (S**168**). If the number of times of repeating does not reach the predetermined number of times (No in S**166**), there is a probability of bubbles being provided on the wall of the water tank **1** or in the ultrasonic propagation material **6**. Thus, the control unit **35** moves the measurement unit **49** up or down, and attempts to remove bubbles by causing the wall of the water tank **1** to be rubbed on the hole structure **10** or the liquid-tight structure **9**. Then, the control unit **35** brings the measurement unit **49** back to the original position (S**167**). After such processes are performed, the control unit **35** performs the process of S**126** to S**129** regarding transmission and reception of an ultrasonic wave, again. Thus, it is possible to avoid an occurrence of a situation in which an erroneous correction parameter is set due to the presence of bubbles. As a result, it is possible to measure the target **3** with higher accuracy.

[0155] FIG. **13** illustrates an example of the predetermined distribution in S**165** in FIG. **12**. FIG. **13**A illustrates distribution in which bubbles are not provided on the wall of the water tank **1** or in the ultrasonic propagation material **6**, but variation in reception signal intensity is shown by manufacturing variation of the transmission and reception unit **31** or the transducer **4***a*. The reception signal intensity is provided in a range indicated by a dot line. On the contrary, in a case where bubbles are provided on the wall of the water tank **1** or in the ultrasonic propagation material **6**, a state like FIGS. **13**B, **13**C, and **13**D occurs.

[0156] FIG. **13**B illustrates a case where bubbles are provided at a Position which is very close to the transmission side transducer **4***a*. The ultrasonic signal S**21** transmitted from the transmission side transducer **4***a* is scattered at almost angles by bubbles, and thus the reception signal intensity is significantly decreased. FIG. **13**C illustrates a case where bubbles are provided at a position which is very close to a specific reception side transducer **4***a*. In this case, the reception signal intensity is significantly decreased only at an angle corresponding to the specific reception side transducer **4***a*. FIG. **13**D illustrates a case where many fine bubbles are provided in the ultrasonic propagation material **6** or the ultrasonic propagation material **2**. In this case, variation in reception signal intensity occurs significantly largely depending on the angle. As described above, the distribution of the reception signal intensity is determined, and thus it is possible to estimate whether or not bubbles are provided.

[0157] FIG. **14** is a diagram illustrating a modification example of the measurement unit and the material circulation unit configured to circulate the ultrasonic propagation material in the measurement unit. In FIG. **14**, the illustration of the position detection sensor **17** is omitted.

[0158] FIG. **14**A illustrates a configuration in which a liquid level sensor **40** different from the liquid level sensor **19** is installed on the outside of the wall on the upper surface of the containment vessel **5**, and a material circulation unit **41** in which a valve **42** is provided at the hose **7** connected to the upper portion of the containment vessel **5** is provided, in comparison to FIG. **2**D.

[0159] FIG. **14**B illustrates a configuration in which the liquid level sensor **40** different from the liquid level sensor **19** is installed on the outside of the wall on the upper surface of the containment vessel **5** and a material circulation unit **43** is provided, in comparison to FIG. **2**D. In the material circulation unit **43**, a pump **22** and a degassing device **24** are installed on the hose **7** connected to the upper portion of the containment vessel **5** so as to cause the ultrasonic propagation material **6** to flow in the containment vessel **5**, a valve **42** is installed on the hose **7** connected to the lower portion of the containment vessel **5** so as to cause the ultrasonic propagation material **6** to flow out to the material reservoir **21**.

[0160] With the configuration in FIG. **14**A or FIG. **14**B, the control unit **35** can detect the ultrasonic propagation material **6** which remains on the upper surface of the containment vessel **5**, by the liquid level sensor **40**. The control unit **35** can control the valve **42** so as to control the amount of the ultrasonic propagation material **6** such that the ultrasonic propagation material **6** does not overflow.

[0161] FIG. **15** is a flowchart illustrating an operation example of the control unit in which control is performed so as to cause the ultrasonic propagation material remaining on the upper surface of the containment vessel not to overflow in the configuration illustrated in FIG. **14**.

[0162] Firstly, the control unit **35** confirms outputs of the liquid level sensors **19** and **40** (S**138**). The control unit **35** detects whether or not the liquid level of the ultrasonic propagation material **6** is lower than an upper limit liquid level at which the ultrasonic propagation material **6** does not overflow from the upper surface of the containment vessel **5**. The detection is performed based on the output of the liquid level sensor **40** (S**139**). In a case where the liquid level thereof is lower than the upper limit liquid level (Yes in S**139**), the control unit **35** detects whether or not the liquid level of the ultrasonic propagation material **6** is higher than a lower limit liquid level suitable for measurement, based on the output of the liquid level sensor **19** (S**140**). In a case where the liquid level thereof is higher than the lower limit liquid level (Yes in S**140**), the control unit **35** ends this control because the liquid level of the ultrasonic propagation material **6** is in a desired range. The control unit **35** repeats the control in FIG. **15** at a predetermined cycle during the measurement preparation processing and during the measurement execution processing.

[0163] In a case where the liquid level thereof is higher than the upper limit liquid level in S**139** (No in S**139**), or in a case where the liquid level thereof is lower than the lower limit liquid level in S**140** (No in S**140**), the control unit **35** stores a period when the state continues, in the storage unit **38**. The control unit **35** determines whether or not the state continues during a predetermined period or for a predetermined number of times (S**141**).

[0164] In a case where the state of No in S**139** or No in S**140** continues during the predetermined period or for the predetermined number of times (Yes in S**141**), the control unit **35** outputs an alert to the display unit **39** because there is a probability of an occurrence of abnormality in the measurement unit **49**, the material circulation units **41** or **43**, the hose **7**, or the like. For example, a portion of the measurement unit **49** or the hose **7** is broken and thus liquid leakage is caused. Thus, for example, the liquid level of the ultrasonic propagation material **6** is required to be higher than the lower limit liquid level. In a case where the period is shorter than the predetermined period or the number of times is smaller than the number of times of determinations in S**141** (No in S**141**), the control unit **35** transmits a material unit control instruction to the material circulation units **41** and **43**. The control unit **35** controls the pump **22** to control the inflow amount of the ultrasonic propagation material **6** into the containment vessel **5** or controls the valve **42** to control the outflow amount of the ultrasonic propagation material **6** from the containment vessel **5**. Then, the control unit **35** performs the process of S**138** again, and confirms the liquid level of the ultrasonic propagation material **6**.

[0165] With the configuration in FIGS. **14** and **15**, the transducer array **4** can be managed such that the liquid level of the ultrasonic propagation material **6** is maintained to have a position which is appropriately for the position of the transducer array **4**. It can be detected whether or not abnormality occurs in the measurement unit **49**, the hose **7**, the material circulation units **41** and **43**, or the like. Thus, it is possible to secure certainty of the measurement result.

[0166] FIG. **16** is a diagram illustrating another modification example of the measurement unit and the material circulation unit configured to circulate the ultrasonic propagation material in the measurement unit. In FIG. **16**, the illustration of the position detection sensor **17** is omitted. FIG. **16**A illustrates a configuration of including a material circulation unit **44** in which a flowmeter **45** is installed on the hose **7** connected to the upper portion of the containment vessel **5** and a flowmeter **45** is installed on the hose **7** connected to the lower portion of the containment vessel **5**, in comparison to FIG. **14**A. FIG. **16**B illustrates a configuration of including a material circulation unit **46** in which a flowmeter **45** is installed on the hose **7** connected to the upper portion of the containment vessel **5** and a flowmeter **45** is installed on the hose **7** connected to the lower portion of the containment vessel **5**, in comparison to FIG. **14**B. With the configuration in FIG. **16**A or FIG. **16**B, it is possible to manage the inflow amount and the outflow amount of the ultrasonic propagation material **6** into and from the containment vessel **5**. It is possible to fill the containment vessel **5** with the appropriate amount of the ultrasonic propagation material **6** while it is detected whether or not liquid leakage of the ultrasonic propagation material occurs. The flow in FIG. **15** can be also applied to the configuration in FIG. **16**.

[0167] FIG. **17** is a flowchart illustrating an operation example of the control unit that detects whether or not liquid leakage of the ultrasonic propagation material occurs in the containment vessel or the hose in the configuration illustrated in FIG. **16**. The control unit **35** repeats the control in FIG. **17** during the measurement preparation processing and during the measurement execution processing.

[0168] Firstly, the control unit **35** confirms outputs of the two flowmeters **45** (S**144**). Then, the control unit **35** determines whether or not the inflow amount of the ultrasonic propagation material **6** into the containment vessel **5** is greater than the outflow amount of the ultrasonic propagation material **6** from the containment vessel **5** by a predetermined value (S**145**). In a case where the inflow amount thereof is greater than the outflow amount thereof (Yes in S**145**), there is a probability of the ultrasonic propagation material **6** being leaked in any of the containment vessel **5** and the hose **7**. In this case, the control unit **35** stores a period when this state continues, in the storage unit **38**. The control unit **35** determines whether or not the state continues during a predetermined period or for a predetermined number of times (S**146**). In a case where the state of Yes in S**145** continues during the predetermined period or for the predetermined number of times (Yes in S**146**), the control unit **35** displays an alert in the display unit **39** (S**147**).

[0169] If it is determined to be No (No in S**145** and No in S**146**) in any of S**145** and S**146**, it is considered that no leakage of the ultrasonic propagation material **6** occurs in the hose **7** or the containment vessel **5** or leakage thereof occurs temporarily via the liquid-tight structure **9** with moving the measurement unit **49** up and down. Thus, there is no problem. The ultrasonic propagation material **6** leaked from the liquid-tight structure **9** can be collected by the material receiving tray **48**. Thus, if the amount of the leaked ultrasonic propagation material **6** is small and the leakage thereof occurs temporarily, there is no problem on an operation of the ultrasonic imaging apparatus **52**.

[0170] With the configuration in FIGS. **16** and **17**, it is possible to perform management such that the liquid level of the ultrasonic Propagation material **6** is maintained to be at a position which is suitable with respect to the transducer array **4**. It can be detected whether or not the ultrasonic propagation material **6** is leaked from the measurement unit **49** or the hose **7**. Thus, it is possible to secure certainty of the measurement result.

[0171] FIG. **18** is a diagram illustrating a modification example of the containment vessel. In this modification example, a portion of the side wall of the containment vessel **5** is a stretchable wall **47** which can be stretched. FIG. **18**A illustrates a state where the stretchable wall **47** is retracted. FIG. **18**B illustrates a state where the stretchable wall **47** is stretched. As described above, the portion of the side wall of the containment vessel **5** is a stretchable wall **47** is configured to be the stretchable wall **47**, and thus a configuration in which the lower surface of the containment vessel **5** does not move up and down and the liquid-tight structure **9** is not required is made. The signal wiring **11** is disposed on the side wall other than the stretchable wall **47** or is disposed at the fitting portions **13** and **16**. Thus, the signal wiring **11** does not disturb motion of the stretchable wall **47**. Other components are similar to those in FIG. **2**A. With this configuration, the volume of the containment vessel **5** is changed in accordance with the position of the transducer array **4**, and thus the amount of the required ultrasonic propagation material **6** is also changed. However, the liquid-tight structure **9** is not required and the material receiving tray **48** is also not required. The change of the volume of the containment vessel **5** can be solved by setting the volume of the material reservoir **21** to be sufficient.

[0172] As a modification example of the measurement unit **49**, a wall may be provided between the hole structure **10** and the liquid-tight structure **9**, and thus the ultrasonic propagation material **6** may be caused not to directly come into contact with the side wall of the water tank **1**. In this case, a third ultrasonic propagation material may be provided between the side wall of the water tank **1** and the measurement unit **49**, and acoustic impedance of the paths may match with each other.

[0173] According to the above configurations, since the transducer array **4** is installed on the outside of the water tank **1**, and the measurement unit **49** which includes the transducer array **4** and the ultrasonic propagation material **6** moves up and down along the side wall of the water tank **1**, it is possible to three-dimensionally measure a target. Since the amount of the ultrasonic propagation material **6** in the containment vessel **5** is reduced, maintenance management of the ultrasonic propagation material **6** is easily performed. It is possible to treat the ultrasonic propagation material **6** with high accuracy, and to obtain the shape of a target **3** and acoustic characteristics in a wide range which is close to the vicinity of the opening portion of the water tank **1**.

REFERENCE SIGNS LIST

[0174] **1** water tank
[0175] **2**, **6** ultrasonic propagation material
[0176] **3** measurement target
[0177] **4** transducer array
[0178] **5** containment vessel
[0179] **9** liquid-tight structure
[0180] **10** bubble removal mechanism
[0181] **12** stage
[0182] **13**, **16** fitting portion
[0183] **14** driving device
[0184] **15** guide rail
[0185] **20**, **27** material circulation unit
[0186] **21** material reservoir
[0187] **28** electronic control device
[0188] **31** transmission and reception unit
[0189] **35** control unit
[0190] **47** stretchable wall
[0191] **48** material receiving tray
[0192] **49** measurement unit
[0193] **50** main apparatus
[0194] **51** screw structure
[0195] **53** wave source
[0196] **54** virtual wave source

1. An ultrasonic signal processing apparatus comprising:
a water tank which has an opening portion;
a measurement unit which includes a transducer array configured to transmit and receive an ultrasonic signal and a space which is filled with a material for propagating the ultrasonic signal, is disposed on an outside of the water tank, and is configured to measure the ultrasonic signal; and
a moving unit which is connected to the measurement unit and moves the measurement unit between the opening portion and a bottom portion of the water tank, along a side wall of the water tank.

9. The ultrasonic signal processing apparatus according to claim **1**, further comprising:
a material circulation unit that circulates the material,
wherein a circulation direction of the material is directed from a lower portion of the measurement unit to an upper portion thereof.

3. The ultrasonic signal processing apparatus according to claim **2**,
wherein the measurement unit has a liquid-tight structure between the water tank and a wall of the measurement unit on a lower surface which is a bottom portion side of the water tank, and
the ultrasonic signal processing apparatus further comprises a tray for collecting and receiving the material which is leaked from the liquid-tight structure.

4. The ultrasonic signal processing apparatus according to claim **2**, further comprising:
a support unit which is disposed at a position which faces the side wall of the water tank and is configured to support movement of the measurement unit, which is performed by the moving unit.

5. The ultrasonic signal processing apparatus according to claim **1**,
wherein a wall of the measurement unit on an upper surface which is the opening portion side of the water tank is thinner than the wall of the measurement unit on a lower surface thereof which is a bottom side of the water tank.

6. The ultrasonic signal processing apparatus according to claim **5**,
wherein the wall on the upper surface has a ventilation structure for causing a gas in the measurement unit to pass therethrough.

7. The ultrasonic signal processing apparatus according to claim **6**,
wherein the ventilation structure is in contact with the water tank.

8. The ultrasonic signal processing apparatus according to claim **6**,

wherein the ventilation structure is a foam structure having elasticity or a brush structure.

9. The ultrasonic signal processing apparatus according to claim **6**,

wherein the ventilation structure is a structure into which the material is permeated.

10. An ultrasonic imaging apparatus which transmits and receives an ultrasonic signal to and from a measurement target and captures an image of the measurement target, the apparatus comprising:

an ultrasonic signal processing apparatus that transmits and receives the ultrasonic signal to and from the measurement target and processes the received ultrasonic signal; and

a control device that controls the ultrasonic signal processing apparatus and calculates a shape of the measurement target or acoustic characteristics based on the ultrasonic signal which has been received by the ultrasonic signal processing apparatus,

wherein the ultrasonic signal processing apparatus is the ultrasonic signal processing apparatus according to claim **1**, and

the control device calculates a shape of the measurement target or acoustic characteristics by using a correction parameter which reflects a difference of a sound speed of the ultrasonic signal between the water tank, the material in the water tank, and the material in the measurement unit.

11. The ultrasonic imaging apparatus according to claim **10**,

wherein the correction parameter includes virtual position coordinates of a transducer constituting the transducer array, a signal response time between a transmission unit configured to transmit the ultrasonic signal and a transmission-side transducer, a signal response time between a reception unit configured to receive the ultrasonic signal and a reception-side transducer, and directivity regarding a signal delayed time in the virtual transducer.

12. The ultrasonic imaging apparatus according to claim **11**,

wherein the control device acquires signal intensity distribution of the ultrasonic signal received by the ultrasonic signal processing apparatus, determines whether or not bubbles are provided in the material, based on the signal intensity distribution, and calculates the correction parameter based on a determination result.

13. A control method in an ultrasonic signal processing apparatus which includes a water tank having an opening portion and processes an ultrasonic signal which is transmitted and received to and from an inside of the water tank, the method comprising:

moving a measurement unit which is disposed on an outside of the water tank, includes a transducer array for transmitting and receiving the ultrasonic signal and a space which is filled with a material for propagating the ultrasonic signal, and measures the ultrasonic signal, between the opening portion and a bottom portion of the water tank along a side wall of the water tank.

* * * * *

patsnap

专利名称(译)	超声波信号处理装置，使用其的超声波成像装置以及超声波信号处理装置中的控制方法
公开(公告)号	US20180140273A1
公开(公告)日	2018-05-24
申请号	US15/819856
申请日	2017-11-21
[标]申请(专利权)人(译)	株式会社日立制作所
申请(专利权)人(译)	HITACHI，LTD.
当前申请(专利权)人(译)	株式会社日立制作.
[标]发明人	TERADA TAKAHIDE KAWABATA KENICHI SUZUKI ATSUROU TSUBOTA YUSHI WU WENJING YAMANAKA KAZUHIRO
发明人	TERADA, TAKAHIDE KAWABATA, KENICHI SUZUKI, ATSUROU TSUBOTA, YUSHI WU, WENJING YAMANAKA, KAZUHIRO
IPC分类号	A61B8/00 G01S15/89 A61B8/08
CPC分类号	A61B8/4281 G01S15/8922 A61B8/0825 A61B8/406 A61B8/4483 A61B8/15 A61B8/5207 A61B8/54 G01S15/894
优先权	2016226402 2016-11-22 JP
外部链接	Espacenet USPTO

摘要(译)

提供一种超声波信号处理装置，其中减小了存储换能器阵列的测量单元中的超声波传播材料的量，同时换能器阵列和目标彼此分离，因此超声波传播材料的维护是容易管理。 超声波信号处理装置包括具有开口部分的水箱，测量单元和移动单元。设置在水箱外部的测量单元包括：发送和接收超声波信号的换能器阵列;以及填充有用于传播超声信号的材料的空间，并测量超声信号。移动单元连接到测量单元，并使测量单元沿着其侧壁在水箱的开口部分和底部之间移动。