

United States Patent [19]

Takemura

[11] 3,927,661

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[54] **ULTRASONIC WAVE DIAGNOSIS
APPARATUS WITH
GALVANOMETER-DRIVEN PROBE**[75] Inventor: **Yasuhiko Takemura**, Yokohama,
Japan[73] Assignee: **Tokyo Shibaura Denki Kabushiki
Kaisha**, Kanagawa, Japan[22] Filed: **Oct. 11, 1974**[21] Appl. No.: **514,181**[30] **Foreign Application Priority Data**

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Oct. 15, 1973	Japan	48-119735[U]
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128/24 A[51] **Int. Cl.²**..... **A61B 5/00**[58] **Field of Search**..... 128/2 V, 2.05 Z, 24 A;
73/67.8 S

[56]

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Primary Examiner—William E. Kamm*Attorney, Agent, or Firm*—Stevens, Davis, Miller &
Mosher

[57]

ABSTRACT

In a ultrasonic wave diagnosis apparatus wherein a probe for transmitting and receiving ultrasonic wave to and from a portion of a patient to be diagnosed is scanned in a sector shape, the probe is driven at a uniform speed by a galvanometer energized by the output of a triangular wave generator. The probe is immersed in electric insulating acoustic medium having a relatively large viscosity and high transmission loss.

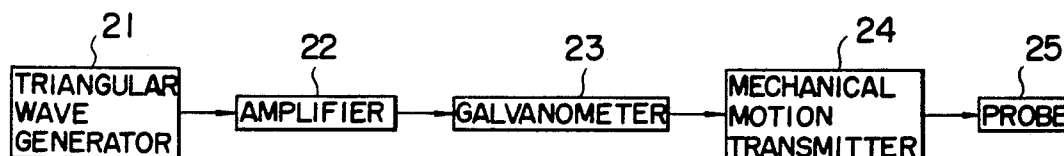
10 Claims, 9 Drawing Figures

FIG. 1
PRIOR ART

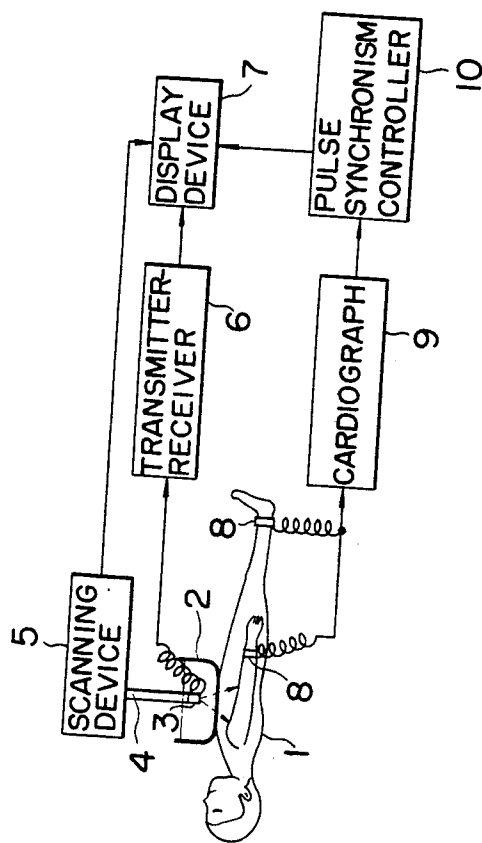


FIG. 2

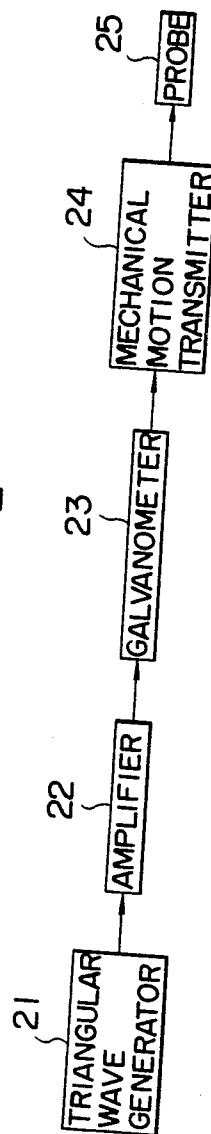


FIG. 3

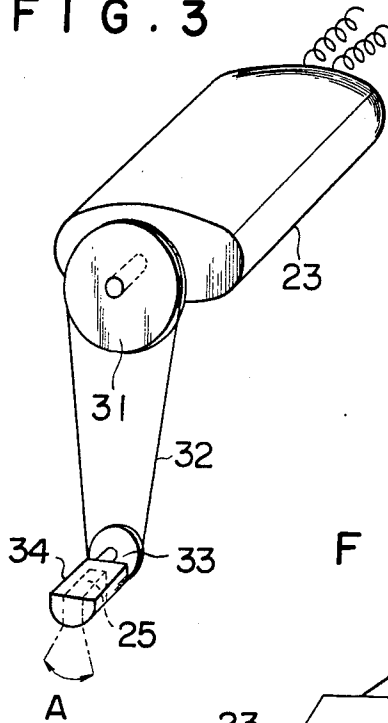


FIG. 4

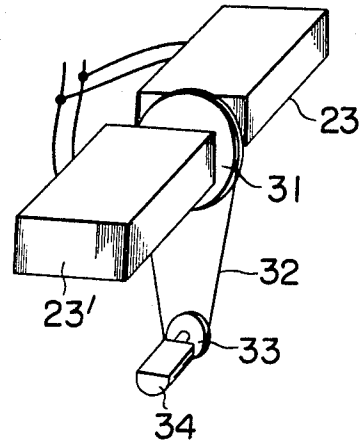


FIG. 5

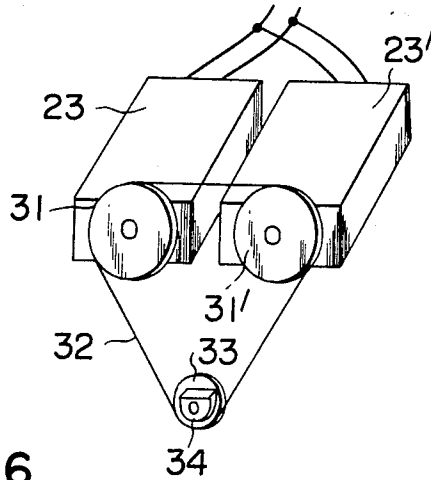


FIG. 7

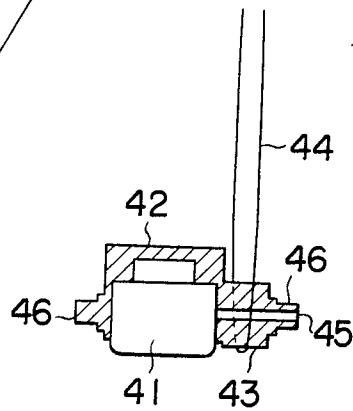
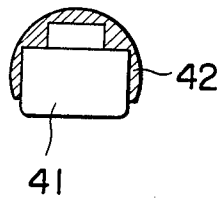


FIG. 6



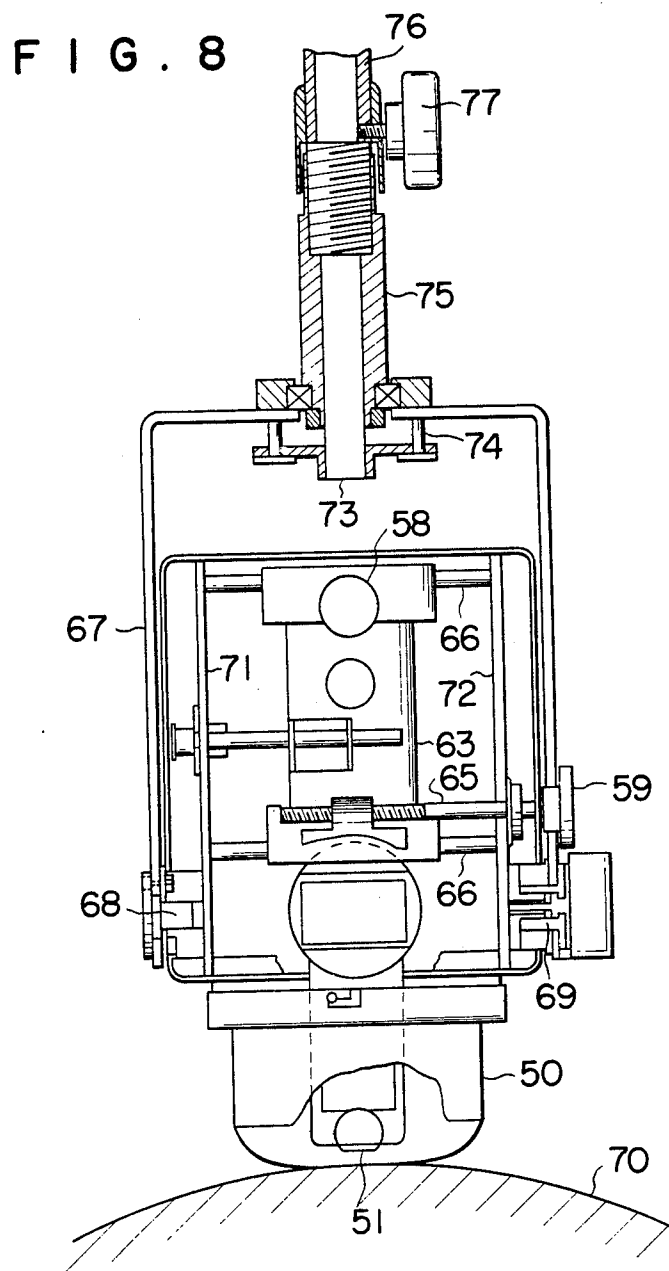
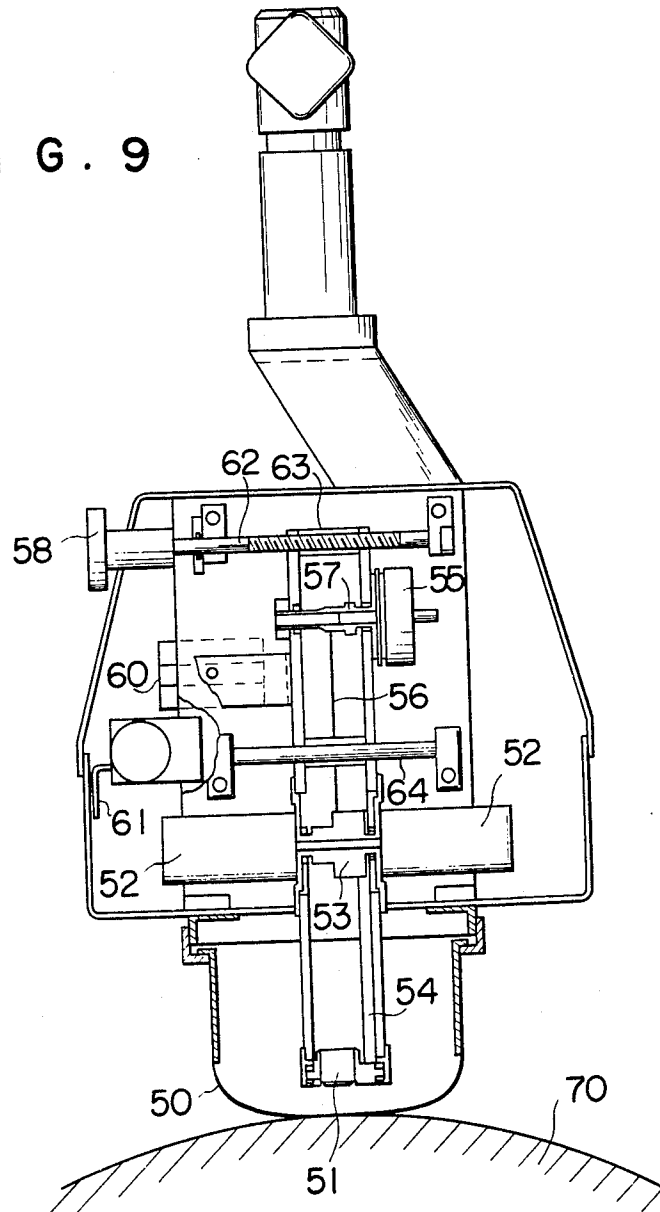


FIG. 9



ULTRASONIC WAVE DIAGNOSIS APPARATUS WITH GALVANOMETER-DRIVEN PROBE

BACKGROUND OF THE INVENTION

This invention relates to ultrasonic wave diagnosis apparatus and more particularly to diagnosis apparatus wherein a ultrasonic wave is scanned at a high speed in a sector shaped region (hereinafter termed "sector scanning") so as to obtain, without any time lag, tomograms of a diseased portion of a patient, for example a heart.

In ultrasonic wave diagnosis apparatus, in order to obtain tomograms of the diseased portion of a patient it is necessary to scan the beam of a ultrasonic wave across the diseased portion according to a scanning system appropriate for the diseased portion.

For example, to obtain tomograms of a diseased heart it is necessary to install a ultrasonic wave probe so as to radiate the beam of the ultrasonic wave upon the heart through a gap between ribs of the patient and to scan the beam in an area of sector shape without being affected by the ribs. In such a case, since the heart is constantly moving it is necessary to display the reflected or echo signals of the ultrasonic wave in synchronism with the pulse of the heart.

Heretobefore, the ultrasonic wave diagnosis apparatus for obtaining tomograms of a heart has been constructed as diagrammatically shown in FIG. 1. Thus, a container 2 is mounted on the breast of a patient 1 and a ultrasonic wave probe 3 for transmitting a beam of a ultrasonic wave and receiving echo signals is disposed in the container 2 which is filled with liquid capable of transmitting the ultrasonic wave without loss. The probe 3 is supported by a holder 4 which is moved in the X and Y directions with respect to the heart of the patient 1 by means of a scanning device 5 thus performing a sector scanning in a manner to be described later in more detail. The probe 3 is electrically connected to a transmitter-receiver combination 6 which supplies to the probe 3 the beam signal of the ultrasonic wave and transforms into an echo video signal the echo signal received by the probe 3. The echo video signal from the transmitter-receiver combination 6, a position signal representing the position of the probe 3 and an angle signal representing the angular position of the probe 3 during the sector scanning, which are generated by the scanning device 5, are supplied to a display device 7 for displaying a tomographic image of the diseased portion. For the purpose of synchronizing the operation of the display device with the pulse of the heart one or more pulse detecting electrodes 8 attached to suitable portions of the patient and a cardiograph 9 are provided and the signal generated by the cardiograph 9 is converted into a signal for operating the display device by a pulse synchronism controller 10.

A pulse signal generated by the transmitter-receiver combination 6 is converted by the probe 3 into a ultrasonic wave signal which is transmitted to the patient and the echo signal from the patient is received by the probe 3.

The probe 3 is moved by the scanning device 5 to perform the sector scanning, and the position signal and the angle signal concerning the probe are sent to the display device 7 from the scanning device 5. In response to these position signal, angle signal and the echo video signal from the transmitter-receiver combination 6 the display device displays a tomographic

image. In order to prevent the displayed image from becoming obscure the display device is controlled by the signal generated by the pulse synchronism controller 10. More particularly, a sampling signal is formed always at the same instant in one cycle of the pulse so as to display the echo signal with respect to the angle signal and the position signal of the probe 3 at that instant of sampling. The sampling is made for several cycles of the pulse so as to compose a single tomographic image of the heart.

With the prior art apparatus described above since a tomographic image is formed by sampling several times the pulse signal, it takes some time to display the image. Moreover, as the pulse does not always occur under the same condition at respective sampling points, it is not always possible to obtain accurate tomographic images. This is enhanced by the fact that with the prior art apparatus it is impossible to sector scan the probe at high speeds because the probe is moved by mechanical means.

Accordingly, it is necessary to provide an improved display device which can display the information without any time lag, which is obtained by the probe when it is sector scanned at high speeds. In order to accurately display the detail of the profile of the tomographic image of the heart it is necessary to form the image information at a rate of about 30 frames per second, for example, and to scan the probe at a corresponding high speed.

Further, the prior art apparatus was difficult to sector scan the probe at a high speed and at a uniform angular velocity. The apparatus constructed to fulfill these requirements has been extremely bulky and expensive.

Heretobefore deaerated water has been used as the liquid contained in the container 2. However, the probe immersed in the liquid is impressed with a high operating voltage. For this reason, it has been necessary to enclose the probe with a water proof and electric insulating casing. This increases not only the dimension but also the weight of the probe, thus requiring a large power for driving the probe at a high speed. Use of water also causes rusting of rotary members.

Considering in more detail the reflection of the ultrasonic wave the following two modes of reflection are predominate. In one mode, the ultrasonic wave reflected by the patient, or the echo wave is reflected by the probe and directed again towards the patient, and this process is repeated several times. In the other mode, the echo wave from the patient is reflected by the upper surface of the medium filling the container or by the inner wall thereof towards the patient. This process is also repeated several times. These complicated reflections add a quasi-echo image to the tomographic image.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to provide an improved ultrasonic wave diagnosis apparatus capable of sector scanning a probe at a high speed and at a uniform speed thereby producing a clear tomographic image of the diseased portion of a patient without any time delay.

Another object of this invention is to provide an improved ultrasonic wave diagnosis apparatus utilizing a probe having a small weight and small moment of inertia.

Still another object of this invention is to provide an improved ultrasonic wave diagnosis apparatus includ-

ing improved means that can readily vary the position of the probe with respect to the body of a patient.

A further object of this invention is to provide an improved ultrasonic wave diagnosis apparatus utilizing a novel acoustic liquid which can not only electrically insulate the probe but also eliminate a quasi-echo image caused by complicated reflection of the ultrasonic wave.

According to this invention, these and other objects can be accomplished by providing a ultrasonic wave diagnosis apparatus of the class wherein a probe for transmitting and receiving ultrasonic wave to and from a portion of a patient to be diagnosed is scanned in a sector shape, characterized in that there are provided galvanometer means operatively connected to the probe, a triangular wave generator, and means for applying the output of the triangular wave generator to the galvanometer means to cause it to swing at a uniform triangular speed.

According to another aspect of this invention, the apparatus just described is provided with means for moving the probe in either one of two directions which intersect at right angles in a horizontal plane, means for rotating the probe about a horizontal axis, and means for rotating the probe about a vertical axis.

It is also a feature of this invention to use electric insulating oil, castor oil, silicone oil or liquid paraffin as the acoustic medium in which the probe is immersed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 is a diagram showing the construction of a prior art ultrasonic wave diagnosis apparatus;

FIG. 2 is a block diagram showing one embodiment of this invention;

FIG. 3 is a perspective view showing one example of an arrangement of a galvanometer and a probe;

FIG. 4 and 5 are perspective views showing different arrangement of the galvanometers and a probe;

FIG. 6 shows a cross-sectional view of a probe and a probe holder embodying the invention;

FIG. 7 shows a longitudinal sectional view of the probe and probe holder shown in FIG. 6;

FIG. 8 shows a front view of the ultrasonic wave diagnosis apparatus embodying the invention; and

FIG. 9 shows a side view of the apparatus shown in FIG. 8.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to one aspect of this invention a galvanometer is used to drive the probe. Any one of many galvanometers which are used in recording or measuring apparatus may be used in this invention. However, the galvanometer of the most common type comprises a pair of opposed pole pieces, a moving coil disposed to be rotatable in a space between the pole pieces and a pointer mounted on a spindle of the moving coil. The moving coil and the pointer are rotated by an angle corresponding to the electric signal applied to the moving coil. Thus, the angle of rotation of the spindle is proportional to the magnitude of the input signal. According to this invention, this rotation of the galvanometer is used to perform the sector scanning of the probe

As shown in the block diagram of FIG. 2 there are provided a triangular wave generator 21, a power amplifier 22 for amplifying the output signal from the

triangular wave generator 21, a galvanometer 23 connected to receive the amplified output of the amplifier 22, and a mechanical motion transmitter 24 for transmitting the rotary motion of the galvanometer 23 to probe 25. As shown in FIG. 3, one example of the mechanical motion transmitter 24 comprises a pulley 31 secured to the spindle of the galvanometer 23, a pulley 33 secured to the rotary shaft of probe 25, and an endless belt 32 passed about pulleys 31 and 33. The probe 25 is rotatably mounted on a holder 34.

In operation, the triangular wave generated by the triangular wave generator 21 is amplified by amplifier 22 and is then supplied to the moving coil (not shown) of the galvanometer 23. In response to the amplified triangular wave the moving coil and its spindle rotate by an angle corresponding to the magnitude of the triangular wave. Thus, the spindle rotates in one direction in response to the build-up portion of the triangular wave and in the opposite direction in response to the build-down portion. Since these build-up and build-down portions comprise straight lines, the spindle rotate at a uniform angular speed in both directions. The swinging motion of the spindle of the galvanometer 23 is transmitted to probe 25 through pulleys 31 and 33 and belt 32 thus causing the probe 25 to swing as shown by arrow A, FIG. 3.

Thus the swinging speed or the sector scanning speed of the probe 25 is determined by the frequency of the triangular wave. Where the frequency of the triangular wave is selected to a value, for example 15 Hz, at which the galvanometer 23 can swing with sufficient linearity, the probe 25 will scan the heart at a rate of 30 times per second, whereby a video signal is supplied to the display device 7 at a rate of 30 frames per second. The swinging angle of the probe 25 is determined by the ratio between the diameters of pulleys 31 and 33. Denoting the swinging angle of the galvanometer by θ and the ratio between the diameters of the pulleys by n , then the swinging angle of the probe 23 will be represented by $n\theta$. It will thus be clear that it is possible to obtain any desired swinging angle θ of the probe by selecting suitable diameter ratio n of the pulleys. In this manner, according to this invention it is possible to clearly display without any time delay the manner of pulsing of a heart.

Although in the embodiment described above only one galvanometer was used, where a larger torque is desired for driving the probe 25 two or more galvanometers may be used as shown in FIGS. 4 and 5. In an embodiment shown in FIG. 4, two galvanometers 23 and 23' are mounted on a common shaft on the opposite sides of pulley 31, whereas in another modification shown in FIG. 5, two galvanometers 23 and 23' are provided with independent pulleys 31 and 31' which are operatively connected with the pulley 33 for driving probe 25 (see FIG. 3). In these embodiments two galvanometers are connected in parallel across the output from amplifier 22 (see FIG. 2) to produce torques in the same direction.

Use of one or more galvanometers enables high speed sector scanning of the probe. Further, use of a triangular wave assures uniform angular speed in both directions of the swinging movement of the probe. Moreover, it is possible to select any desired scanning speed and swinging angle by adjusting the frequency and amplitude of the triangular wave.

As described above it is also an object of this invention to provide a probe having light weight and small

moment of inertia thus enabling high speed sector scanning. An improved probe shown in FIGS. 6 and 7 comprises a probe 41 connected as shown in FIG. 1 and driven by a galvanometer as shown in FIGS. 2 and 3, and a holder 42 having generally a semicircular cross-section as shown in FIG. 6. As shown in FIG. 7, the holder 42 includes a cylindrical projection 43 which acts as a pulley for receiving an endless belt 44. The projection 43 is provided with a central bore 45 for passing conductors (not shown) connected to the probe 41. On both ends of the holder 42 are provided shafts 46 for rotatably supporting the probe and holder by a stationary member, not shown.

Since the holder is formed with integral pulley and bearing shafts it is possible to reduce the size, weight and moment of inertia thus enabling high speed scanning. Moreover, as the holder has a shape of a semicircle, it is possible to reduce liquid resistance when it is rotated in liquid.

The detail of the ultrasonic wave diagnosis apparatus embodying the invention is shown in FIGS. 8 and 9. Thus, a probe 51 having a construction as shown in FIGS. 6 and 7 is rotatably mounted on the lower portion of the apparatus and immersed in acoustic liquid contained in a bowl shaped container 50 which is mounted on the body of a patient 70. A pair of opposed galvanometers 52 are mounted above the probe 51 for swinging probe 51 through a pulley 53 and an endless belt 54 in the same manner as has been described in connection with FIG. 4. There are also provided a potentiometer 55 which is driven by the pulley 53 through an endless belt 56 and a pulley 57, a knob 58 for moving the probe 51 in the direction Y, and a knob 59 for moving the probe in the direction X, the movements of the probe in the Y and X directions being indicated by scales and pointers 60 and 61 respectively. When knob 58 is operated its threaded shafts 62 moves a frame 63 which supports probe 51 and galvanometers 52 in the Y direction along guide rods 64, whereas when the knob 59 is operated its threaded shaft 65 moves the frame 63 in the X direction along guide rods 66.

The scanning head including various elements described above is rotatably mounted on the lower end of a frame 67 by horizontal shafts 68 and 69 connected to the respective side plates 71 and 72 of the scanning head so that the scanning head is tiltable about shafts 68 and 69 by manual operation. The upper end of frame 67 is connected to the lower end of a threaded rod 73 through connecting rods 74 and an adjusting nut 75 is mated with the threaded rod 73. Accordingly, by turning the nut 75 the vertical position of the scanning head, and hence the probe with respect to the body of the patient can be adjusted finely. The upper end of the threaded rod 73 is rotatably supported by a bearing 76 provided with a set screw 77. With this construction it is possible to rotate the scanning head about the axis of the threaded rod 76 and to hold the scanning head at an adjusted position by set screw 77.

In this manner, since means for adjusting the probe in the X and Y directions, means for tilting the probe about a horizontal axis and means for swinging the probe for effecting the desired sector scanning are all mounted on a scanning head it is possible to construct it compact and small size. In addition, since there are also provided means for finely adjusting the vertical height of the scanning head and means for rotating the same about a vertical axis it is possible to direct the

probe in any direction thus greatly simplifying diagnosis.

It is also a feature of this invention to use electric insulating oil (usually mineral oil) as the liquid which fills the container 2 (see FIG. 1) or 50 (see FIGS 8 and 9) and through which the ultrasonic wave is transmitted between the patient and the probe. By using electric insulating oil instead of deaerated water, it is not necessary to use any casing which encloses the probe, thereby decreasing the size and weight of the probe. Moreover as the probe and its bearings are bodily immersed in the insulating oil as shown in FIGS. 8 and 9 it is not only possible to adequately lubricate the bearings but also to prevent rusting thereof. Since electric insulating oil is more viscous than water, splashing can be prevented when the probe is swung at high speeds.

Considering the effect of the quasi-echo image, its magnitude is determined depending upon the difference in the acoustic impedances of the patient and of the acoustic medium filling the container 2, and the transmission loss of the ultrasonic wave in the acoustic medium. Since the difference in the acoustic impedances is determined essentially by the sound speed, it is advantageous to select an acoustic medium through which the ultrasonic wave travels at substantially the same speed as in the body of the patient. Further, it is advantageous to select an acoustic medium having as large as possible transmission loss for the purpose of eliminating the effect of the quasi-echo image.

I have found that castor oil, silicone oil and liquid paraffin are more advantageous than electric insulating oil because they have higher transmission loss and viscosity and through which the ultrasonic wave travels at substantially the same speed as in the body of the patient.

I claim:

1. In a ultrasonic wave diagnosis apparatus of the class wherein a probe for transmitting and receiving ultrasonic wave to and from a portion of a patient to be diagnosed, is scanned in a sector shape, the improvement which comprises galvanometer means operatively connected to said probe, a triangular wave generator, and means for applying the output of said triangular wave generator to said galvanometer means to cause it to swing at a uniform angular speed.

2. The ultrasonic wave diagnosis apparatus according to claim 1 which further comprises a transmitter-receiver combination which supplies a high frequency pulse to said probe and converts the ultrasonic wave echo signals received by said probe into ultrasonic wave echo video signals and display means responsive to said ultrasonic wave echo video signals for displaying a tomographic image of said portion to be diagnosed.

3. The ultrasonic wave diagnosis apparatus according to claim 2 wherein said portion to be diagnosed is the heart of a patient and said apparatus further comprises means for detecting the pulse of said heart, a cardiograph responsive to the output of said pulse detecting means for forming a cardiogram signal, and means responsive to said cardiogram signal for controlling the operation of said display means in synchronism with said pulse.

4. The ultrasonic wave diagnosis apparatus according to claim 1 wherein said galvanometer means comprises a plurality of discrete galvanometers which are operatively connected to said probe.

5. The ultrasonic wave diagnosis apparatus according to claim 4 wherein said galvanometers are mounted on

a common shaft and said apparatus further comprises a first pulley mounted on said common shaft, a second pulley mounted on the shaft of said probe and means for operatively interconnecting said first and second pulleys.

6. The ultrasonic wave diagnosis apparatus according to claim 4 wherein said galvanometers are provided with discrete pulleys which are operatively connected to a pulley provided for said probe.

7. The ultrasonic wave diagnosis apparatus according to claim 1 wherein said probe is contained in a holder having semicircular cross-section, a cylindrical extension acting as a pulley operatively connected to said galvanometer means through an endless belt, and bearing shafts on the opposite ends.

8. The ultrasonic wave diagnosis apparatus according to claim 1 wherein said probe is immersed in an acoustic medium contained in a container, said acoustic

medium being a member selected from the group consisting of electric insulating oil, castor oil, silicone oil and liquid paraffin.

9. In a ultrasonic wave diagnosis apparatus of the type wherein a probe for transmitting and receiving ultrasonic wave to and from a portion of a patient to be diagnosed is scanned in a sector shape, the improvement which comprises galvanometer means operatively connected to said probe, means for moving said probe in either one of two directions which intersect at right angles in a horizontal plane and means for rotating said probe about a horizontal axis.

10. The ultrasonic wave diagnosis apparatus according to claim 9 which further comprises a frame pivotally mounted on said horizontal axis, means for rotating said frame about a vertical axis, and means for moving said frame in the vertical direction.

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