M. MASON.

DETERMINATION OF WAVE ENERGY DIRECTION.

APPLICATION FILED JUNE 25, 1919.

1,422,876.

Patented July 18, 1922.

2 SHEETS—SHEET 1.

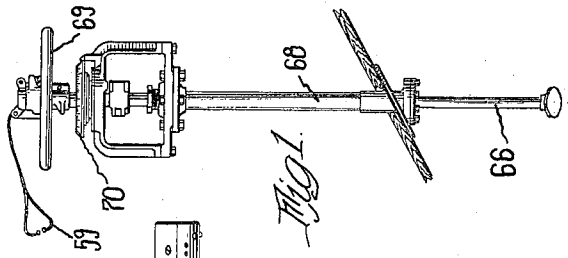


Fig 1.

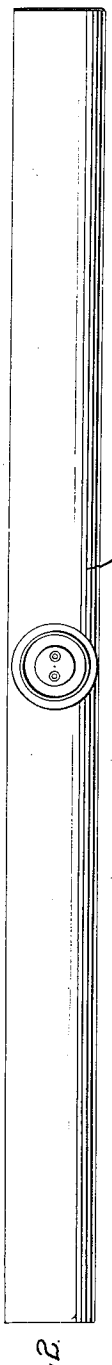


Fig 2.

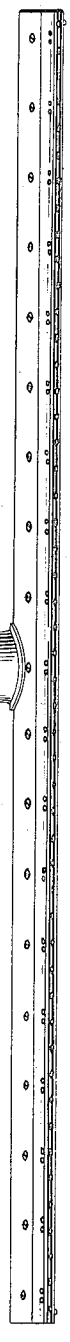


Fig 3.

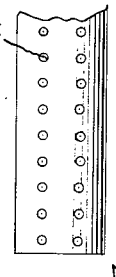


Fig 4.

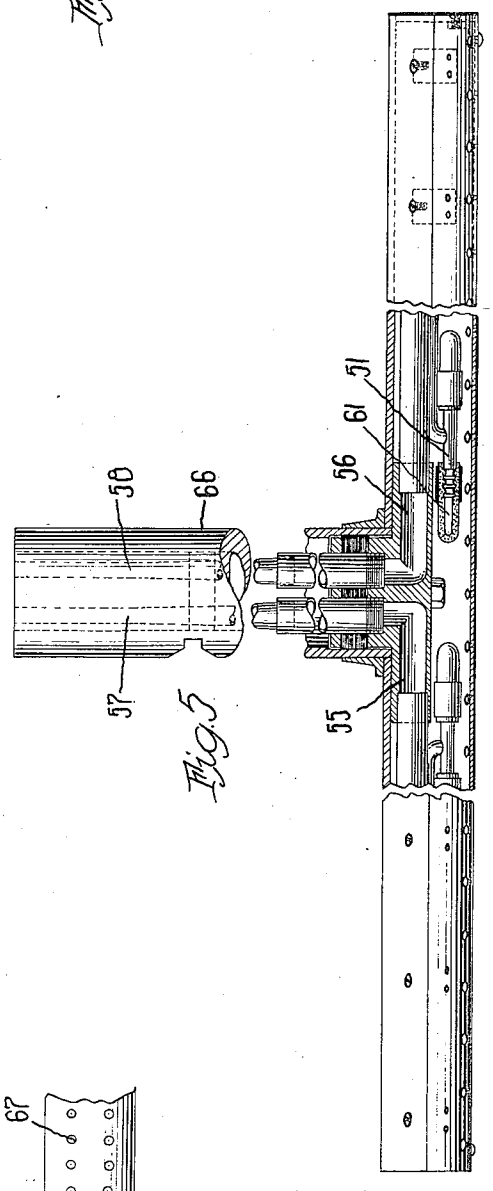


Fig 5.

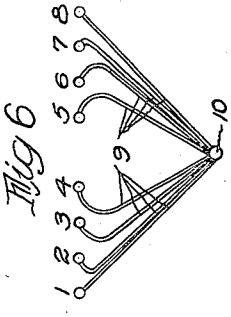


Fig 6.

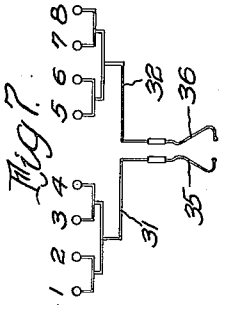


Fig 7.

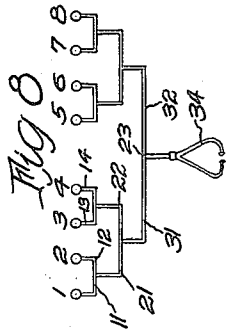


Fig 8.

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2 SHEETS—SHEET 2.

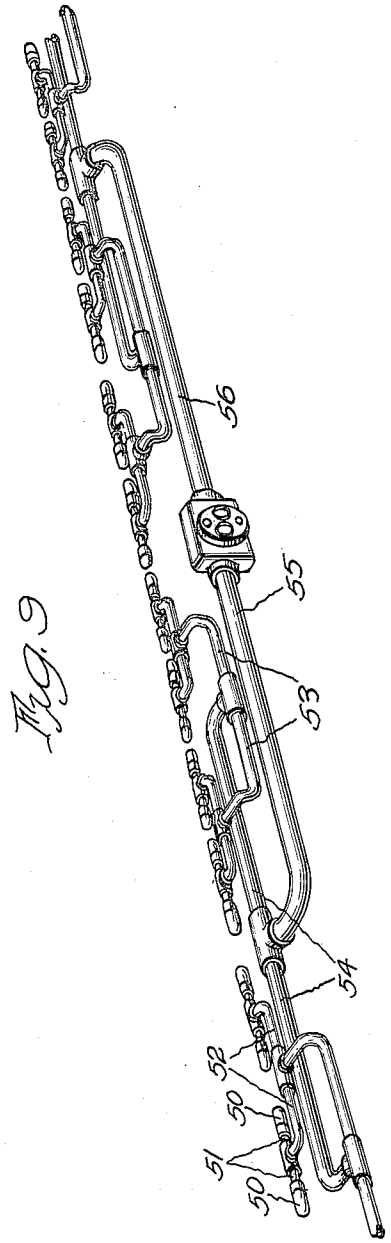


Fig. 9

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UNITED STATES PATENT OFFICE.

MAX MASON, OF NEW LONDON, CONNECTICUT, ASSIGNOR TO SUBMARINE SIGNAL COMPANY, OF PORTLAND, MAINE, A CORPORATION OF MAINE.

DETERMINATION OF WAVE-ENERGY DIRECTION.

1,422,876. Specification of Letters Patent. Patented July 18, 1922.

Application filed June 25, 1919. Serial No. 306,683½.

To all whom it may concern:

Be it known that I, MAX MASON, a citizen of the United States, residing at New London, in the county of New London and State of Connecticut, have invented new and useful Improvements in Determination of Wave-Energy Directions, of which the following is a specification.

The present invention relates to the determination of wave energy direction, and more particularly to apparatus for determining the direction from which the wave energy is coming, comprising a plurality of receivers, normally disposed broadside to the wave front, and compensated leads from the receivers to bring the energy into phase at the place of utilization.

The present invention is specifically illustrated as embodied in device for determining the direction of submarine sounds in which a plurality of receivers, disposed in a row, may be turned broadside to the sound source. The invention, however, is not limited in application to submarine sound reception but may be employed for other purposes as will be apparent from the following description:

Referring to the illustrated embodiment of the invention, Fig. 1 is an elevation of submarine listening device embodying the invention. Figs. 2 and 3 are a top plan view and a side elevation of the receiver containing casing. Fig. 4 is a fragmentary view showing a portion of the bottom of the receiver casing. Fig. 5 is an elevation, partially in section, of the receiver casing and its mounting post. Figs. 6, 7, and 8 are illustrative diagrams, and Fig. 9 is a perspective view showing the assembly of the receivers and collecting tubes.

The principles underlying the invention will first be explained with particular reference to the diagrams shown in Figs. 6, 7, and 8. Let a row of sound receivers 1, 2, 3, 4, 5, 6, 7, and 8 be disposed in a straight line in the water or other surrounding sound conducting medium. Let the several receivers be connected to a common collection point 10 by means of air columns 9 which are all of the same length.

Then if sound strikes the receivers in a direction at right angles to the row of receivers, the sound waves will be brought together in phase at the collection point 10 and the sound will be amplified. Suppose, however, the sound comes from other direction, for example from the left, either along the line of the receivers shown in Fig. 6 or at some acute angle thereto. Then the sound will strike the receivers, 1, 2, 3, 4, etc. in succession and the sound waves transmitted through the tubes will be brought successively to the collecting point 10. The waves will be out of phase and interfere so that the sound will be greatly less than that heard for a wave striking the line of receivers broadside. A line of receivers of the type for focusing sounds coming broadside is termed a "beam compensated" line, and if the paths for transmitting the sound from the receivers to the common collection point have predetermined fixed lengths, the compensation is termed "fixed compensation", as contrasted with variable compensation in which provision is made for varying the length of the transmitting paths from the receivers.

In practice, it is found convenient to bring the energy from the receivers together progressively in a plurality of collection stages. Such arrangement is shown diagrammatically in Fig. 8. The sounds received by the receivers 1 and 2 travel over tributary branch paths of equal length, 11 and 12, to a lead 21. Similarly the receivers 3 and 4 are joined through branch paths 13 and 14 to a lead 22. The leads 21 and 22 are of the same length and join a lead 31. The receivers 5, 6, 7 and 8 are similarly connected to a lead 32 which meets the lead 31 at a junction point 33, to which is connected a stethoscope 34. It will be seen from an inspection of the Fig. 8 that the paths from the several receivers to the stethoscope are all of the same length so that the waves transmitted from the several receivers will all be brought into phase at the stethoscope, for wave fronts striking the line of receivers broadside.

The diagrams of Figs. 6 and 8 show arrangements in which the sound direction is indicated by the maximum of sound observed when the row of receivers is turned broadside to the direction of the sound. The determination of the maximum may be combined with what is known as a binaural centering of the sound. The combination of receivers to achieve this is shown diagrammatically in Fig. 7. In Fig. 7 the receivers 1, 2, 3 and 4 are connected by branch paths

of equal length to the lead 31, and the receivers 5, 6, 7 and 8, are connected by branch paths of equal length to the end of the lead 32. Instead of having the leads 31 and 32 joined, they are connected respectively with the left and right ear pieces 35 and 36 of the stethoscope. The leads 31 and 32 are of equal length and the tubes of the two halves of the stethoscope are also of equal length. If a sound strikes the row of receivers broadside, the sound waves from the receivers 1, 2, 3, and 4 will all be brought into phase at the left ear, and the sound waves from the receivers 5, 6, 7, and 8 will all be brought into phase at the right ear. Also the sounds coming into the two ears will be in phase with each other, so that the sound will appear to the observer to be centered in a medium plane through the observer's head, or is said to be binaurally centered. The arrangement shown in Fig. 7 has the advantage that it combines binaural centering with a sound maximum. Under some circumstances, however, it is found preferable to rely upon a maximum alone, without the binaural.

Suppose the row of receivers 1 to 8 inclusive are mounted so as to be turned in any direction. When the row of receivers is turned so that the sound wave has a different time of arrival at the several receivers, the sound will be weak and blurred, but when the row is turned so that the sound comes from broadside, striking all the receivers at the same time, the sound suddenly becomes clear and distinct, with greatly increased loudness. By turning the row of receivers back and forth the point of maximum loudness can be determined.

In case the receivers are connected to two halves of a listening device for binaural listening, if the row is turned so that the sound waves arrive at one end of the row first, the sound will appear to be located in the corresponding ear of the observer. As the row of receivers is turned broadside to the sound, the intensity of the sound not only increases, but the location of the sound appears to the observer to travel until it is centered with respect to the observer's ears.

When branching air tubes are used for collecting the sounds from the several receivers, it is found that for the best conservation of the sound, the cross sectional area of the air path through the tubes should be conserved. For example, the lead 21 should have a cross sectional area equal to the sum of the cross sectional areas of the leads 11 and 12, and the lead 31 should have a cross sectional area equal to the sum of the cross sectional areas of the leads 21 and 22. This prevents the reflection and loss of sound which would otherwise take place at a sudden reduction or increase in the diameter of the sound paths. If for any reason a sound conducting tube must be changed in diameter, it should be done by a gradual coning of the tube.

It is also important that the several receivers should be non-resonant for the wave frequencies which are to be received. In the case of submarine sound receivers placed at the ends of conducting air tubes, the partition wall or diaphragm between the water and the air should be made to have little, if any, natural frequency of its own, which lies near the frequencies of sound to be received. Otherwise if the receiver diaphragms start vibrating at their own natural frequencies such free vibrations will in general be out of phase and will cause interference in the system.

In Figs. 1 to 5 inclusive, and in Fig. 9, is illustrated a beam compensated rotatable listening device employed for determining the direction of submarine sounds.

The branching air pipes to the several receivers is as shown in Fig. 9. The receivers thirty-two in number are secured to the ends of thirty-two short pipes 51, all of the same length. These pipes join in pairs to sixteen pipes 52, all of the same length, which in turn join eight pipes 53, all of the same lengths. The pipes 53 join four pipes 54 all of the same length. The ten pipes 54 at one half line join a pipe 55, while the ten pipes 54 which are at the other half of the line join the pipe 56, thus connecting the receivers of one half of the line to pipe 55 and those of the other half to pipe 56. These pipes 55 and 56 are connected to upright tubes 57 and 58, which as shown by the dotted lines in Fig. 5 are gradually coned down to reduce the cross sectional area. However, coning may be omitted in some cases. The tubes 57 and 58 are connected at the top to the two ear pieces respectively of a stethoscope 59.

As shown in Fig. 9 the size of the several air tubes is such that the cross sectional area of any two is equal to the sum of the cross sectional areas of its tributary branch tubes.

The receivers are shown as of the rubber nipple type. Referring to Fig. 5 each receiver consists of a small nipple 61, of soft rubber, which is clamped with a watertight connection over the end of the tube 51. It is found that rubber makes excellent material for the receiver walls in making a non-resonant receiver. While a receiver of the nipple type is shown, receivers of other types have been used, for example receivers of the rubber button or diaphragm type.

The receivers with their branching collection pipes are housed in the cross arm 65 which is carried on the bottom of the post 66. The cross arm 65 is hollow and is provided with openings 67 through the bottom, through which the water has free access to the space around the receivers. The sound waves in the water pass through the metal

walls of the casing 65 and the holes 67 and act upon the rubber nipples 65, which yield and in turn set up sound waves in the air paths through the branching collecting tubes. The post 66 is mounted in housing 68 which extends through the bottom of the ship. The post 66 and cross arm 65 may be turned in any direction by means of a hand wheel 69, and the angular direction read by means of a scale 70. The scale is calibrated to indicate the direction of the sound when the receivers are turned broadside to it, and enable the observer, who is generally in the hold of the ship to immediately determine the angular bearing of the sound source with respect to the ship's head. It will be noted that a line of receivers with "beam compensation" as here described will give a maximum response to sounds coming at right angles to its length, so that a maximum will be heard from sound either directly in front or behind the line of receivers. Also sounds directly in front or behind the line of receivers will be binaurally centered. However, it is found that when a sound is in front of the row of receivers, and the right hand section of the receivers is connected to the right ear and the left hand section to the left ear, upon swinging the receivers through a small angle to the right the binaural shift of the sound will be to the left, while if the sound is coming from behind it will appear to shift to the right. By this means the observer can quickly eliminate the 180 degree ambiguity of direction of the sound approaching from in front and from behind the line of receivers.

In the listening device illustrated in Fig. 9 there are thirty-two receivers, sixteen being connected to each ear. It is found that the maximum or focus is much sharper when there are a considerable number of receivers connected so that the waves from them are brought into phase before entering the ear. For example, if two receivers are used, one connected with each ear, a binaural centering may be made but with no appreciable maximum. On the other hand if a plurality of receivers is connected to each ear as shown in the drawings, a maximum response as well as a binaural centering will be obtained. In general, the greater the number of receivers, the sharper the maximum, the ultimate number of receivers of course being limited by mechanical construction and the length of the collecting tubes. It is found that not only is the maximum of aid in determining the direction of sound, but is of great aid in that it focuses out or minimizes sounds from interfering sources located at other angular bearings. For example, if the row of receivers is turned broadside to a particular sound source, the sound from such source will be loud and distinct, while sounds from sources having other angular bearings will be weak and blurred. This gives the instrument the power of discrimination in focusing on the desired sound, and focusing out or minimizing undesirable sounds. This is found of particular advantage when there are a number of ships in the sound field and it is desired to follow a particular ship to the exclusion of the others, and when there are interfering sounds from waves etc.

While the energy transmitting paths from the receivers to the place where the energy is utilized, (in the present case the stethoscope), are shown as air paths in the illustrated embodiment of the invention, it is obvious that other transmitting means might be used. While the invention has been described with particular reference to a device for determining the direction of submarine sounds, it may be used for determining the direction of sources of other kinds of wave energy. It is to be understood therefore that the present invention is not limited to its illustrated embodiment but may be embodied in other structures within the scope of the following claims.

I claim:

1. In apparatus of the character described, the combination of sound receivers disposed in a row, divided into two sections of a series of receivers each, means for bodily turning the row of receivers, a listening device having two ear pieces, one for each ear of the observer, and energy collecting means having branching tributary paths between the receivers of each section and the corresponding ear piece of the listening device, the several paths all having the same time of energy travel from the receivers to the listening device, substantially as described.

2. In apparatus of the character described, the combination of at least four sound receivers disposed in a row, means for bodily turning the row of receivers, and means for collecting and utilizing the received wave energy including two ear pieces, one for each ear of the observer, and energy transmitting paths all having the same time of travel, for the energy from the several receivers, substantially as described.

3. In apparatus of the character described, a combination of acoustic receivers disposed in a row, divided into two sections of a plurality of receivers each, means for bodily turning the row of receivers, a listening device having two ear pieces, and means for conducting the sound waves from the receivers to the listening device, comprising air paths all of the same acoustic length leading from the receivers of the respective sections to the respective ear pieces, substantially as described.

4. In apparatus of the character described, the combination of the plurality of acoustic receivers, a listening device, and connections

from the receivers to the listening device, comprising an air tube having tributary branches of equal length, each branch in turn having tributary branches of equal length, and so on, the last set of branches being connected to the receivers substantially as described.

5. In apparatus of the character described, the combination of a plurality of acoustic receivers, a listening device, and connections from the receivers to the listening device, comprising an air tube having tributary branches of equal length, each branch in turn having tributary branches of equal length, and so on, the last set of branches being connected to the receivers, the cross section of each tube being substantially equal to the combined cross sections of its tributary branches, substantially as described.

6. In apparatus of the character described, the combination of four or more receivers of wave energy disposed in a straight line, means for bodily turning the line of receivers and means for collecting and utilizing the received energy, comprising fixed beam compensated connections from the several receivers, substantially as described.

7. In apparatus of the character described, the combination of at least four receivers of wave energy disposed in a row, means for bodily turning the row of receivers, and means for transmitting and utilizing the received energy comprising energy conducting paths from the several receivers which the energy traverses in equal time, substantially as described.

8. In apparatus of the character described, the combination of plurality of receivers disposed in a row, a binaural listening device, means for turning the row of receivers, and means for obtaining a binaural centering together with a maximum response, comprising a binaural listening device having two ear pieces respectively connected with the receivers of the respective sections by a plurality of wave conducting paths all of the same length, substantially as described.

MAX MASON.