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A. E. MELHOSE

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HYDROPHONE

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FIG. 1

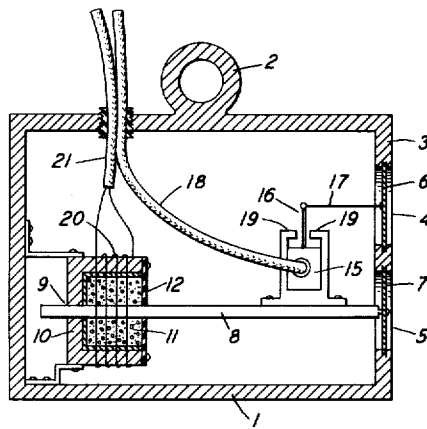
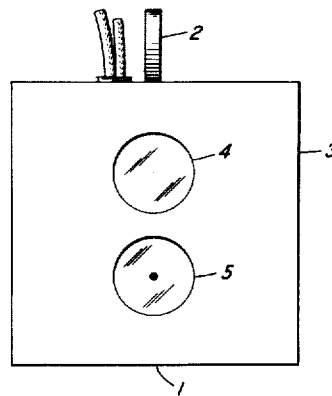


FIG. 2



INVENTOR
A. E. MELHOSE
BY *Harry C. Hart*
ATTORNEY

1

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HYDROPHONE

Alfred E. Melhose, Westfield, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

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10 Claims. (Cl. 340—14)

This invention relates to submarine signaling and has for its principal object the recovery of acoustical vibrations of very low frequencies which occur in sea water being generated, for example, by the movements of seagoing vessels and of objects or apparatus within them.

In the past, the designer of a subaqueous microphone or hydrophone has been confronted by the problem of maintaining its sensitivity to audio frequencies or a fair fraction thereof despite the wide variations of hydrostatic pressure which the hydrophone encounters by reason of submersion to a considerable depth below the surface of the water. Each increase of 34 feet in the depth of the hydrophone below the surface of the sea results in an increase in the pressure to which it is subjected of an atmosphere, so that when the unit is submerged to a depth of 300 feet or so below the surface, it must be able to operate under a hydrostatic pressure of 120 pounds per square inch or more, i.e., a pressure which is many thousands of times greater than the amplitude of any vibratory pressure to be picked up.

In connection with the investigation of vibrations of a certain class, such as are generated, for example, by the movements of seagoing vessels and of objects within them, it becomes necessary to recover acoustic vibrations of frequencies which lie well below the audio range, as low, indeed, as $\frac{1}{10}$ cycle per second or less. It is still more difficult to maintain the sensitivity of the hydrophone to such low frequencies despite submersion than it is to maintain its audio frequency sensitivity.

In order that the hydrophone shall respond to vibratory pressures of small amplitude, its diaphragm must be an elastic membrane. Consequently, if the hydrophone diaphragm is sufficiently delicate to respond at all to the small vibratory pressures, it is inevitably displaced inwardly by the large static pressures. If the body of the transducer which converts diaphragm movements into electric signals were rigidly fixed to the casing, this displacement of the diaphragm, which is linked to the sensitive member of the transducer, would either damage it or impede its operation. Therefore, it has been common in the past not to mount the body of the transducer rigidly on the casing but to provide it with, or to support it on, a member of large mass on the principle that the reaction of such a mass to the acceleration of the vibratory movement is considerable while it offers no substantial reaction to the displacement of the transducer as a whole due to the hydrostatic pressure. However, in order that this principle shall be successful in practice, the mass of the transducer body or of some member to which it is fixed must be sufficient to oppose a substantial reaction to vibratory movements at the lowest frequency to be encountered, and the structures of the prior art suffer from the fact that their sensitivity is greatly reduced at the lower frequencies as compared with its value at higher frequencies. To pick up or record vibrations of frequencies as low as $\frac{1}{10}$ cycle per second or lower with any degree of reliability, the required mass becomes prohibitively large.

2

The present invention is based on the recognition that a mechanical frictional element serves as a practical substitute for a large mass, provided it does not interfere with the vibratory movements of the vibration-sensitive diaphragm. In accordance with the invention, therefore, there is provided within the hydrophone casing a mounting for the transducer body which may be displaced inwardly by a diaphragm when subjected to the hydrostatic pressure but only against the resistance offered by a mechanical frictional element. The large pressures encountered are sufficient to overcome this friction so that, as the unit is gradually submerged, the body of the transducer gradually moves inwardly of the casing. When it has reached the desired depth, this movement ceases; and the transducer body has adopted a position which is dependent on the depth of submersion. Vibratory pressures which now occur and act on the sensitive element of the transducer are insufficient to overcome the friction so that, under these vibratory pressures, the transducer body remains fixed and only its sensitive element moves.

The viscous properties of liquids are generally such that the force which they exert is proportional to the velocity of relative movement so that, no matter what the liquid, when the movement takes place sufficiently slowly, the force offered is negligible. For this reason, it is preferred to employ a solid frictional element which manifests static friction as well as sliding friction.

The frictional element may take various forms. One which is preferred comprises an annular magnet between whose poles there is placed a mass of magnetizable granules, for example, steel spheres of the grain size of bird-shot. A magnetizable member such as a rod of steel on which the transducer body is mounted is linked to a pressure-sensitive diaphragm so as to move axially as the diaphragm is displaced. This rod passes through the center of the mass of magnetizable granules. Under the influence of the magnetic field of the magnet, the granules adhere to each other and to the surface of the steel rod, thus creating mechanical friction which resists the axial movement of the rod. Furthermore, and unlike a viscous liquid resistance device, this construction provides static friction as well as sliding friction so that, while the rod can be moved inwardly and outwardly of the grain mass by the exertion of a sufficient force, it remains absolutely immobile when the force applied to it is less than a threshold amount. This threshold force is adjusted to be somewhat greater than the greatest vibratory force to be encountered. Consequently, except while the hydrophone is being submerged or withdrawn from the water, the transducer body is effectively fixed inside the casing.

In a preferred embodiment this diaphragm is relieved of the duty of transmitting vibratory pressures, its sole function being to locate the transducer body at the correct distance from a second diaphragm to the center of which the sensitive element of the transducer is linked.

The invention will be fully apprehended from the following detailed description of the preferred embodiment thereof taken in conjunction with the appended drawings, in which:

Fig. 1 is a cross-sectional view of a hydrophone in accordance with the invention; and

Fig. 2 is an exterior view of the front face of the hydrophone.

Referring now to the drawings, the invention contemplates a massive rigid casing 1 for example, of steel, and having a hoisting ring 2 fixed to its upper surface. One vertical face 3 of the casing is provided with two circular openings 4, 5 preferably of the same size, in each of which a diaphragm 6, 7 is fixed. Each of these diaphragms must be able to withstand the greatest pressures encountered, for example ten atmospheres, without rup-

3

ture or damage. Therefore, they are preferably constructed of high-grade sheet steel. They may be supported in position with waterproof gaskets and metal bushings in the customary fashion.

To the center of one of these diagrams, for example, the lower one 7, there is fixed a horizontal member, for example, a rod 8 of steel of square cross section. At its other end, the rod 8 passes through a squared opening 9 in a magnet 10 which is rigidly fixed to the interior walls of the hydrophone casing 1 as by brackets. The magnet 10 has the shape of a cup, the square hole 9 being located in the bottom of the cup, and the space thus defined between the bottom of the cup and its rim is substantially filled with magnetizable granules 11, for example, minute steel spheres of the approximate grain size of bird-shot. These are retained in place by a sheet 12 of non-magnetizable material such as brass or fibre placed over the rim of the cup and having a squared hole which snugly fits the rod 8. The direction of the magnetic axis of the cup is not critical, so long as the magnetic flux passes through the granules and the body of the rod.

The body of a transducer 15 is rigidly fixed to the rod 8, and its sensitive element 16 is coupled by way of a light rigid link 17 to the center of the upper diaphragm 6. The transducer may be of any convenient variety. A unit which has been found to be suitable is the so-called mechano-electronic transducer made by the Radio Corporation of America under the code number 5734. This unit requires heater current and anode voltage, both of which may be supplied from the operator's station above the surface by way of a cable 18. The transducer 15 is protected from excessive movement of its sensitive element 16 by limit stops 19 which are fixed to the transducer body or to the rod 8 on which it is mounted. With this construction, for a fixed position of the rod 8 and the transducer body 15 in which the sensitive element 16 is approximately centered between its limit stops 15, vibrations of the upper diaphragm 6 cause movement of the sensitive element 16 and generation of an electric signal at its output terminals which may be brought to the surface and to an appropriate recording instrument by way of the cable 18. The frictional resistance offered by the magnetized granules 11 to movements of the rod 8 is such that vibratory pressures of this character are insufficient to cause vibratory movement of the lower diaphragm 7 so that, under these conditions, the transducer body 15 remains effectively fixed. When, however, pressures much greater than this are encountered, as, for example, during the process of submerging the hydrophone to a desired depth in the sea or raising it to the surface, these pressures cause movement of the lower diaphragm 7 as well as of the upper one. Movement of the upper diaphragm drives the sensitive element 16 against one or the other of its limit stops 19; and, were it not for the movement of the transducer body 15, its sensitive element might be damaged. However, before this can occur, the lower diaphragm 7 has moved, the rod 8 has moved axially through the magnetized grain mass 11, and the transducer body 15 has been displaced with it in such a direction as to relieve the force on the limit stops.

The cup-shaped magnet 10 may be a permanent magnet or an electromagnet, as preferred. If a permanent magnet is employed, the holding force which is exerted may be increased by the provision of a magnetizing current flowing in a winding 20 from a source at the surface under control of an operator and connected to the winding by way of a cable. However, in view of the high quality of permanent magnet materials which are now available, sufficient frictional force is generally obtainable by a permanent magnet alone. It is a simple matter so to adjust the magnitude of the cross section of the steel rod 8, the numbers and sizes of the magnetizable grains 11, and the field strength of the magnet

4

10 that the static friction opposed by the magnetizable grains 11 to movement of the rod 8 is somewhat in excess of any vibratory force to be encountered. The determination of these parameters may be made by experiment or by computation from the properties of the materials employed, as preferred.

Variations of the particular structure disclosed which yet embody the principles expounded above will suggest themselves to those skilled in the art.

What is claimed is:

1. A hydrophone which comprises a casing, two similar pressure-sensitive diaphragms mounted in a face of said casing, a first member reciprocally attached to one of said diaphragms, a transducer having a body and a movement-sensitive element, said transducer body being fixed to said first member, a second linkage member, the movement-sensitive element of said transducer being coupled by way of said second member to the other of said diaphragms.

2. A hydrophone which comprises a casing, two similar pressure-sensitive diaphragms mounted in a face of said casing, a first member reciprocally attached to one of said diaphragms, a transducer having a body and a movement-sensitive element, said transducer body being fixed to said first member, a second linkage member, the movement-sensitive element of said transducer being coupled by way of said second member to the other of said diaphragms, and friction means for resisting vibratory movements of said first member.

3. Apparatus as defined in claim 2 wherein the friction means manifests standing friction in excess of its sliding friction.

4. Apparatus as defined in claim 2 wherein the friction means comprises a mass of magnetized solid granules which are in mechanical and magnetic contact with said first member.

5. A hydrophone which comprises a casing, two similar pressure-sensitive diaphragms mounted in a face of said casing, a relatively massive member reciprocally attached to one of said diaphragms, a transducer having a body and a movement-sensitive element, said transducer body being fixed to said massive member, a relatively light linkage member, the movement-sensitive element of said transducer being coupled by way of said light member to the other of said diaphragms, and friction means for resisting vibratory movements of said massive member.

6. Apparatus as defined in claim 5 wherein the friction means manifests standing friction in excess of its sliding friction.

7. Apparatus as defined in claim 5 wherein the friction means comprises a mass of magnetized solid granules which are in mechanical and magnetic contact with said first member.

8. A hydrophone which comprises a casing, a pressure-sensitive diaphragm mounted in a face of said casing, a link member reciprocally attached to said diaphragm, a friction element arranged to offer a resistance to vibratory reciprocal movements of said member, a transducer having a body and a movement-sensitive element, said transducer body being fixed to said link member, and diaphragm-operated means for actuating said movement-sensitive element.

9. Apparatus as defined in claim 8 wherein the friction element manifests standing friction as well as sliding friction.

10. Apparatus as defined in claim 8 wherein the friction element comprises a plurality of magnetized granules, at least some of which are in mechanical and magnetic contact with said link member.

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