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ACOUSTIC TRANSDUCER FOR USE IN DENSE MEDIUM

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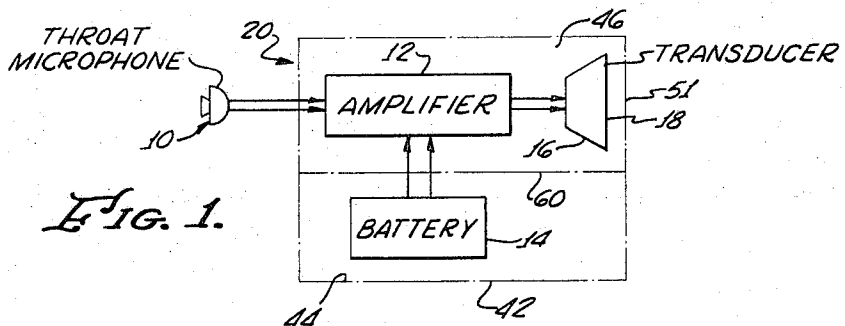
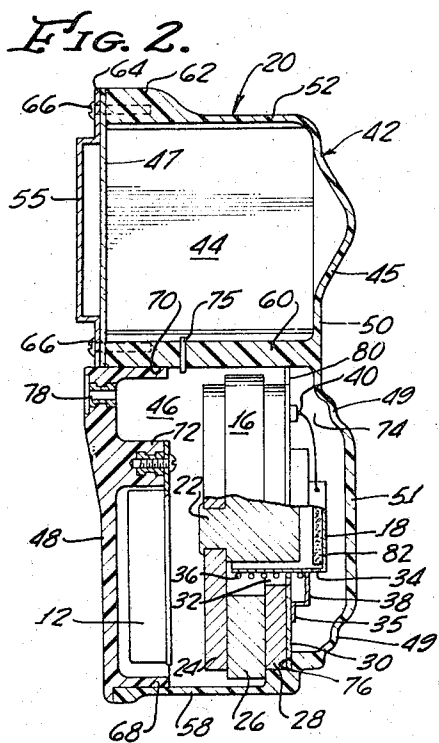
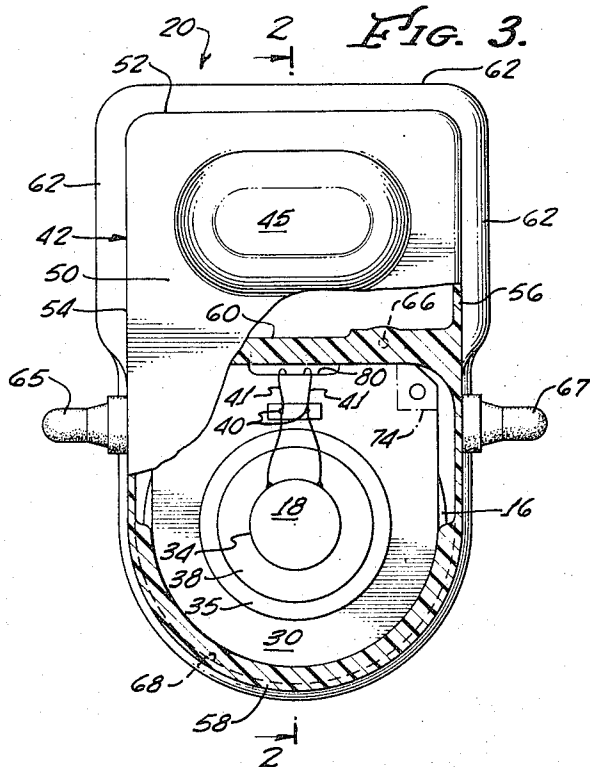
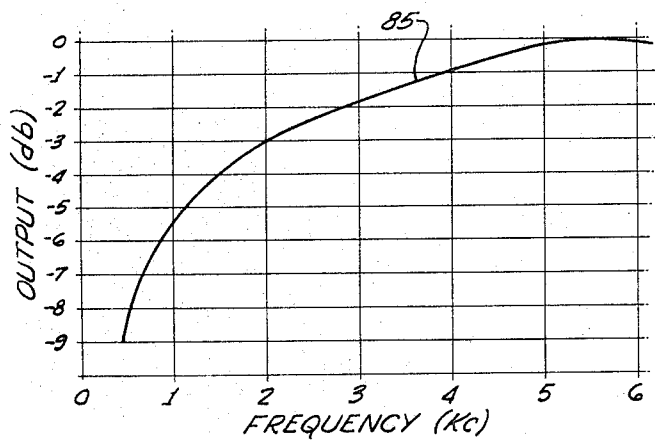


FIG. 4.

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ACOUSTIC TRANSDUCER FOR USE
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9 Claims. (Cl. 340-8)

This application is a continuation-in-part of application Ser. No. 447,671 filed Apr. 13, 1965 and now abandoned.

The present invention relates to an electro-acoustic transducer, for transmitting or receiving acoustic signals in a relatively dense surrounding medium such as water.

A particular application of the present invention is in an underwater communication device operable in the audio frequency range. Heretofore, such underwater communication devices have been in general very inefficient, bulky, easily damaged and expensive to manufacture. Relatively large driving power has been required for the transducer as a result of poor impedance matching between electro-mechanical and acoustical media. In addition, the use of vulnerable diaphragms in direct contact with the surrounding water has required intricate compensating bags or other mechanisms for equalizing pressure changes brought about by operation at varying depths. The Patent No. 3,118,125 issued to Sims discloses such an arrangement. Such usages not only have tended to reduce reliability of the device but have also imposed severe if not complicated structural requirements which have made the operating task more difficult and the initial cost higher.

In the present invention, as will be explained, such diaphragms and compensating bags are not needed and yet the underwater communication device disclosed and claimed is light, compact, inexpensive and highly efficient at relatively low audio power levels regardless of the depths of operation.

It is therefore an object of the invention to provide an improved acoustic transducer for use in a dense medium.

It is another object of the invention to provide an underwater communication device that utilizes a fluid force transmitting medium for coupling the output transducer to the surrounding water for propagating sound waves therethrough.

It is still another object of the invention to provide a device of the type to be described which is efficient and reliable in operation, light and compact in geometry, and relatively inexpensive to manufacture.

It is yet another object of the invention to provide a device of the type described which has a relatively wide frequency response in the audio frequency range.

Another object of the invention is to provide a device of the type described which is virtually insensitive to temperature and pressure variations as a function of depth.

These and other objects and features of the invention will be more readily understood from the following description taken in conjunction with the accompanying drawing in which:

FIGURE 1 is a block diagram of a communication system utilizing the present invention;

FIGURE 2 is a cross-sectional end view of an underwater communication device of the present invention showing a preferred embodiment thereof;

FIGURE 3 is a plan view partially in section of the device of FIGURE 2; and

FIGURE 4 is a graph showing the desired characteristic response of the device according to the invention.

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Referring now to FIGURE 1, shown there in block diagrammatic form is a system comprising a microphone 10 and an underwater communication device 20 in accordance with the invention. The device 20 includes a conventional transistorized audio amplifier 12 coupled to microphone 10, a battery or power source 14 for supplying electrical power in suitable form to amplifier 12, and a transducer 16 having a movable diaphragm 18 with a forward radiating surface and coupled to amplifier 12.

The transducer 16, shown in partial cross-section in FIGURE 2, comprises a cylindrical soft iron core 22 which is pressed into a rear pole piece 24. A permanent magnet 26 in the form of a cylinder is bonded on one end thereof to the pole piece 24 and on the other end thereof to a front pole piece 28 to which is also welded a mounting plate 30. Into the cylindrically shaped gap 32 thus formed is positioned a cylindrical coil support member 34 on which is wound a voice coil 36. A perforated spider 38 is attached at its outer periphery 35 to mounting plate 30 and supports the coil support member 34 in the gap 32. The voice coil 36 is terminated at terminals 40 and coupled by leads 41 to amplifier 12. Current flowing through the voice coil 36 interacts with the magnetic field in the gap 32 to drive the forward radiating surface of movable diaphragm 18 extending across the end coil support member 34. Alternatively, when the transducer is used for signal reception, vibration of diaphragm 18 induces current flow in the voice coil.

A housing 42 is provided for the device 20 and includes a battery storage compartment 44 and an oil-filled compartment 46 in which amplifier 12 and transducer 16 are mounted. The primary purpose of housing 42 is to separate the components of the device 20 from the surrounding water and at the same time provide some structural support for battery 14 and the oil surrounding the transducer 16 and amplifier 12 without causing a significant insertion loss. With this arrangement the output impedance of the transducer 16 is very closely matched with the oil substantially surrounding it and the impedance of this oil medium is closely matched with the impedances of both the housing and the surrounding water. As will be pointed out, the thickness of the housing is relatively small compared to the wavelength of sound and as such very little energy is reflected by the housing 42.

In FIGURES 2 and 3, a preferred embodiment of the device 20 is shown and, although a stainless steel or other non-corrosive metal may be used, we prefer to form the housing 42 by injection moulding using a high impact ABS plastic such as "Cyclocac."

The housing 42 comprises a one-piece base portion 45, a removable cover plate 47 for the battery storage compartment 44, and a permanently bonded moulded cover 48 for the compartment 46. The base portion 45 is further defined by a front wall 50, a top wall 52, side walls 54 and 56 interconnected by a curved wall portion 58, and a dividing wall 60 extending between side walls 54 and 56. An enlarged edge portion 62 having an end surface 64 extends from the dividing wall 60 along the edge of side walls 54 and 56 to and including the top wall 52. Conventional threaded fasteners 66 may be used to attach cover plate 47 to the end surface 64 and to the dividing wall 60; a gasket, not shown, is provided to assure a watertight connection for the compartment 44.

A bracket 55 is provided on the outside of cover plate 47 for receiving a strap, not shown, for securing the device 20 to an operator, such as a skin diver.

The moulded cover 48 is permanently bonded to the base portion 45 at a surface junction 68 adjacent the curved end wall 58, and to dividing wall 60 at a surface junction 70. The cover 48 also includes a mounting post 72 to which amplifier 12 is suitably attached. Transducer

16 is similarly supported in compartment 46 by means of mounting posts 74 to which the mounting plate 30 is connected. An annular bearing surface 76 is also provided for mounting plate 30 along the inner surface of the curved wall portion 58 near the front wall 50.

An important feature of the invention is the provision of means for preventing radiation from the rearward surface of movable diaphragm 18, in a direction toward the rear pole piece 24, which would otherwise largely cancel the radiation in the forward direction through outer wall portion 51 of housing 42. In accordance with the invention a quantity of air or gas is entrapped in a suitable manner, on the rearward side of diaphragm 18, to serve as a pulsation damper. For this purpose a gas bubble, floating within the oil, may be entrapped on the rearward side of diaphragm 18 and within the confines of cylindrical support member 34.

It is greatly preferred, however, to utilize a device 82, illustrated in FIGURE 2, which is glued or otherwise bonded to the rearward surface of diaphragm 18. Device 18 is a solid body of closed-cell neoprene material having air entrapped in the individual cells thereof. Due to resilience of the material, pressure fluctuations (acoustic vibrations) cannot be efficiently transmitted either through or past the device 82. This result is not primarily due to energy absorption, because the vibrating energy accepted by the device 82 is substantially entirely yielded up at a later point in the same vibration cycle; rather, it is primarily due to an impedance mis-match which destroys the transfer efficiency.

In its presently preferred form the device 82 is a solid cylinder approximately one inch in diameter and $\frac{3}{8}$ inch in thickness. It may if desired fit tight against the interior wall of support member 34, but spacing it away from the iron core 22, as shown, is greatly preferred, and might in fact be essential.

Moulded inserts 75 of conductive material are extended through the dividing wall 60 and provide continuity for the power circuit connected between the battery 14 and the amplifier 12. Similar inserts, not shown, may be provided in the top wall 52 of housing 42 for connecting the microphone 10; in that event, additional inserts would be provided in dividing wall 60 in order to complete the circuit connection to the amplifier 12.

Two conventional switches 65 and 67 are positioned inside compartment 46 and are connected to side walls 54 and 56 respectively, the actuating levers of switches 65 and 67 being enclosed by commercially available flexible covers. The switch 65 functions as a manually operated ON-OFF switch for the battery 14; switch 67 in turn serves to alter the circuitry of the amplifier 12 to convert it into an oscillator adapted to generate a 400 to 500 cycle tone which may be used at the operator's command to signify a predetermined condition or event such as, for example, a distress situation. When the device 20 is operated in this steady tone mode, its range of reception is significantly increased.

An opening 78, which subsequently is sealed, is provided in cover 48 for filling the compartment 46 with a supply of silicone oil preferably of the type commercially available as type SF-96-5 through the General Electric Company. To provide an unrestricted passage of oil to the space intermediate the transducer 16 and the front wall 50 of compartment 46, a portion of the mounting plate 30 is removed along its edge adjacent to the dividing wall 60 as indicated by the reference numeral 80. The perforations in spider 38 permit oil to substantially fill the gap 32 as well as the space between the radiating surface 18 and the core 22. With this arrangement, the pressure on each side of the radiating surface 18 is for all practical purposes equal. The rigid construction of housing 42 permits transmission of acoustic vibrations therethrough, but at the same time prevents the internal pressure level of the device from changing in response to changes in the ambient pressure of the environment.

The lower portion of front wall 50, that is that portion of the front wall which coextends and forms a part of compartment 46, as seen in FIGURE 2, extends outwardly to form a dome 51 which is centered about the radiating surface 18. One or more concentric rings 49 having a bellow-like appearance surrounds the dome 51. With this type of structure, we have found that higher efficiencies are obtainable at the higher audio frequencies of operation. A curve 85 in FIGURE 4 is representative of the output response as a function of frequency of the device 20.

If desired, a web-like pattern of increased thickness may be formed over the inner surface and as an integral part of the dome 51. In the preferred embodiment, the dome 51 has a thickness of $\frac{1}{16}$ of an inch, which is still very small relative to the wavelength of sound. However, such a thickness is not limiting in any sense for with other materials, for example, the dome thickness could be paper thin.

In operation, the output of the microphone 10 is fed to amplifier 12 through suitable moulded inserts as explained above, the signal amplified by amplifier 12 and in turn fed to transducer 16. Pressure variations in the form of sound waves are developed by the radiating surface 18, and coupled to the surrounding water by way of the silicone oil through the dome 51. Because of the efficient matching of impedances between the silicone oil, the dome 51 and the surrounding water, these sound waves are transmitted without significant insertion loss.

The breadth of diaphragm 18 is relatively small compared to the minimum dimension of housing 42. The breadth of the diaphragm is also very small compared to the wave length of audio frequency sound waves, and hence the diaphragm 18 acts essentially as a point source for radiating the sound energy in all directions. This omni-directional radiation pattern is made possible by the oil which fills the entire interior portion of the housing 42.

While the communication device is illustrated as being a transmitter only, it is apparent that with suitable circuit modifications the same transducer can be used for reception as well.

Although our invention is fully capable of achieving the results and providing the advantages hereinbefore mentioned, it is to be understood that it is merely the presently preferred embodiment thereof, and that we do not mean to be limited to the details of construction above described other than as defined in the appended claims.

What is claimed is:

1. An acoustic transducer adapted for use under water or other dense medium at varying depths, comprising:
 - a rigid housing adapted for transmission of acoustic vibrations therethrough;
 - a movable diaphragm disposed within said housing, having two opposed radiating surfaces both of which are spaced from said outer wall of said housing;
 - transducer means disposed within said housing and cooperatively associated with said diaphragm for converting electrical energy into acoustical vibrations of said diaphragm, or vice versa;
 - a pulsation damper disposed in engagement with one surface of said diaphragm, and including resilient means within which a quantity of gas is entrapped; and a quantity of relatively dense liquid filling the interior of said housing, including the space around said pulsation damper and the space between the other surface of said diaphragm and said housing outer wall;
 - said rigid housing maintaining the pressure level in said dense liquid substantially constant despite variations in the ambient pressure to which said transducer is subjected;
 - the acoustic receiving or transmitting capability from said one surface of said diaphragm being greatly

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diminished by the action of said pulsation damper while the acoustic transmitting or receiving capability from the other surface of said diaphragm is efficiently coupled at approximately a matched impedance level through said quantity of liquid and through said housing outer wall to the surrounding water.

2. An acoustic transducer as claimed in claim 1 wherein said resilient means of said pulsation damper provides a number of relatively small pockets within which gas is entrapped.

3. An acoustic transducer as claimed in claim 2 wherein said resilient means consists of a body of closed-cell neoprene material.

4. An acoustic transducer as claimed in claim 2 wherein said housing outer wall is made of high impact plastic material and said relatively dense liquid is a silicone oil.

5. An acoustic transducer as claimed in claim 2 wherein said transducer means is electromagnetic, wherein the breadth of said diaphragm is relatively small compared to the minimum dimension of said housing, and wherein the spacing of said diaphragm from said housing outer wall is of a magnitude comparable to the breadth of said diaphragm; said diaphragm serving essentially as a point source for acoustic vibrations and the radiation pattern through said housing outer wall into the surrounding water being omni-directional in nature.

6. An acoustic transducer as claimed in claim 5 wherein said housing outer wall is made of high impact plastic material and said relatively dense liquid is a silicone oil.

7. An acoustic transducer adapted for use in a dense medium, comprising:

a rigid housing adapted for transmission of acoustic vibrations therethrough;

a movable diaphragm disposed within said housing, having two opposed radiating surfaces both of which are spaced from the outer wall of said housing, the breadth of said diaphragm being relatively small compared to the minimum dimension of said housing, said diaphragm serving for transmitting acoustic vibrations through said housing outer wall;

transducer means disposed within said housing and cooperatively associated with said diaphragm for converting electrical energy into acoustical vibrations of said diaphragm, or vice versa;

a pulsation damper disposed in engagement with one surface of said diaphragm;

and a quantity of relatively dense material filling the interior of said housing, including the space around said pulsation damper and the space between the other surface of said diaphragm and said housing outer wall;

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The acoustic receiving or transmitting capability from said one surface of said diaphragm being greatly diminished by the action of said pulsation damper while the acoustic transmitting or receiving capability from the other surface of said diaphragm is efficiently coupled at approximately a matched impedance level through said quantity of dense material and through said housing outer wall to the surrounding medium;

said pulsation damper including a number of relatively small pockets of material whose acoustic impedance is mis-matched with the impedance of said dense material;

said rigid housing maintaining the pressure level in said dense material substantially constant despite variations in the ambient pressure to which said transducer is subjected.

8. An acoustic transducer as claimed in claim 7 wherein said housing is made of high-impact plastic material, said transducer means is electromagnetic, said relatively dense material filling the interior of said housing is a silicone oil, and said pulsation damper includes a pad of closed-cell neoprene material.

9. An acoustic transducer for use under water or other dense medium, comprising:

a movable diaphragm having two opposed radiating surfaces;

transducer means cooperatively associated with said diaphragm for converting electrical energy into acoustical vibrations of said diaphragm, or vice versa;

a pulsation damper secured to one surface of said diaphragm, including means providing a number of relatively small pockets within which quantities of gas are permanently entrapped in isolation from each other;

and means subjecting said pulsation damper to a substantially constant pressure level irrespective of variations in the ambient pressure to which said transducer is subjected.

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