May 15, 1956 L. W. CAMP 2,746,026

HALF WAVE ANNULAR TRANSDUCER

Filed Aug. 14, 1953

Fig. 5

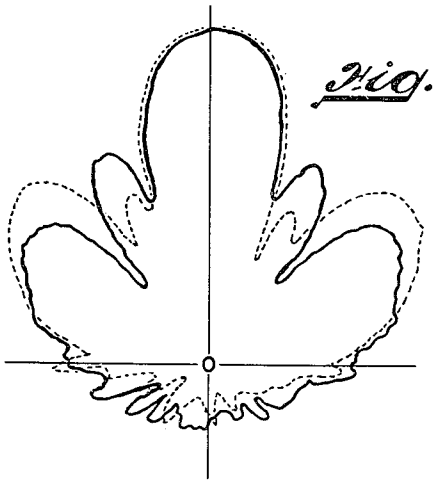


Fig. 2

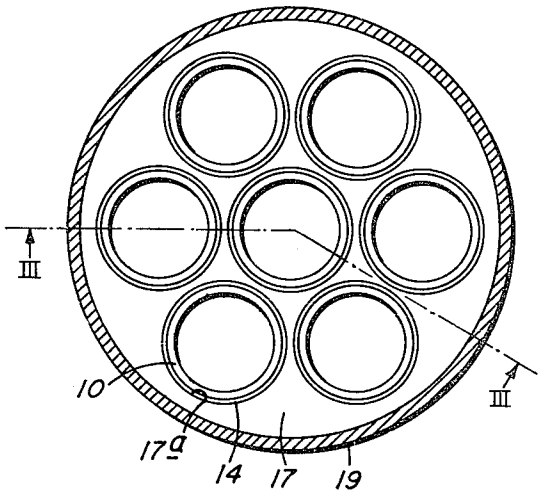


Fig. 3

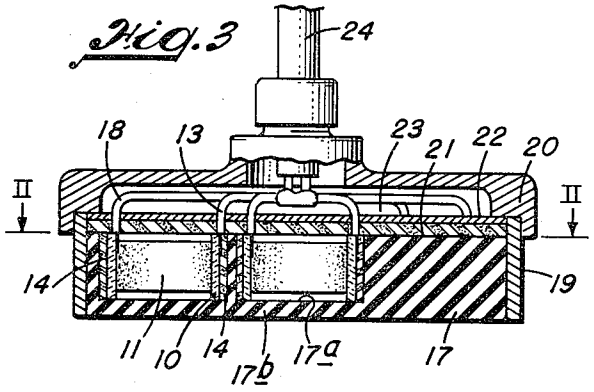


Fig. 4

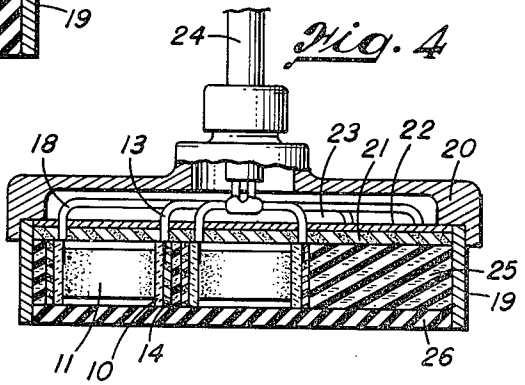
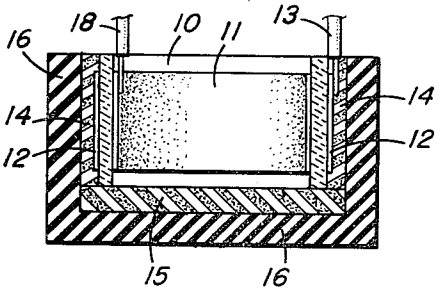


Fig. 1



INVENTOR.
Leon W. Camp
BY
Ellsworth
ATTORNEY

United States Patent Office

2,746,026

Patented May 15, 1956

2,746,026

HALF WAVE ANNULAR TRANSDUCER

Leon Walton Camp, Glendale, Calif., assignor to Bendix Aviation Corporation, North Hollywood, Calif., a corporation of Delaware

Application August 14, 1953, Serial No. 374,211

6 Claims. (Cl. 340—8)

This invention relates to transducers of the radially vibratile ring type in which the inner surface of the ring is exposed to a liquid medium by which waves are transmitted or received through one end of the ring. Such transducers are particularly useful in underwater sound transmission and reception at ultrasonic frequencies, although their use is not limited to any particular frequency or fluid medium.

An object of the invention is to increase the efficiency and reduce the cost and weight of transducers of the general type described.

Other more specific objects and features of the invention will appear from the description to follow.

As heretofore constructed, transducers of the type referred to have been closed at the rear end by a massive backing member, and the axial length of the ring has been made one-quarter wave length of sound in the liquid medium contained within the ring at the resonant frequency of the latter. Such transducers are efficient and practicable but are heavier and more expensive than they would be if the massive backing member could be eliminated. Heretofore, the backing member has been considered a necessary adjunct to obtain good acoustic efficiency, and its thickness, for best efficiency, should be one-quarter the wave length of sound in it at the operating frequency. The wave length decreases with an increase in the density of the material, but even with a dense metal such as lead the backing plate should have a thickness of 0.125 in. for a transducer operating at 50 kc. Such a plate constitutes a substantial portion of the total weight of the transducer and adds materially to its cost. At lower frequencies it becomes increasingly heavy.

In accordance with the present invention, the massive backing plate can be eliminated and the efficiency actually improved by making the vibratile ring one-half wave length long, and substituting for the massive backing plate a body of substantially less density than the liquid medium within the ring. Where the liquid medium is water or other substance of similar acoustic transmission properties, the backing body may be a gas or material having essentially the acoustic properties of gas, such as air cell rubber or the equivalent. The thickness of the backing member is preferably approximately 0.125 inch, but it is not critical.

The new construction has proved to have higher acoustic efficiency and better directional characteristics than equivalent quarter wave transducers employing massive backing plates. Although the length of the vibratile rings is doubled, that is not a serious objection in most underwater transducers, either with respect to cost or bulk, and it is more than compensated for by the elimination of the weight and cost of the backing plate.

Both the present invention and the prior art devices depend upon reflection of sound at the rear end of the ring or cylinder to augment the sound energy at the front end and to prevent radiation or reception at the rear end. Sound reflection is produced by a change in acoustic impedance and is proportional to the magnitude of the change, and the reflected wave differs in phase 180°, depending upon whether the reflection results from an increase or a decrease in impedance. Whereas the prior art devices produced the reflection by providing a body of higher impedance at the end of a quarter wave length cylinder or ring, the present invention produces it by a body of lower acoustic impedance at the end of a half wave length cylinder or ring.

A complete understanding of the invention may be had from the following detailed description, read in connection with the drawing in which:

Fig. 1 is a longitudinal section through a simple single-element transducer in accordance with the invention;

Fig. 2 is a cross section taken in the plane II—II of Fig. 3, showing a seven-element transducer;

Fig. 3 is a section taken along the line III—III of Fig. 2;

Fig. 4 is a view similar to Fig. 3 but showing a modified construction; and

Fig. 5 is a polar diagram showing the directional characteristics of a transducer in accordance with the present invention and a corresponding prior art (quarter wave) transducer.

Referring to Fig. 1, the invention in its simplest form may comprise a radially vibratile ring member **10** open at one end and exposed at its inner surface through the open end to the liquid medium through which sound is to be transmitted or received. This ring **10** may be a barium titanate ceramic having electrodes **11** and **12** on its inner and outer surfaces, respectively, connected by leads **13** and **18** to a suitable transmitting or receiving circuit. Such a ring expands and contracts circumferentially when alternating current is applied to its electrodes **11** and **12**, and if the frequency of the current corresponds to the mechanical resonant frequency of the ring, it is capable of vibrating at relatively large amplitudes. The vibratile ring member may be of the magnetostrictive type if desired, since the present invention relates to the dimensions and acoustic setting of the ring rather than to its specific electromechanical nature.

The outer surface of the ring **10** to which the electrode **12** is attached is acoustically shielded by a layer of material **14** of low acoustic impedance as compared to that of the liquid within the ring, so that the major portion of the sound emanating from the outer surface is reflected. Likewise, the rear end of the ring is closed by a layer or wall **15** of a material having a low acoustical impedance. Both the member **14** and wall **15** may, in practice, consist of air cell rubber or the equivalent. To provide mechanical support for the assembly and further shield the outer and rear surfaces acoustically from the water or other medium in which the unit is immersed, a cup-shaped case **16** of some acoustic insulating material, such as corprene, may be provided.

The essential feature of the present invention resides in making the ring or cylinder **11** of axial length equal to one-half wave length of sound in the liquid medium within the ring at the operating frequency and closing the rear end of the ring with the wall **15** of low acoustic impedance. It is found that this produces a higher efficiency at lower cost and with less weight than the prior art transducers in which the length of the ring **10** was one-quarter wave length and a massive wall, usually of metal, was employed in place of the wall **15**.

Although the invention may be employed in a single unit device as shown in Fig. 1, it is usually preferable to employ an array of individual units in order to increase the power capacity and improve the directional pattern. A transducer containing such an array of units is shown in Figs. 2 and 3. Here each unit **10** corresponds exactly to the unit **10** of Fig. 1, there being seven of these units positioned as shown in Fig. 2. Each ring **10** is

surrounded with a ring **14** of low impedance acoustic material, the same as in Fig. 1, but the seven rings **10** and their associated insulating rings **14** are supported with respect to each other in a single member **17** of acoustic rubber or the like having recesses **17***a* in its rear face for receiving the rings **10** and their surrounding rings **14** and retaining them in position with respect to each other. The member **17** also defines thin front wall sections **17***b* overlying each ring **10** and constituting a sound window through which sound is transmitted from a liquid, such as a suitable oil, contained within the rings **10**, and the water or external medium through which sound is to be transmitted or received. The body **17** may be supported by an annular frame **19** of metal or other relatively rigid material which, in turn, is supported by a back wall member **20**. The rear ends of the rings **10** are all closed by a single layer or wall **21** of material, such as air cell rubber, having a low acoustic impedance and which performs the function of the layer **15** in Fig. 1. This layer **21**, which is usually of low mechanical strength, is mechanically supported against the body **17** and the rear ends of the rings **10** by a relatively thin wall **22** of some material having substantial mechanical strength, such as steel. The leads **13** and **18** from the units **10** may be brought through the walls **21** and **22** into a cavity **23** defined between the walls **20** and **22**, where they may be connected together and extended through a suitable cable **24** attached to the rear wall **20**.

The modified construction shown in Fig. 4 is identical in all respects to that shown in Fig. 3, except that two layers **25** and **26** of different materials are substituted for the single body **17** in Fig. 3. The body **25** is of thickness equal to the axial length of the vibratile rings **10** and encloses them. This body **25** may be of some relatively rigid acoustic material, such as corprene. The wall **26** functions as a sound window to acoustically couple the liquid within the transducer to the external liquid and should be of a rubber or similar material having substantially the same sound transmission properties as water.

In both Fig. 3 and Fig. 4, all free space within the transducer may be filled with the same oil or other liquid which constitutes the liquid medium filling the rings **10**.

The following table shows the relative acoustic characteristics of a transducer of the type shown in Fig. 3 and a prior art transducer identical therewith, except that the rings **10** are quarter wave length and the backing member **21** is of a dense material such as lead or steel:

	Quarter Wave Cavity	Half Wave Cavity
f_r	26.3	26.1
S	−83.2	−81.8
T	99.3	100.8
Q_e	8.4	7.8
Q_m	8.4	7.7

Where:

f_r is the natural resonant frequency in kilocycles of the ceramic ring;

S is the voltage, measured in decibels above 1 volt, developed across the open terminals of the transducer when it is in a sound field of pressure one dyne/cin^2;

T is the sound pressure developed at one meter distance from the transducer in decibels above one dyne/cin^2 with one ampere into the transducer;

Q_e is the ratio of the reactive to the resistive impedance component;

Q_m is given by

$$Q_m = \frac{f_r}{f_2 - f_1}$$

where f_2 and f_1 are the half power frequencies above and below the resonant frequency.

The table shows that as compared to the quarter wave prior art transducers, the new half-wave transducer has approximately 20% improvement in efficiency, a somewhat broader band width, and a slightly lower electrical Q. All of these features are definitely advantageous in the operation of an underwater transducer.

The improvement in directional characteristics of the present transducer, as shown in Fig. 3, relative to the characteristics of a corresponding prior art quarter wave transducer is shown in the polar diagram of Fig. 5, in which the solid line shows the characteristic of the present half wave transducer and the dotted line shows the characteristic of the corresponding prior art quarter wave transducer. It will be observed that the present transducer approaches the action of a vibrating piston more closely than does the quarter wave transducer, and produces a superior pattern with lower secondary lobes.

Although for the purpose of explaining the invention, a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the exact details shown and described.

I claim:

1. In a transducer for translating sound waves in a liquid body into electrical waves in an electric circuit and vice versa: a hollow, generally cylindrical, open-ended radially vibratile member of electromechanically responsive material and means electrically responsive to radial vibration of said member for electrically coupling it to said electric circuit; means, including a sound-transmitting effectively liquid medium within said member in contact with the inner surface thereof, defining a sound transmission path from said inner surface to said liquid body through one end of said member; and means of substantially less acoustic impedance than said liquid medium closing the other end of said member, said member being of axial length substantially equal to one-half wave length of sound in said liquid medium at the natural frequency of radial vibration of said member.

2. A transducer according to claim 1 in which said means closing the other end of said member has substantially the acoustic impedance of a gas.

3. A transducer according to claim 1 in which said means closing the other end of said member comprises a wall of air cell rubber in contact with said medium within said member.

4. A transducer according to claim 1 including an array of said vibratile members in side-by-side relation; supporting means for said members comprising a first layer of acoustic insulating material having cavities the walls of which are in supporting engagement with the peripheral outer surfaces of said members; said means closing said other ends of said members comprising a second continuous layer of acoustic insulating material lying against the said other ends of said members and the corresponding face of said first-mentioned layer.

5. Apparatus according to claim 4 including a relatively rigid thin wall lying against the outer face of said second layer of insulating material and mechanically supporting it against said members and said first layer.

6. Apparatus according to claim 5 including a front wall member of substantially the same acoustic impedance as said liquid medium lying against said one end of said members and the corresponding face of said first-mentioned layer.

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