May 9, 1950 K. W. McLOAD 2,506,608

PIEZOELECTRIC TRANSDUCER

Filed July 23, 1947

FIG. 1.

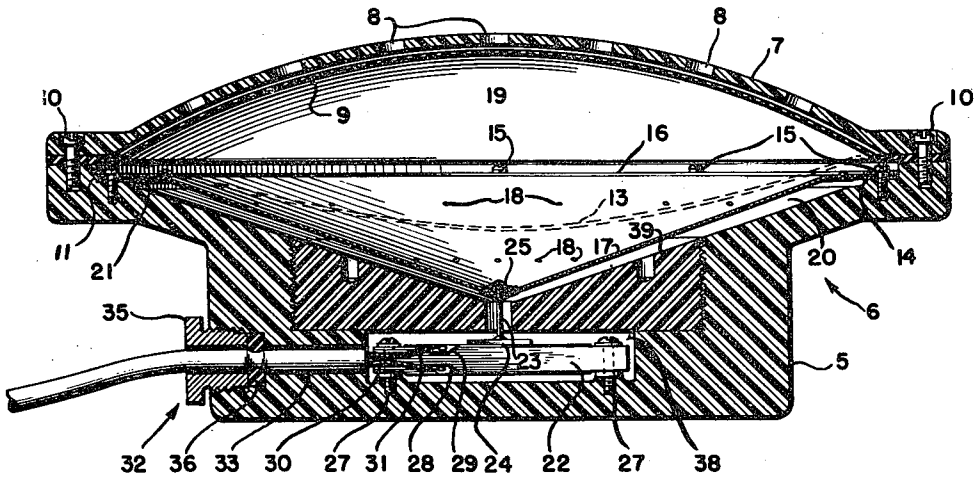
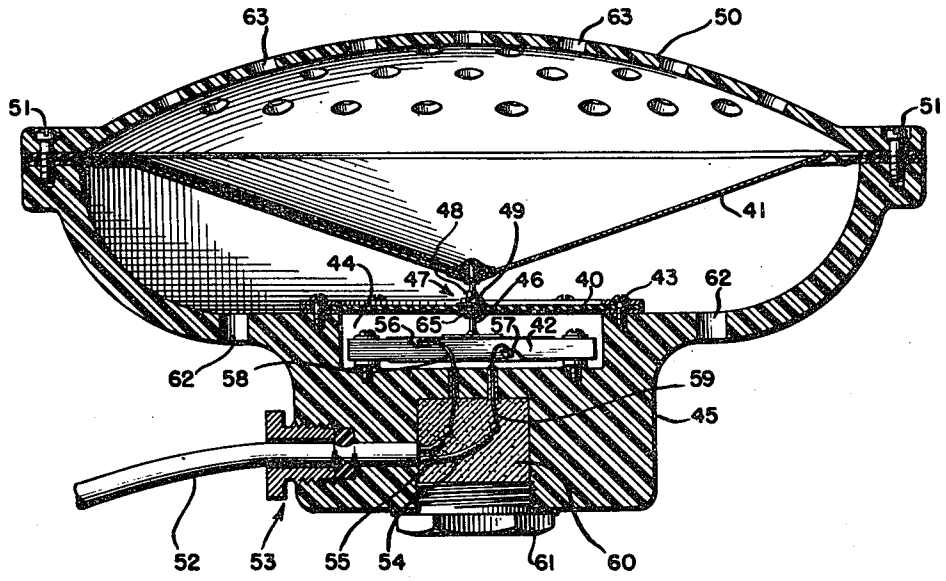


FIG. 2.



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PIEZOELECTRIC TRANSDUCER

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This invention relates generally to acoustic transducers and more specifically to a moisture-proof nonmagnetic device of this character capable of withstanding extremely high pressures such, for example, as the pressure applied to diving apparatus when submerged some distance below the surface of a body of water.

With the development of magnetic responsive mines, there arose the need for new and varied countermine apparatus, one form thereof being nonmagnetic diving equipment which would permit divers to ferret out and destroy such mines without undergoing the hazard of exciting these mines to detonation by reason of magnetic disturbances set up therein by their diving gear.

To provide diving apparatus of this character it was necessary to eliminate therefrom all magnetic material including the magnetic speakers and headphones used generally in such equipment and substitute therefor transducers of the nonmagnetic piezoelectric type. It was found, however, when substituting conventional piezoelectric transducers, that the high pressures to which they were subjected so distorted the cone thereof as to render the device inoperative, and further, when attempting to equalize the pressure on the enclosed side of the cone by providing pressure relief ports within the housing walls thereof, as is the usual practice with electromagnetic devices, the moisture admitted to the casing in this manner soon destroyed the piezoelectric qualities of the crystal element therein.

It is an object of the present invention to provide a new and improved nonmagnetic acoustic transducer that is impervious to moisture and capable of withstanding high hydrostatic pressures.

It is a further object to provide a piezoelectric transducer wherein a pressure responsive diaphragm is operative to communicate pressure to the interior of the transducer but adapted to prevent the entrance of moisture therein.

It is a still further object to provide a piezoelectric transducer wherein the air volume about the piezoelectric element therein is reduced to a minimum thereby to reduce the movement of a diaphragm operative to communicate the surrounding hydrostatic pressure to the air volume.

It is a still further object to provide a transducer of the piezoelectric type wherein the pressure on either side of the cone thereof is equalized by means of perforations provided in the surface of the cone for the passage of gas therethrough.

A further object is to provide a new and improved piezoelectric transducer wherein the cone and piezoelectric element are adapted to be protected from moisture by a moisture impervious diaphragm arranged thereover.

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A still further object is to provide a piezoelectric transducer wherein the crystal element therein is hermetically sealed from the voice cone by means of a resilient diaphragm interposed between the element and the cone.

Additional objects, features, and advantages of the present invention are those residing in and relating to the novel construction and arrangement of the elements thereof, as will more clearly appear from the following description, reference being made to the accompanying drawings of which:

Fig. 1 is a view partly in section and partly in elevation of the preferred embodiment of the invention; and

Fig. 2 is a view partly in section and partly in elevation of an alternate form of the invention.

According to the preferred embodiment of the invention, disclosed in Fig. 1, the housing 5 of the transducer generally designated 6 is formed preferably as a casting from material such as plastic, to which is secured in a manner to close the open side thereof, a protective cover or plate member 7. This protective plate 7 is perforated at 8, or may be otherwise suitably formed, to permit acoustic pressure signals to pass therethrough to or from the resilient diaphragm member 9 arranged beneath the plate and secured to the housing by screws 10 employed to secure the plate thereto. The diaphragm 9 is operative to communicate acoustic pressure signals to or from the interior of the housing 5 while hermetically sealing the interior thereof against moisture. The diaphragm is preferably preformed to normally maintain the position indicated adjacent the cover 7 but adapted when forced inwardly responsive to a predetermined increase in pressure being applied to the outer surface thereof to assume the approximate position within the housing as indicated by the dashed line 13.

Arranged beneath the diaphragm 9 and secured to flange 14 of the housing by screws and washers 15 and 16 respectively, is a cone 17 preferably of paper and having therein a plurality of small pin point perforations 18 through which gas may pass from volume 19 into volume 20 at such time as the diaphragm 9 is driven inwardly to reduce volume 19 responsive to a greater external pressure thereagainst. This interchange of gaseous pressure through the diaphragm enables a uniform or equalized static

pressure condition to be maintained about cone 17 enclosed within the housing regardless of the pressure being applied to the outer surface of the transducer.

Provided in cone 17 adjacent the attached rim portion 11 thereof is a plurality of annular corrugations 21 whereby the stiff or rigid cone section 17 thereof may be vibrated freely in an axial direction when driven from the point thereof by the transducer element 22 connected thereto by the shaft 23 which is cemented in the usual manner to the element and cone at points 24 and 25 respectively.

The transducer element 22 may be one of several well known crystals having piezoelectric qualities such, for example, as quartz or Rochelle salts and may be mounted in any suitable manner for operating, as known in the art, either as a bender or a twister element. The arrangement of the crystal illustrated in Fig. 1 provides that it be secured to the housing by screws 27 in a manner to operate therein as a one strip bender element, however, it is apparent that, if desired, a multiple strip element may be used such, for example, as a "Bimorph" variety thereof.

Electrical connection is made with the element by means of the metallic plates 28 and 29 generally in the form of foil secured to the pole faces of the element in the conventional manner by a suitable bonding agent such, for example, as an electroconducting cement. Leads 30 and 31 enter the housing through the gland nut assembly generally designated 32 and pass through the bore 33 provided therefore in the housing to make connection in the usual manner with plates 28 and 29 respectively. The nut 35 of gland assembly 32, when tightened, is adapted to compress the resilient washer 36 about the cable and thereby prevent moisture entering the housing between the cable and bore 30.

In the operation of the device let it be assumed for the purpose of description that the transducer is connected in the usual manner in an underwater communicating system for operation therein as a speaker, it being apparent to those skilled in the art that a device of this character is operative either as a speaker or as a microphone depending upon the manner in which the apparatus is connected in the communication circuit.

As the diving apparatus, including the transducers, is lowered within a body of water, the gradually increasing hydrostatic pressure now being applied to the outer surface of the transducers slowly forces the diaphragm 9 thereof inwardly in the direction of cone 17 thereby causing a reduction in volume 19 that would normally compress the gas therein to such an extent that, if left uncompensated, would soon distort and rupture cone 17, thereby to render the device inoperative.

In the present invention, however, instead of an increase in pressure against the concave surface of the cone 17 as volume 19 is reduced, a portion of the gas therein flows out through the relief ports 18 in volumes 20 and 38 thereby to equalize the pressure being applied to the two sides of the cone and allow the member to remain in an unbiased free operating position regardless of the pressure being applied to the outer surface of the transducer.

To reduce the quantity of gas compressible within volumes 19 and 38, thereby to reduce the inward movement of the diaphragm 9 in the direction of cone 17 when the transducer is operating at pressures several times that of the atmosphere, a concave plug member 39 is adapted to threadedly connect with the housing in a manner to reduce the air volume behind the cone to a minimum. It will be apparent, however, to those skilled in the art to which such devices appertain that numerous other methods may be employed to reduce this air volume such, for example, as by casting a suitable wax, or the like, in the space not occupied by other elements of the device.

As the apparatus is withdrawn from the water and the pressure thereagainst is relieved, the gas within volumes 20 and 38, now under the greater pressure, will flow in the reverse direction through the cone 17 and into volume 19 as the diaphragm 9 moves to normal position adjacent the cover plate 7.

As cone 17 vibrates responsively to the energization of element 22 rigidly connected therewith, the acoustic pressure signals projected outwardly from the cone, set up a corresponding vibration in diaphragm 9, the gaseous medium within volume 19 operating to communicate the pressure signals from the cone to the diaphragm with negligible loss in pressure intensity by reason of the perforations 18 in the cone. The diaphragm, as signals are received thereby, projects the signal out into the gaseous medium surrounding the transducer in substantially the same manner as would the cone if arranged in a similar manner within the wall of the housing.

The present arrangement of the invention permits the moisture sensitive elements of the device, namely the element 22 and cone 17, to be at all times hermetically sealed within the housing yet free to operate in the conventional manner to receive or transmit acoustic signals, as the case may be, notwithstanding that the device is operating under pressures several times that of the atmosphere.

Fig. 2 illustrates an alternate form of the invention wherein a resilient diaphragm member 40 is arranged between an unperforated cone 41 and piezoelectric element 42, the diaphragm being secured to the housing by screws 43 in a manner to enclose and hermetically seal the element within a recess 44 provided therefor in the housing body 45, while leaving the cone member exposed to the atmosphere to vibrate freely in response to movement of the element rigidly connected therewith by shaft 46.

A connection is made between the diaphragm and shaft by the clamp assembly generally designated 47 which includes a threaded tubular bolt 48 having a flanged portion 65 adapted to be drawn to the diaphragm for connecting therewith in a watertight manner as the nut 49 is tightened on the bolt. A seal is made between the shaft and bolt by flowing solder or cement therebetween before the cone is cemented to the shaft in the usual manner. The cone is clamped along the periphery thereof between the housing and the cover plate 50 which is fastened thereto by screws 51.

Electrical impulses are communicated to or from the piezoelectric element 42 by way of the two conductor cable 52 that enters the housing through the gland nut assembly generally designated 53, the conductors 54 and 55 of the cable making connection with the terminals 56 and 57 of the element through leads 58 and 59 respectively. Electrical connections are made between the cable and leads within a recess 60 provided

therefor in the base of the housing, the recess subsequently being filled with wax and closed by the threaded plug member 61. The wax within the cavity first serves to insulate the leads from each other and secondly to reduce the air volume about the piezoelectric element 42.

For the reason that in the present embodiment of the invention the cone member is at all times in communication with the surrounding atmosphere admissible thereto through ports 62 and 63 in housing 45 and cover plate 50 respectively, it is preferable that the cone be formed from moisture resistant material such, for example, as plastic or wax impregnated paper so that the dampness to which the cone is frequently subjected will not distort or alter the conical configuration thereof.

When operating as a microphone, for example, acoustic pressure signals received by the cone set up vibrations therein proportional to the amplitude of the signals. These vibrations are transmitted through the rigid rod member 46 to the crystal element 42 and set up corresponding vibrations therein which cause an electrical signal to be generated within the crystal proportional to the amplitude of the vibrations. The electrical signal is communicated to the amplifying circuit of the system (not shown) through the leads 58 and 59 and conductor cable 52.

It is apparent to those skilled in the art to which the device relates that the diaphragm 40 thereof will be forced inwardly into the recess 44 to thereby compress the air therein when the pressure against the outer surface of the diaphragm is substantially increased, such as would be caused when the device is employed in diving equipment and lowered therewith several feet below the surface of a body of water. However, the effect of this biasing pressure on the acoustic response of the transducer is negligible, the diaphragm still being sufficiently resilient, even when distorted by a relatively great external pressure applied thereagainst, to respond to the vibration of the cone and element.

While the invention has been described with reference to two examples thereof which give satisfactory results, it is to be understood by those skilled in the art to which the invention pertains, after understanding the invention, that various changes and modifications may be made therein without departing from the spirit and scope of the invention, and it is intended therefore, in the appended claims to cover all such changes and modifications.

The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. A piezoelectric electric transducer of the character disclosed for use with nonmagnetic diving apparatus comprising, in combination, a nonmagnetic housing having an opening therein, an initially outwardly extending concavo-convex flexible diaphragm closing said opening thereby to enclose a volume of air within said housing, said housing having an inverted conically formed surface terminating in a centrally arranged recess of cylindrical configuration, a cylindrical filler plug threadedly arranged in said recess and having a conically formed surface adapted to form a continuation of said conically formed surface of said housing and to form a small chamber in said housing beneath said filler plug, a piezoelectric element disposed in and substantially filling said chamber, a cone having the configuration of said conically formed surface and continuation thereof and secured in close adjacency therewith to said housing, the concave surface of said cone facing the inner surface of said diaphragm, said cone having a plurality of perforations therein whereby the air pressure on opposite sides of the cone is equalized as the diaphragm is flexed inwardly in response to increases in static pressure applied to the outer surface thereof, said filler plug having an orifice extending therethrough at the apex of said conically formed surface therein, and a driving bar connecting said element with said cone and movable in said orifice whereby acoustic pressure signals are transmitted between said element and said flexible diaphragm.

2. A piezoelectric transducer of the character disclosed comprising a housing having an opening therein, a concavo-convex flexible diaphragm for closing the opening initially with the diaphragm extending outwardly of the housing thereby to enclose a volume of air within the housing, means for securing the diaphragm to the housing in air-tight relation therewith, said housing having a recess therein, a piezoelectric element arranged in and substantially filling said recess, electric conductor means for said element extending outwardly through said housing and arranged in air-tight relation therewith, said housing having an inverted conically formed surface facing said diaphragm, a closure for said recess having an inverted conical surface forming a continuation of said conically formed surface in the housing and having an aperture at the apex of said conically formed surface therein, a cone conforming to said conical formed surfaces and secured in close adjacency therewith to said housing, said cone having perforations therein whereby the air pressure on opposite sides of the cone is equalized as the diaphragm is flexed inwardly by an increase in the external static pressure, a driving connection between the element and the cone movable in said aperture whereby acoustic pressure signals received by the cone from said diaphragm are communicated to the surface of said element.

3. A piezoelectric transducer of the character disclosed for use with nonmagnetic diving apparatus including, in combination, a dish-shaped nonmagnetic housing, an initially concavo-convex diaphragm closing the open side of said housing in moisture proof relation therewith, a concavo-convex protective shield arranged over said diaphragm and having perforations therein whereby acoustic pressure signals may be communicated to the outer surface of said diaphragm, a cone secured about its periphery within said housing and arranged to present the concave surface thereof to the concave surface of said diaphragm, the inner surface of said housing conforming to the contour of the convex surface of said cone and arranged in close adjacency thereto, said inner housing surface terminating centrally in an annular recess adjacent the apex of said cone, an annular filler plug threaded into said recess and having a concave surface therein conforming to the contour of said cone and arranged in close adjacency thereto to form a continuation of said housing inner surface and a chamber in the housing beneath said plug, a piezoelectric element arranged in and substantially filling said chamber, said plug having a central opening, a

driving connection movable through said opening in the annular plug for connecting said element with the apex of said cone whereby acoustic signals are transmitted from said cone to said element in response to acoustic pressure signals transmitted to the cone from said resilient diaphragm, said cone having a plurality of perforations therein whereby the air pressure on opposite sides of the cone is equalized as the diaphragm is flexed inwardly in response to increases in the static pressure applied to the outer surface of the diaphragm.

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