This invention relates to underwater transducers of the type for converting electrical signal to sound waves or sound waves to electrical signals.

The vibratory surface of a transducer usually drives, or is driven by a motor of the electromagnetic or by electrostrictive type or by magnetostriuctive ceramics. The performance of all such transducers is unfortunately affected by depth of submergence, and they are generally quite heavy, quite fragile and difficult to handle and stow on the deck of a ship.

The object of this invention is to provide an improved transducer.

A more specific object of this invention is to provide a transducer which is light in weight, small in size, rugged in construction, convenient to handle and stow and is independent of hydrostatic pressure.

The object of this invention is attained by a long rubber-like tube resembling a garden hose, but of a material having relatively high magnetic permeability. The wall of which containing particles of magnetic material. A magnetic core is placed within the tube and extends diagonally across the interior of the tube, the pole faces of the core being shaped to conform to the interior walls of the tube but terminating short of said wall so that flexure of the wall will measurably vary the reluctance of the magnetic circuit including the core and the wall. A coil inductively coupled with the core will generate a signal voltage as the walls are flexed by pressure waves. Alternatively, the tube walls can be driven in and out when electrical power is applied to the coils.

Other objects and features of this invention will become apparent to those skilled in the art by referring to the specific embodiments proposed in the following specification and shown in the accompanying drawings in which:

FIG. 1 is a partly sectioned perspective view of one embodiment of the transducer of this invention;

FIG. 2 is a view of an operational transducer embodying this invention, and

FIG. 3 is a cross-sectional end view of a transducer with a rectangular cross-section.

Wall 10 in FIG. 1 is shown as circular tube. The wall of the tube is rubber-like in that it is flexible and is characterized by its content of occluded ferromagnetic particles. The particles may be pure iron filings or granules of iron compounds. The percentage content of the particles in the rubber base is sufficient to provide a magnetic permeability that is considerably above unity. The thickness and stiffness of the wall 10 is to be consistent with the use to which the transducer may be put. The wall would be heavier and less compliant if the transducer is to be used for the projection of considerable power into the surrounding water. Less weight and greater compliance would be the desideratum for sound detection of depth of submergence. Depth of submergence, also would be an important factor in stiffness design. If the transducer is to be used as a hydrophone, and shallow depths only involved, the wall of the tube would be thin and compliant. The length of the tube will be dictated also by the use to which the transducer may be put. If, for example, the end of the transducer is weighted and is to extend vertically to great depths in the ocean, the tube length may be measured in hundreds of feet. Alternatively, the transducer may be short and used as a point source of sound waves.

Extending diagonally across the interior of the circular tube is the core member 11. The core member is of extruded plastic or rubber containing iron particles and may have one, two or more pairs of poles. If two pairs of poles are employed the core would be cross-shaped in cross-section and have four pole faces 21, 22, 23 and 24 as shown in FIG. 1. The pole face at the outer ends of the arms of the cross as preferably extended and rounded to conform to the interior surface of tube 10. A winding 15 is placed on each leg of the core, and the terminals of the windings are connected in series aiding or parallel aiding, depending upon the impedance desired.

Spacers 20 of nonmagnetic material are placed between each pole face and the interior wall of the tube to establish the median air gap of the magnetic circuit.

If the wall between the spacers is flexed inwardly or outwardly, the air gap in the magnetic circuit containing the core and tube wall is changed. A steady magnetic field may be created by either the magnetized particles in the material of the wall at the core, or by a biasing direct current winding on the core. In either case the variable reluctance will change the number of magnetic lines and will induce signal voltages in the windings coupled to the magnetic circuits.

To operate the transducer as a radiation projector it is merely necessary to apply the signal power to the windings 15 which will drive the walls of the tube inward and outward in consonance with the magnetic field. As a receiving hydrophone, the arriving sound waves flex the side walls 10 between spacers 20 which changes the reluctance of the magnetic circuit, which changes the numbers of magnetic lines and induces voltages in windings 15.

It is apparent that the pressure inside and outside the walls of the tube must be substantially equal to prevent no-signal distortion of the tube wall. As the depth of submergence increases the internal pressure in the tube must correspondingly increase. If the end of the tube is weighted and the tube extends vertically downward, the lower end of the tube will be subjected to maximum hydrostatic pressure, and the pressure would be progressively less nearer the surface. According to this invention the internal air pressure is increased by a pressure pump suggested at 26 in FIG. 2 attached to the upper end of the central air duct 12. At the outer or lower end of the transducer the duct 12 communicates with the interior of the tube 10 and the pressure is adjusted so that the wall stands unstressed at the lower high-pressure end. At suitable depth intervals above the lower end a pressure relief valve is placed between the sections to provide for the progressively less hydrostatic pressure. In the embodiment shown in FIG. 1 the relief valve comprises the bulkhead member 16 of a size and shape to substantially plug the tube 10. The band 17 encircles the bulkhead and squeezes the wall of the plastic tube against the bulkhead 16. The band 17 is of elastic material and is of such a length that the pressure applied to the junction between the wall and the bulkhead is predetermined to permit escape of gas or air above a predetermined pressure. That is, the elasticity of the tube, augmented by the elastic band 17 at the bulkhead, permits leakage around the bulkhead from a lower to an upper chamber until the internal pressure equals or exceeds sea pressure by a specified acceptable amount. At the top end of the tube a mechanical compensator, not shown, would cut off the supply through the duct 12 when surrounding sea pressure was properly exceeded.

According to the embodiment shown in FIG. 3 the sensitivity of the transducer may be increased. If the portions of the wall 10 are flattened between the support...
members 20a the compliance of the wall may be materially increased. The core member 11 preferably extends diagonally across the rectangle formed by the tube, and the pole faces 11a are shaped to conform to the rectangular corners of the tube. Now by constructing the walls 10a of relatively thin magnetic material the compliance of the walls may be quite high and in fact the transducer may be adapted for use in air.

Since the core and the tube are of flexible plastic material impregnated with magnetic material, the transducer is flexible and is not subject to breakage even with rough shipboard handling. Each coil 15 and its core may be of any desired length and any desired number of coils 15 may be placed end to end along the tube to provide a long hose-like transducer. Such a transducer can be sunk to any desired depth. The coils may be electrically connected end-to-end or, alternatively, the leads for each coil may be threaded through the duct 12 to the shipboard end so that the phase relations of the signals at the several cores may be predetermined. The long hose-like transducer may be towed behind a fast moving ship with minimum drag and turbulence noise.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings.

What is claimed is:

1. A transducer comprising:
   an elongated tube of flexible rubber-like material,
   the flexible walls of the tube being of a material the magnetic permeability of which is substantially greater than one,
   a magnetic core member within and extending across the interior of said tube, the pole faces of the core being shaped to the interior wall of the tube and terminating short of said wall to define an air gap so that flexure of said wall will measurably vary the reluctance of the magnetic circuit including said core and said wall, and
   a coil inductively coupled with said magnetic circuit so that current in said coil may be a function of the flexure of said wall.

2. In the transducer defined in claim 1, said coil being wound on said core and having lead wires extending to the end of said elongated tube.

3. In the transducer defined in claim 1, said core being of rubber-like material impregnated with paramagnetic particles so that the magnetic permeability of said core is substantially greater than unity.

4. In the transducer defined in claim 1 said tube being substantially circular in cross section and each pole face of said core being spaced from the inner wall of said tube with a longitudinally disposed spacer strip of non-magnetic material to determine an air gap in the magnetic circuit of said tube and core.

5. In the transducer defined in claim 1 said tube being substantially rectangular in cross section and having non-magnetic spacer strips between the tube and core at the corners of the rectangle.

6. In the transducer defined in claim 1 a plurality of core and coil assemblies placed end-to-end in said tube and lead wires from said coils to one end of said tube.

7. The transducer defined in claim 1 having an elongated tube of flexible material, further comprising:
   a duct extending longitudinally through said core and communicating with the interior of said tube at one end of the tube,
   means for coupling an air compressor to the duct at the other end of said transducer for inducting said core to a pressure commensurate with the expected hydrostatic pressure at said one end, and pressure relief valves spaced along said tube to divide the interior of the tube into end-to-end compartments of progressively different pressures.

8. The transducer defined in claim 1 having an elongated tube of flexible material, further comprising:
   a duct extending longitudinally through said core and communicating with the interior of said tube at one end of the tube,
   means for coupling an air compressor to the duct at the other end of said transducer for inducting said core to a pressure commensurate with the expected hydrostatic pressure at said one end, and at least one air pressure relief valve intermediate the ends of said transducer interiorly of said tube to divide said tube into a plurality of end-to-end chambers, the pressure relief valve being adjusted to exhaust the higher pressure air in the end chamber to a predetermined lower pressure in the adjacent chamber.

References Cited by the Applicant

UNITED STATES PATENTS
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