Nov. 24, 1970 W. L. ANGELOFF 3,543,059

FLUTED CYLINDER FOR UNDERWATER TRANSDUCER

Filed Oct. 28, 1968

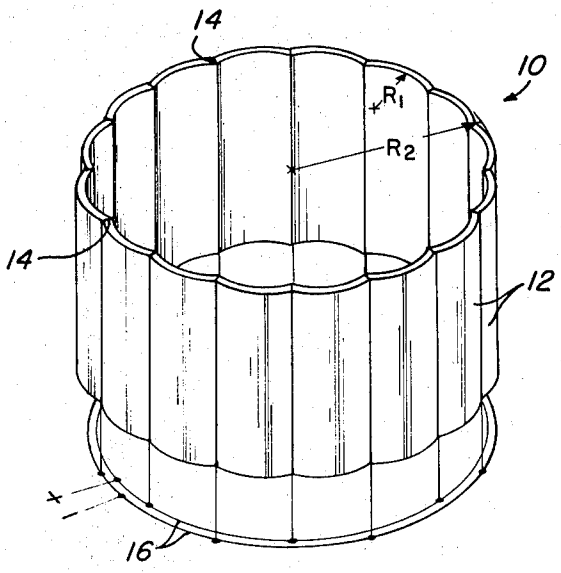


FIG. 1

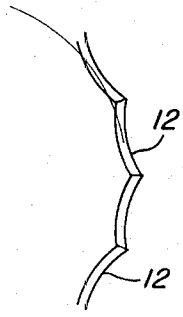


FIG. 2

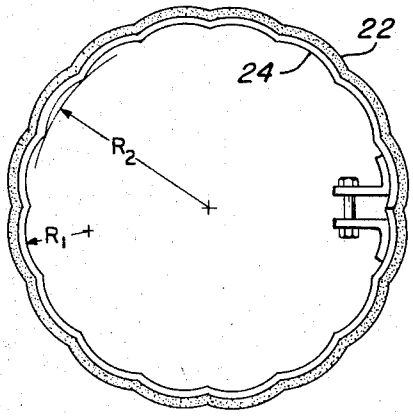


FIG. 3

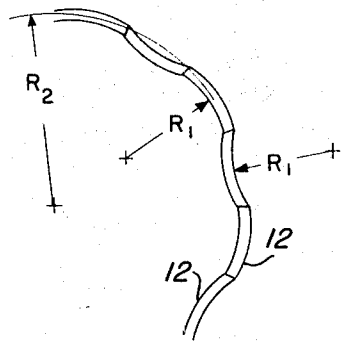


FIG. 4

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United States Patent Office 3,543,059 Patented Nov. 24, 1970

3,543,059

FLUTED CYLINDER FOR UNDERWATER TRANSDUCER

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Filed Oct. 28, 1968, Ser. No. 771,224
Int. Cl. H02k 7/00
U.S. Cl. 310—8.7 4 Claims

ABSTRACT OF THE DISCLOSURE

The walls of a cylindrical transducer are fabricated of slats or staves of electroacoustic material. Each stave is curved in cross section, the radius of curvature of the staves being less than the mean radius of the cylinder. The staves are so arranged and joined, side-by-side, as to increase the circumferential length of the cylinder wall. The cylinder, thus constituted, will be more compliant for a given wall thickness and wall diameter and, hence, will have a lower natural mechanical resonant frequency and will operate at lower frequencies.

STATEMENT OF GOVERNMENT INTEREST

The invention described herein 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.

BACKGROUND OF THE INVENTION

Cylinders of electroacoustic material such as piezoelectric ceramic or magnetostrictive or electrostrictive metals are currently employed because, when free-flooded, they can be operated at any depth, inasmuch as the hydrostatic pressure is equalized at all parts of the cylinder. Unfortunately, the lowest natural resonant frequency of a cylinder is a function of the stiffness which in turn is a function of wall thickness and diameter of the cylinder and cannot be economically reduced below a fairly high value without increasing the diameter to unwieldy dimensions. Likewise, there is a definite limit to the minimum wall thickness to get compliance because of the inherent weakness of most ceramics.

SUMMARY OF THE INVENTION

The objects of this invention are obtained by constructing the cylindrical transducer of staves of the electroacoustic material which staves are joined edge-to-edge to form the cylinder. The staves, or slats, are irregular in cross section, so that when they are joined edge-to-edge, the length of the circumferential path in the cylinder is greater than the mean circumferential diameter of the cylinder. It follows that the ratio of mean diameter to thickness is increased so that compliance and the natural frequency of resonance of the cylinder is correspondingly decreased.

OBJECTS OF THE INVENTION

Accordingly, the principal object of this invention is to produce an improved cylindrical transducer which will operate efficiently at lower frequencies. A more specific object of this invention is to lower the mechanical resonant frequency of a cylindrical transducer.

Other objects and features of this invention will become apparent to those skilled in the art by referring to preferred embodiments described in the following specification and shown in the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of one cylindrical transducer of this invention.

FIG. 2 and FIG. 4 are end views of differently arranged staves.

FIG. 3 is an end view of a cast metal cylinder of this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The cylinder **10** shown in FIG. 1 is fabricated of staves **12**. The staves **12** are relatively long, narrow slats of electroacoustic material and are joined edge-to-edge by adhesives or solder. If each stave is a piezoelectric ceramic, the soldered junctions **14** may contain connections **16** to the signal circuit. Preferably, the ceramic is of a barium titanate or lead zirconate titanate and preferably is polarized during manufacture by electrodes of opposed potential along opposite edges of the slats. Alternate electrodes in the cylinder are connected together and to external circuits. The external circuits may lead to either a transmitter or a receiver.

According to an important feature of this invention, the staves **12**, in FIG. 1, are irregular in cross section, the irregularity comprising a radius of curvature, R_1, which is less than the mean radius of, R_2, the cylinder. The concaved sides of the slats can each be oriented toward the inside of the cylinder as suggested in FIGS. 1 or 3, or toward the outside of the cylinder as suggested in FIG. 2, or the concavity may alternate among these slats as shown in FIG. 4. It follows that the length of the circumferential path through the electroacoustic material is greater than in a cylinder of the same mean diameter with a smooth wall.

It can be shown that the natural mechanical resonant frequency, at which the cylinder will operate, is proportional to the "stiffness" or compliance of the cylinder which in turn is a function of the ratio of the diameter of the cylinder to the wall thickness of the cylinder, water loaded. That is, as the diameter, and the circumferential length of the cylinder wall are increased for a given wall thickness, the natural resonant frequency decreases. The order of magnitude of this ratio, found to be practical in sea operations, is about 30 to 1. If the diameter to wall thickness is still further increased, the end result approaches that of a paper-thin tube or "wet noodle" which of course is mechanically unfeasible. For most ceramics, at present in use in this art, the ratio of diameter to wall thickness should not substantially exceed 30 to 1.

Where greater ruggedness in the cylinder is required than can be provided by ceramic materials, metal may be used. Motion in the cylinder wall as a function of signal voltages may now be produced by magnetostriction. If the cylinder is of sheet nickel or other ferromagnetic metals, the signal can be inductively coupled to the cylinder, as suggested, for example, in the U.S. patent to Green, No. 3,177,382, issued Apr. 6, 1965. In fabricating such a transducer **22**, FIG. 3, a single sheet of metal could be rolled with integral side-by-side flutes and the cylinder then closed with a single seam.

Still another technique of construction found to be satisfactory comprises casting the fluted cylinder. More specifically, metal can be vaporized in an electric arc and blown onto a form of the desired shape. As shown in FIG. 3, the metal layer **24** is sprayed on the split cylindrical form **22**. The discrete metal particles of the layer **24** are quite small and densely packed, and can be laid down in layers which will have low eddy current losses, and yet can have a high coefficient of expansion per unit of signal voltage. The voltage gradient preferably is applied by conductors wound around the laminated coating.

What is claimed is:

1. A cylindrical transducer comprising:

a plurality of elongated slat-like staves of piezoelectric

material, said staves being parallel, circularly arranged, and joined edge-to-edge to form a cylinder having a predetermined mean radius,

electrodes contacting each stave to functionally relate signal voltages on the electrodes and physical distortion of the stave in a circumferential direction, the piezoelectric material of said staves being so selected and polarized and the electrodes on each stave being so disposed that said physical distortion is principally expansion and contraction between the side edges of said staves to cause radial displacement of the wall of said cylinder,

said staves being circular in cross-section between the joints, the radius of curvature of said cross section being uniform and less than said mean radius of the cylinder for increasing the length of the path in the wall, circumferentially of the cylinder, beyond the circumference corresponding to said predetermined mean radius for lowering the natural mechanical resonant frequency of said cylinder, the thickness, curvature and width of said staves being selected to stiffen the cylinder and prevent flexure in the walls of the cylinder.

2. In the cylindrical transducer defined in claim **1**:

said staves comprising piezoelectric ceramics of the type selected from the group consisting of barium titanate, and lead zirconate titanate.

3. In the cylindrical transducer defined in claim **1**:

said staves comprising a sheet of magnetostrictive metal.

4. In the transducer defined in claim **1**:

said cylinder comprising magnetostrictive metal cast to the mentioned shape of said staves.

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U.S. Cl. X.R.

310—9.6, 26; 340—10