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REINFORCED CERAMIC CYLINDRICAL TRANSDUCERS

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Fig. 1.

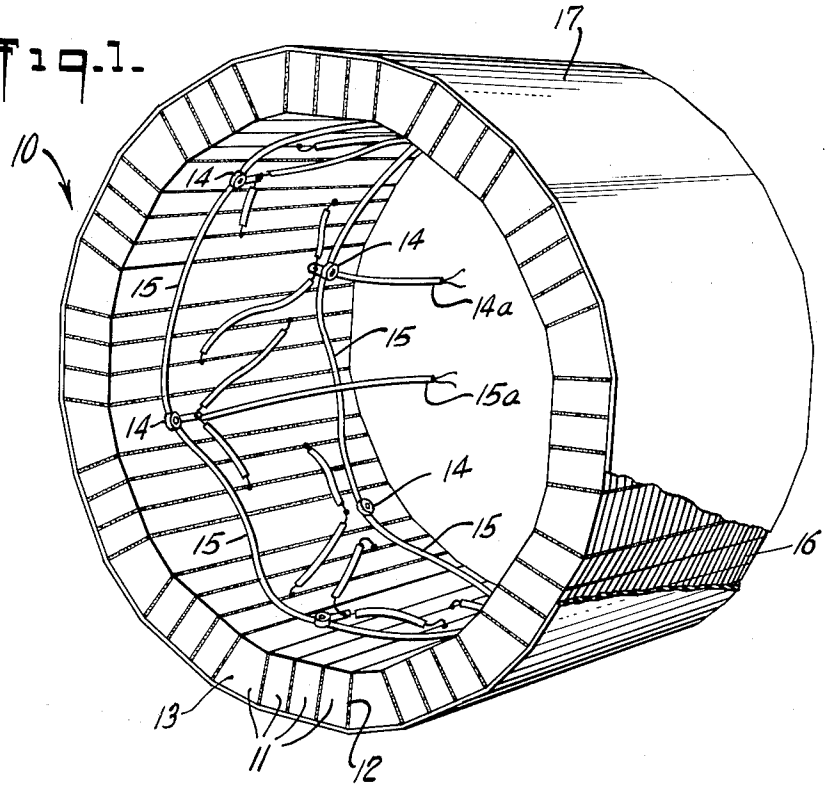


Fig. 2.

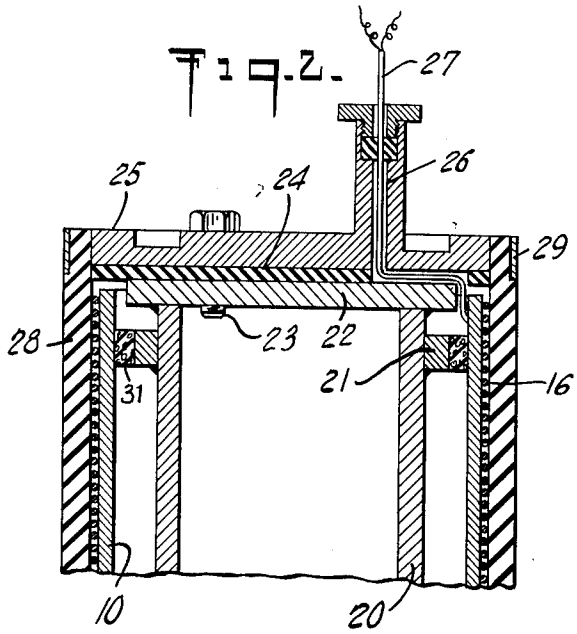
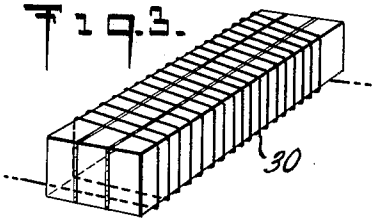


Fig. 3.



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REINFORCED CERAMIC CYLINDRICAL TRANSDUCERS

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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.

This invention relates to improvements in electroacoustic transducers and more particularly to underwater electrostrictive ceramic transducers formed from a plurality of segments joined together in succession.

In United States Patent 3,043,967, there is disclosed an electrostrictive ceramic transducer, including hollow cylindrical transducers, of a plurality of segments joined together in succession. Steel straps under tension surround the succession of transducer segments and electrical insulation is included between the straps and the electrical conductor portions of the segments. The insulation between the straps and the transducer is under compression and is worked when the transducer is energized. If the insulation is penetrated by any of the steel bands, conductor portions may be shorted and the transduced rendered at least partly inoperative.

An underwater transducer requires a water-tight boot. If the boot is assembled over the metal straps, the protuberances on the strap ends bear against the boot and tends to wear local areas of the boot. Also, since the strap ends introduce irregularities on the transducer geometry, the boot cannot be fitted tightly and intimately over the transducer. Therefore, the boot is comparatively loose fitting and a fluid of proper sonic characteristics, such as castor oil, must be introduced into the boot to occupy all the space between the boot and the transducer. If the straps are assembled over the boot, parts of the boot are under compression and are worked during operation of the transducer. The boot material may creep, reducing the strap tension, or may be cut by the straps exposing the transducer to the water.

An object of this invention is to provide a transducer of the type having a plurality of electrostrictive segments joined together in succession, held together under compression and free of the disadvantages discussed above.

Other objects and advantages will appear from the following description of an example of the invention, and the novel features will be particularly pointed out in the appended claims.

FIG. 1 is a perspective view of an embodiment of this invention including a hollow cylindrical electrostrictive transducer having a plurality of segments in succession and a filamentary glass girdle,

FIG. 2 is a section view of an underwater transducer including the embodiment shown in FIG. 1, and

FIG. 3 illustrates this invention applied to a subassembly of the transducer shown in FIG. 1.

There is shown in FIG. 1 a hollow right circular cylindrical electrostrictive transducer **10** substantially identical to the transducer shown in Patent No. 3,043,967, for operation in the circumferential mode, formed from a plurality of stave-like segments **11** bonded together in succession parallel to the axis of the cylinder. The segments **11** include among them a plurality of substantially identical electrostrictive segments **12** and a plurality of substantially identical metal segments **13**; three out of every four consecutive segments are the electrostrictive segments **12** while every fourth segment **13** is of a metal preferably having approximately the same

rho–c characteristic as the electrostrictive segments. Brass is a satisfactory material for metal segments **13**. The metal segments **13** provide conveniently located electrical terminals **14** for the connecting leads **15** and have a trapezoidal or keystone shape in cross-section, whereby when all the stave-like segments **11** are assembled in succession they form a cylinder. Metal segments **13** are less costly than electrostrictive segments **12** and lend themselves more readily to machine shop processes whereby the mounting of electrical terminals **14** thereon and the machining step to provide the keystone shape are relatively inexpensive and devoid of complications. The electrostrictive segments **12** are rectangular in cross-section rather than trapezoidal for two reasons, namely, to reduce cost and to obtain uniform polarization between the electrodes; while not essential, it is preferable to polarize across opposed parallel faces than to polarize across opposed keystone faces.

The electrostrictive segments **12** may be fabricated from any of the well-known electrostrictive ceramic materials, e.g. barium titanate, lead titanate-lead zirconate or others that are marketed commercially. Each segment **12** has electrode coatings on the two opposed radial surfaces which surfaces are normal to the thickness dimension and is polarized between its electrodes in the thickness dimension, which dimension corresponds to the circumferential mode when transducer **10** is assembled. Each segment **12** is marked immediately before or immediately after polarization to indicate the direction of polarization to the assembler mechanic to enable him to orient the segments properly. Consecutive electrostrictive segments **12** are oriented prior to bonding so that the direction of polarization in each pair of consecutive electrostrictive segments is opposite. The reason for this is to simplify the electrical connections since with this arrangement contiguous electrodes of successive segments **12** may be connected in common. Since the electrode coatings extend to the edges of the surfaces which they coat and may even overlap the adjacent surfaces slightly, one end of a conducting lead is readily connected to a pair of contiguous electrodes along the inner scan edge by soldering.

The particular segment-to-segment bonding cement for the transducer is not critical; the cement should be rigid when cured or hardened to ensure good mechanical coupling between segments. A preferable bonding cement is one that can be applied in a fairly thin layer free of air bubbles and that forms a rigid joint comparable in stiffness to the segments joined. An epoxy resin cement that forms rigid bonded joints is satisfactory. A work bench fixture may be used to support the segments while they are bonded to ensure that the last segment assembled in place closes the cylinder. The electrical connections are completed in such manner that the relationship between polarization direction and instantaneous signal polarity is the same in all the electrostrictive segments **12** at every instant so that circumferential elongation and circumferential contractions occur in phase in all of the electrostrictive segments.

Metal segments **13** are not essential in the structural combination illustrated in FIG. 1. All of the segments **11** may be electrostrictive segments and some or all of the electrostrictive segments may be trapezoidal shaped.

The transducer **10** is reinforced and placed under compression in the circumferential direction by filamentary glass **16** in the form of glass serving, glass thread, glass braid, or other, helically coiled about the outer surface of the transducer. The glass is applied in one or more layers. If several units of the glass are coiled onto the transducer side-by-side at the same time, the combination is applied under greater tension. The starting end of the glass is fixed in place either with cement or by

coiling one or more turns over the starting end. The glass is fixed in place with cement **17**. Either the glass is coated with the cement just prior to being coiled about the transducer or the cement is painted over the glass after it is coiled onto the transducer. The cement is not critical. Any of various commercial varieties of epoxy cements that cure preferably at room temperature are suitable for this purpose. Regardless of the glass or cement chosen, the transducer is reinforced. Tougher yet rigid cements and higher quality glass endow the transducer with higher power capacity.

The advantage of the impregnated glass girdle is that it is inexpensive, easy to apply, durable, thin, and nonconducting. It does not significantly alter the outside cylindrical geometry of the transducer and presents an approximately smooth uniform surface so that a waterproofing boot can be applied with ease.

Any of a variety of coiling methods may be used to apply the glass girdle to the transducer. The transducer may be mounted between clamping plates and rotated by a spindle driven by hand or by a power device. The glass may be derived from a spring-loaded spool. As the glass coils onto the transducer it may be guided by a longitudinal feed screw or by a hand operated device so that it is applied helically. The cement is applied to the glass before the glass is coiled onto the transducer.

In FIG. 2, there is shown a waterproofing arrangement for the electrostrictive transducer **10** of FIG. 1. Only one-half the assembly is shown, the other half being substantially the same. A metal tube **20**, provided with spaced rings **21** affixed thereto along the length thereof and metal end plates **22** affixed thereto, and substantially the same length as the transducer **10** is disposed within the transducer. Between the rings **21** and the transducer **10** there is disposed sections of vibration isolating material of unicellular rubber **31** or functional equivalent to support the transducer **10** on the rings **21**. The end plates **22** are formed with threaded holes to receive fastening bolts **23**. A gasket **24** is disposed against the outer face of each plate **22** and a sealing plate **25** is secured to the end plate **22** by the bolts **23** compressing the sealing gasket therebetween. The end plate **25** is provided with a fluid-tight passage **26** for a signal cable that connects with conductor ends **14A** and **15A**. A cylindrical rubber boot **28** radially undersized is stretched and assembled over the reinforced transducer, care being exercised not to trap air pockets between the boot and the transducer. There is no need for castor oil filling if the boot is tight and there are no trapped air pockets between the outer surface of the transducer **10** and the boot. The complete assembly is rendered watertight by means of metal straps **29** at each end tightened sufficiently to compress the ends of the rubber boot firmly against the peripheral edges of sealing plates **25**.

In FIG. 3, there is shown a subassembly of the transducer shown in FIG. 1 wherein several of the segments **12** are bound by a few spaced turns of glass serving **30** under tension cemented in place to the segments. By this expedient, the circumferential compressive stress in the segments may be increased to adjust the electroacoustic properties of the transducer segments. This expedient facilitates design for particular operating characteristics. A further advantage of this expedient is that it facilitates assembly.

It will be understood that various changes in the details, materials and arrangements of parts (and steps), which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

We claim:

1. In an electroacoustic transducer of the type comprising:

(a) a succession of segments in butting relationship, at least one of the segments being electrostrictive for expansion and contraction in the direction between the adjacent segments,

(b) the improvement which comprises a glass serving, coiled about the succession of segments under tension and cemented in place.

2. An electroacoustic transducer as defined in claim **1**, wherein all of said segments are electrostrictive.

3. An electroacoustic transducer as defined in claim **1**, wherein

(a) said succession of segments form a hollow cylindrical transducer and

(b) said coiled glass serving engages and is cemented to the outside cylindrical surface of the transducer.

4. An electroacoustic transducer as defined in claim **3**, wherein

(a) each of said electrostrictive segments includes polarized electrostrictive ceramic and

(b) the direction of polarization extends between the segments on either side thereof, and

(c) wherein each of said electrostrictive segments also includes electrical means for applying electric field energy thereacross in the direction corresponding to the direction of polarization.

5. An electroacoustic transducer as defined in claim **4**, further comprising

(a) a sound transparent water-tight elastomeric boot enveloping the transducer,

(b) said electrical means extending through said boot in water-tight relationship therewith.

6. A hollow cyindrical electroacoustic transducer comprising:

(a) a plurality of electrostrictive stave-like cylinder segments in successive butting relationship, and

(b) a girdle of insulating material defining essentially a circular wall around the segments being a fraction of the thickness in the radial direction of the cylinder segments for continuously applying compressive force to the segments in the circumferential direction, said girdle of insulating material including filamentary glass under tension in the circumferential direction and

(c) a sound transparent water-tight elastomeric boot enveloping the transducer and firmly engaging the outer surface of the girdle of insulating material.

7. A hollow cylindrical electroacoustic transducer as defined in claim **6**, wherein said transducer includes a plurality of subassembly groups of said segments each of which groups are secured with filamentary glass serving under tension cemented in place.

8. An underwater cylindrical electrostrictive transducer comprising:

(a) a plurality of segments cemented in abutting relationship and defining a hollow circular cylinder,

(b) at least some of said segments being of polarized electrostrictive material and the butting faces of which are coated with a conductor layer,

(c) conductor leads joined to the conductive layers,

(d) glass serving coiled under tension about the cylindrical outer surface of the cylinder and cemented in place, and

(e) a sound transparent elastomeric boot enveloping the cylinder and providing a water-tight seal,

(f) the conductor leads extending through the boot.

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