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Whitehouse et al.

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[54] SELF-SUPPORTING TRANSDUCER ASSEMBLY

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**

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[52] **U.S. Cl.** .....**340/9,** 340/8 MM, 340/10, 340/14

[51] **Int. Cl.** **H04b 11/00**

[58] **Field of Search** .....340/8 RT, 8 MM, 9, 14

[56] **References Cited**

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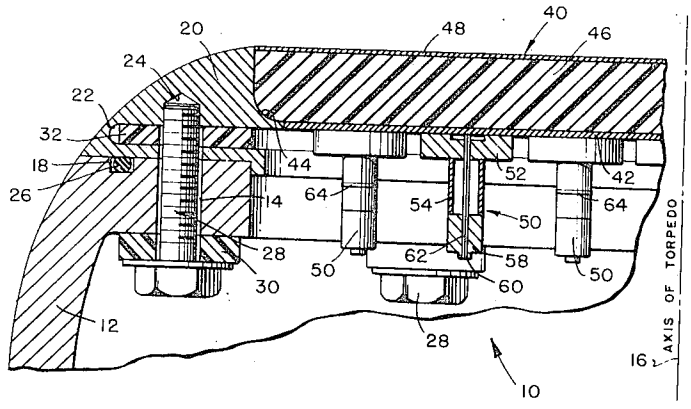
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[57] **ABSTRACT**

A self-supporting transducer assembly, mounted, for example, on the nose section shell of a torpedo, comprising an attachment ring; a diaphragm consisting of: (1) a tension-carrying skin, sealably connected to the inner periphery of the attachment ring, and forming with it a dish-shaped cavity; (2) an acoustically non-refractive and non-reflective composite material in the dish-shaped cavity; (3) a vapor seal, sealably connected to the inner periphery of the attachment ring, serving, with the tension-carrying skin, to confine the composite material to the dish-shaped cavity; an acoustic isolation joint, mounted on the torpedo, for acoustically isolating the transducer assembly from the torpedo; and at least one transducer element bonded directly to the tension-carrying skin.

7 Claims, 2 Drawing Figures



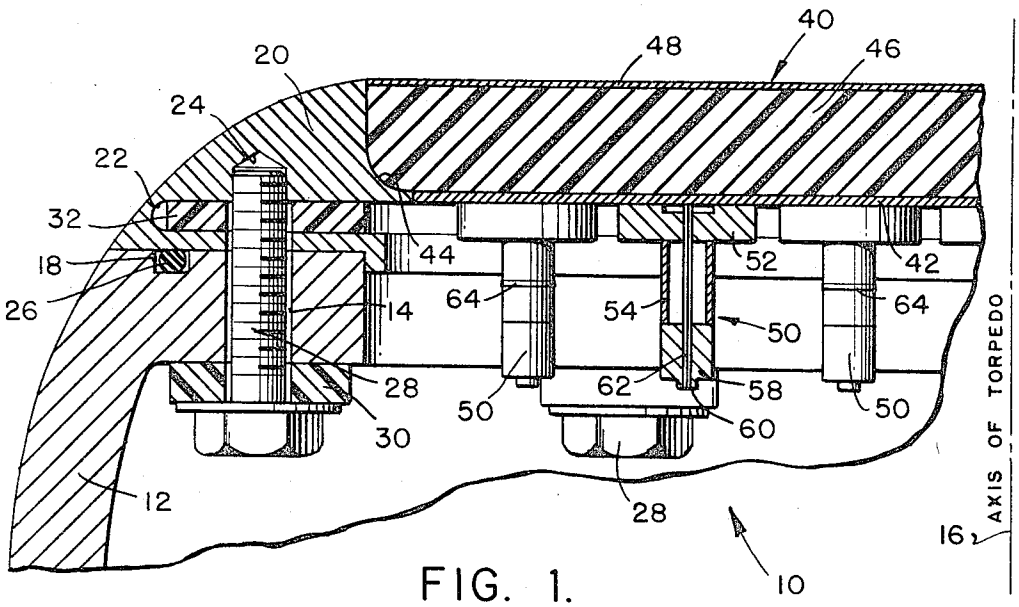


FIG. 1.

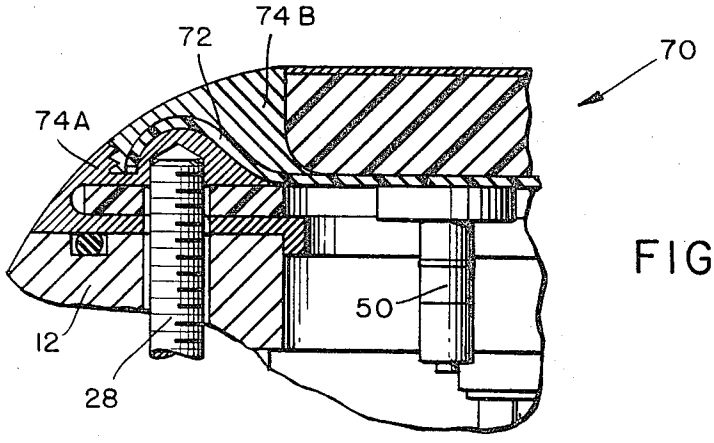


FIG. 2.

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SELF-SUPPORTING TRANSDUCER ASSEMBLY

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 a self-supporting transducer assembly located on the nose cone of a torpedo.

In the field of support assemblies for transducers located on the nose cone of a torpedo and used for detecting and tracking a target, it has been the general practice to back the transducer heads with what is termed a pressure release paper and a pressure backup plate so that the pressure transmitted by a non-self-supporting rubber diaphragm is ultimately transmitted to the somewhat rigid pressure backup plate. The difficulty with this method is that the pressure release paper changes characteristics with increasing pressure and becomes nonfunctional at pressures less than the design depth of the transducer. Any time that a fairly substantial structure has to be put behind the transducer element to hold it, that is to keep it from collapsing, then unavoidably energy is coupled to that structure. This complicates the transducer design because if the backup structure varies as the paper varies, the acoustic tuning changes. The self-supporting structure of this invention is much simpler and has a more efficient transducer design.

In the invention herein described, the face of the transducer element is coupled to the ocean through a diaphragm consisting of a tension-carrying skin, a composite matrix, and a vapor seal, usually another thin skin. The diaphragm is so designed that it has the same acoustic impedance as the seawater. Therefore, as far as the transducer elements are concerned they are "looking" directly into the ocean.

Accordingly, an object of the present invention is the provision of a self-supporting transducer assembly wherein the transducer heads are not restrained by pressure-sensitive backing paper.

Another object is to provide a self-supporting transducer assembly wherein the acoustic and electrical performance is essentially independent of pressure up to the design strength of the composite diaphragm.

A further object of the invention is the provision of a self-supporting transducer assembly including a diaphragm of composite material, with transducer elements attached thereto, which do not have additional, rigid material constraining their heads.

Other objects and many of attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description, when considered in connection with the accompanying drawings, in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIG. **1** is a cross-sectional view through the nose cone of a torpedo, showing a preferred embodiment of the self-supporting transducer assembly.

FIG. **2** is a similar type of view showing another embodiment of the self-supporting transducer assembly.

Referring now to the drawings, wherein like reference numerals designate like or corresponding parts throughout the several views, there is shown in FIG. **1** a self-supporting transducer assembly **10**, mounted, for example, on the nose section shell of a torpedo, including a support **12**, having the form of a shell with an opening in the middle, and could form an integral part of the nose section shell itself. The nose section shell is sometimes called the transducer shell. Its specific function herein is that of a support for the transducer assembly **10**. The support **12** has a plurality of clearance holes **14** aligned in the direction of the axis of the torpedo **16**, and an O-ring groove **18**, encircling all of the clearance holes. An acoustic isolation joint, mounted on the support **12** acoustically isolates the support from the other parts of the transducer assembly **10**, and serves to acoustically isolate the transducer assembly from shell-borne noise. An attachment ring **20**, surrounding the opening in the support **12**, is sealably connected to the support by the acoustic isolation joint. The attachment ring **20** has a plurality of slots **22** with parallel sides which are perpendicular

to the axis **16** of the torpedo and a plurality of tapped holes **24** which are aligned with the clearance holes **14** of the support **12**.

Discussing now in more detail the acoustic isolation joint, an essential element is an O-ring **26** mounted in the groove **18** in the support **12**. A plurality of bolts **28**, one for each hole **14**, draw the attachment ring **20** to the support **12**, and pass through a pair of acoustic isolating washers, a lower washer **30** being located between the head of the bolt **28** and the support **12**, the upper washer **32** being slipped into the slot **22** for each bolt. Lower and upper acoustic isolating washers **30** and **32** may be made of the material called Min-K 2000, manufactured by the Johns-Manville Company of New York, N.Y. This material has a very low acoustic impedance in seawater, lower than that of seawater, and consists essentially of silica particles of sub-micron size in a phenolic binder. A process for making a similar material is fully described in the patent having the U.S. Pat. No. 3,542,723 which issued on Nov. 24, 1970 titled "Method of Molding Aggregate Pressure Release Material," and assigned to the same assignee as the subject application. The bolts **28**, when screwed into the tapped holes **24** compress the two washers **30** and **32** and the O-ring **26**, thereby making a watertight seal between the attachment ring **20** and the support **12**.

It should be pointed out at this point that the diameter of the attachment ring **20** where the upper, acoustic, isolating, washer **32** is positioned is purposely made very thin so that the part of the attachment ring which is between the upper washer and the support **12** or transducer shell can be flexed to some extent. The wall thickness of the attachment ring **20** at its narrowest point is as thin as possible, so that the acoustic coupling around it is minimized and yet just thick enough to prevent it from rupturing or breaking.

The self-supporting transducer assembly **10** further comprises a diaphragm **40** consisting of a tension-carrying skin **42**, sealably connected to the inner periphery **44** of the attachment ring **20**, extending across the opening in the support **12** and forming with the attachment ring a dish-shaped cavity.

In a specific embodiment, the tension-carrying skin **42** consisted of a thin sheet of material having a high-strength and high modulus, such as titanium. The thickness of the titanium would be a factor in determining how rigid the diaphragm **40** was. Stainless steel or a sheet made of boron or glass may also be used as a tension-carrying skin **42**.

The dish-shaped cavity is filled with an acoustically non-refractive and non-reflective composite material **46**, consisting essentially of a predetermined proportion of glass microspheres, filled with a gas at low pressure, and interspersed in a resin base, such as an epoxy resin. The method of making a composite material **46** which is prestressed to a predetermined pressure is completely described in the patent application having the Ser. No. 811,069, dated Mar. 27, 1969, titled "Structural Material with Controlled Gas Entrapment," and assigned to the same assignee as the subject invention.

The relative proportions of the crushed and uncrushed glass and of the base material, consisting for example of an epoxy resin or polyurethane, which comprises the composite matrix **46** will vary to a great extent depending upon the ambient surroundings in which the transducer assembly **10** is to be used.

The material of the diaphragm **40** must meet two rather rigid requirements: (1) it must act as an acoustic window; and (2) it must have enough structural rigidity to avoid collapsing in actual use. The specific proportions required for the material of the diaphragm **40** so that it has the required acoustic properties and the required strength will vary and actually form a family of proportions.

A particularly successful formulation included 150 gm of an epoxy resin known under the trade name of "Epon 815," and manufactured by the Shell Chemical Co., a division of the Shell Oil Co. in New York, N.Y. To this amount was added 10 gm of a hardener known by the trade name of "DEAP" (diethylamine propylamine) and manufactured by the same company, and 10.5 gm of glass microspheres, known under

the trade name of "Glass Bubbles," type B35A, sold by the Reflective Products Division of the 3M Company, in Minneapolis, Minn. In a typical assortment of the microspheres, 90 percent of them will be between 20 and 80 microns in size.

A vapor seal **48**, sealably connected to the attachment ring **20** at the outer side of the shell, serves, with the tension-carrying skin **42**, to confine the composite material **46** to the dish-shaped cavity. The vapor seal **48** may be a thin sheet of metal, for example, aluminum. The vapor seal **48** is needed when the composite matrix **46** is porous and would otherwise absorb the seawater. The characteristics of the composite matrix **46** would change completely if seawater could penetrate it, and this is why a vapor seal **48** may be required. The acoustic density ρ and the acoustic velocity c would change drastically, and therefore the acoustic impedance would change.

When the composite matrix **46** consists of crushed glass in an epoxy resin, it would be a simple matter to put a layer of epoxy on top of the composite matrix and thereby make a vapor seal **48**.

If the vapor seal **48** were a strip of metal it would have to be made to adhere in some manner to the composite matrix **46**, for example by using an adhesive of some kind, or by evaporating the metal onto the composite matrix.

The final major component of the transducer assembly is the transducer **50**. The transducer assembly comprises a two-dimensional array of transducers, of which an end view is shown in the figures. They are bonded directly to the inner surface of the tension-carrying skin **42**, for example, with an epoxy-based adhesive.

On the other hand, the transducer array when used for transmitting requires a large number N of transducers **50** to form the desired transmission pattern. N independent signal sources are required. Each transducer element **50** is a transmitting and receiving element, and may be considered to be a piston-like transmitter or receiver. As a receiver, each transducer element **50** samples the acoustic sound field at statistically independent points. As transmitters, they are used to form the radiation pattern for the transmitter array.

Discussing now the specific structure of each transducer element **50**, the transducer element has an aluminum base **52**, a cylindrical ceramic transducer body **54** and a tungsten or steel end **58**. Each transducer element **50** has a central hole **60** within which is a conductor or rod **62**, for example, of beryllium copper, which is connected to a common ground, the tension-carrying skin **42**. An ungrounded lead **64** encircles each transducer element **50**. The electrical potential is developed across the ungrounded wire **64** and the rod **62**.

In some embodiments, a separate tension-carrying skin **42** was not used, the transducer elements **50** in that case being attached directly to the composite material **46**. While the diaphragm **40** was in this instance not as rigid as when a metallic tension-carrying skin **42** was present, it did perform satisfactorily. A separate tension-carrying skin **42** would in general be absent only if it were known in advance that the torpedo would be used only at comparatively low depths.

FIG. **2** shows another embodiment of the self-supporting transducer assembly **70** wherein the tension-carrying skin **72** may be of a fibrous material, for example, fiber glass, which is placed in position over one part **74A** of a two-part attachment ring **74**. The upper part **74B** of the attachment ring is then screwed onto the lower part **74A**.

In some other embodiment of the self-supporting transducer assembly, not shown, the diaphragm **40** might consist of a homogeneous fibrous material strong enough to not require a tension-carrying skin, nor a vapor seal, the fibrous material itself being impervious to seawater. As an example, the entire diaphragm **40** may consist of a mixture of fiberglas fibers and crushed glass in an epoxy resin base. This composite material has enough mechanical strength to not require a separate tension-carrying skin **42**.

The diaphragm **40** consisting of the tension carrying skin **42**, the composite matrix **46**, and the vapor seal **48** actually comprises an acoustic window and permits acoustic energy to be readily transmitted through it. The components of the diaphragm are so chosen that the resultant combination is nonrefractive and nonreflective.

The design of the self-supporting transducer assembly **10** and **70** involves various compromises or tradeoffs. It is desirable that the torpedo be able to operate at great depths, but this then necessitates a diaphragm **40** which is capable of being subjected to a great stress. This necessitates having a structure having the required strength for supporting the transducer array **10** or **70**. On the other hand, a substantial structure interferes with the operation of the diaphragm **40** as an acoustic window. Therefore, a compromise must be effected between these two requirements.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

We claim:

1. A self supporting transducer assembly, which may be used on a torpedo, comprising;

an attachment ring having a central opening;

a diaphragm sealably mounted to the ring across the central opening and made of an acoustically nonrefractive and nonreflective, composite, self-supporting, material which is impervious to seawater;

at least one transducer element directly bonded to the diaphragm for self support thereto;

a support for the ring; and

means acoustically isolating the ring from the support and sealably connecting the ring thereto.

2. A self-supporting transducer assembly according to claim **1**, wherein

the diaphragm consists of:

a tension-carrying skin, sealably connected across the attachment ring and forming with it a dish-shaped cavity;

an acoustically nonrefractive and nonreflective composite material in the dish-shaped cavity;

a vapor seal, consisting of a thin sheet of material which is impervious to seawater, sealably connected across the attachment ring serving, with the tension-carrying skin, to confine the composite material to the dish-shaped cavity; and wherein

the transducer element is bonded to the tension-carrying skin, the axis of the transducer being parallel to the axis of the ring.

3. A self-supporting transducer assembly according to claim **2** wherein

the attachment ring has a plurality of slots with parallel sides, the sides being parallel to and below the tension-carrying skin, the attachment ring having a plurality of tapped holes in a direction parallel to the axis of the ring;

the ring support has a plurality of clearance holes aligned in the direction of each of the tapped holes; and further comprising:

a plurality of resilient washers, a pair for each hole, one washer of each washer pair being located in each slot, the other washer being located at the surface of the diaphragm support;

an O-ring mounted in a groove in the diaphragm support, the groove forming a periphery which encompasses all of the bolt holes; and

a plurality of bolts, one for each hole, each bolt passing through a pair of washers, the bolts when screwed into the tapped holes compressing the two washers and the O-ring, thereby making a watertight seal between the attachment ring and the support.

4. A self-supporting transducer assembly according to claim **3**, wherein

the composite material consists of a homogeneous mixture of glass microspheres, containing a gas at low pressure, interspersed in an epoxy resin, the composite material being prestressed to a pressure equal to the maximum

pressure at which the self-supporting transducer assembly is to be used.

5. A self-supporting transducer assembly according to claim 4 wherein

the attachment ring is in two sections, one section capable of being screwed into the other section, and

the tension-carrying skin is placed between the two sections of the attachment ring.

6. A self-supporting transducer assembly according to claim 5, wherein

the tension-carrying skin is an elastomeric material.

7. A self-supporting transducer assembly according to claim 6, wherein

the elastomeric material is of fiberglas.

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