(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 1 819 191 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
15.09.2010 Bulletin 2010/37

(51) Int Cl.:
H04R 1/44 *(2006.01)*

(21) Application number: **07109446.0**

(22) Date of filing: **14.12.2005**

(54) **Laminated piezoelectric transducer**

Laminierter piezoelektrischer Wandler

Transducteur piézoélectrique stratifié

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(43) Date of publication of application:
15.08.2007 Bulletin 2007/33

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
05027342.4 / 1 799 009

(73) Proprietor: **Undersea Systems International, Inc.**
Dba Ocean Technology Systems
Santa Ana, CA 92704 (US)

(72) Inventor: **Peck, Jerry**
Mission Viejo, CA 92692 (US)

(74) Representative: **Viering, Jentschura & Partner**
Postfach 22 14 43
80504 München (DE)

(56) References cited:

EP-A- 0 317 167	**EP-A- 0 669 169**
WO-A-95/21512	**WO-A-2005/112503**
GB-A- 1 546 521	**US-A- 3 909 529**
US-A- 4 454 927	**US-A- 5 117 403**
US-A- 5 812 496	**US-A1- 2003 123 692**
US-B1- 6 545 948	**US-B1- 6 693 849**

Remarks:

This application was filed on 01 - 06 - 2007 as a divisional application to the application mentioned under INID code 62.

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 1 819 191 B1

Description

[0001] The invention relates to an underwater acoustic transducer according to the precharacterizing part of claim 1.

[0002] Prior art, underwater acoustic transducers are typically encapsulated using potting compounds like silicone resin or urethane. This requires special potting equipment and facilities. Other prior art diver's microphones use bladders filled with air to cover the microphone. The bladder collapses with depth, pressure compensating the microphone, but eventually stops compensation because the air in the bladder is compressed to a volume smaller than the microphone. When the air inside the bladder is compressed to this point, the microphone ceases to operate.

[0003] Further, prior art underwater acoustic transducers, being potted or fixed in design with an air bladder, have acoustical performances which are fixed by their designs and there is no ready means of tuning them to the specific acoustic characteristics of the facemask, helmet or other headgear with which they are combined and which can material alter their acoustic performance.

[0004] From the US 3,909,529 an immersible diver's microphone according to the precharacterizing part of claim 1 is known. Spaced cover plates with multiple openings are provided on both sides of a kapton diaphragm, the spacing allowing drainage in the event the microphone is flooded. No specific tuning is provided, allowing tuning to whatever face mask, helmet or headgear with which the microphone is combined.

[0005] A further drainable microphone for divers is known from US 5,812,496. From the GB 1 546 521 an underwater transducer is known, in particular a transducer for receiving acoustic waves under water in a determined direction.

[0006] It is an object of the invention to improve the underwater acoustic transducer according to the precharacterizing part of claim 1 in that it is easy and inexpensive to manufacture, but which has no depth limitations on its operation and which can be tuned to optimal performance in whatever facemask, helmet or other headgear with which it is combined.

[0007] This object is achieved by the features in the characterizing part of claim 1.

[0008] The invention is illustrated as an underwater acoustic transducer comprising a laminated waterproof and sealed active acoustic element for transducing sound and electrical signals; a front and rear housing element disposed on each side of the active acoustic element to define a corresponding front and rear acoustic chamber on each side of the active acoustic element, each housing element defining a corresponding port therethrough of a predetermined diameter and thickness to provide tuning of the corresponding acoustic chamber and to provide free flooding acoustic chambers; and a rear cover disposed on the rear housing element and defining a corresponding port therethrough of a predetermined diameter and thickness to provide further tuning of the corresponding rear acoustic chamber while maintaining the free flooding characteristic of the rear acoustic chamber.

[0009] While the apparatus has or will be described for the sake of grammatical fluidity with functional explanations, it is to be expressly understood that the claims, are not to be construed as necessarily limited in any way by the construction of "means" or "steps" limitations, but are to be accorded the full scope of the meaning and equivalents of the definition provided by the claims under the judicial doctrine of equivalents. The invention can be better visualized by turning now to the following drawings wherein like elements are referenced by like numerals.

Brief Description of the Drawings

[0010] Fig.1 is an exploded perspective view of the supermic assembly of the invention.

[0011] Fig.2 is an exploded perspective view of the supermic assembly of Fig. 1 being assembled with the rubber washers used for acoustic tuning and mounting.

[0012] Fig. 3 is an assembled perspective view of the supermic assembly and rubber washers of Fig. 2 showing modification of the washers to accommodate the wires to the supermic assembly.

[0013] Fig. 4 is an assembled perspective view of the supermic assembly and rubber washers of Fig. 3 showing embedding of the wires to the supermic assembly and potting of their connection to the active element.

[0014] Fig. 5 is an exploded perspective view of the supermic assembly and rubber washers of Fig. 4 showing capping of the assembly with a disk cover.

[0015] Fig.6 is a perspective view of the rear side of the covered supermic assembly and rubber washers of Fig. 5 showing reinforcement of the assembly with nickel wire.

[0016] Fig. 7 is a top plan view of rear side the covered supermic assembly of Fig. 6.

[0017] Fig. 8 is a perspective view of the rear side of the completely assembled supermic assembly with the front side of the completely assembled supermic assembly being the opposing side and positioned downwardly out of view.

[0018] The invention and its various embodiments can now be better understood by turning to the following detailed description of the preferred embodiments which are presented as illustrated examples of the invention defined in the claims. It is expressly understood that the invention as defined by the claims may be broader than the illustrated embodiments described below.

Detailed Description of the Preferred Embodiments

[0019] The invention is a transducer assembly 10 designed to be easily manufactured and to be water and pressure-proof. This transducer assembly 10 can be used as an acoustic transducer for use as a diver's mi-

crophone, hydrophone or underwater speaker. The transducer assembly 10 is easily manufactured by using laminated waterproof disks 12 as illustrated by the sequence of drawings of Figs. 1 - 8. As shown in the exploded view of Fig. 1 the active piezoelectric element 14 is sandwiched or laminated between two 0.005-inch Lexan® disks 12 having a waterproof self-adhering adhesive layer 16 on one side. Other plastics or materials of similar properties could be substitute for Lexan®, which is a trademark of General Electric Co. In addition, other types of active elements may be substituted for piezoelectric element 14. The details of the construction or nature of element 14 are not material to the invention. Any acoustic-to-electric signal transducer now known or later devised may be employed. Further, while the invention is described below as a microphone, it is to be expressly understood that the reverse may be true, in other words, piezoelectric element 14 could be arranged and configured according to well known principles to operate as an earphone or speaker, which is acoustically coupled to either air or water.

[0020] Notches 18 on the periphery of the disks 12 provide access or space for connecting wires 20 which are connected to active element 14. These notches 18 are subsequently sealed using a suitable urethane adhesive 22 as depicted in the perspective view of Fig. 4.

[0021] The assembly of elements 12, 14, 16, 20, collectively denoted in the perspective view of Fig. 2 by reference character 26 and termed supermic label, 26, is mounted in a rubber housing 24 comprised of rings resembling rubber washers in form. Two of the washers 24 are attached to the supermic label 26 using a suitable adhesive. For example, a general-purpose urethane such as Kalex Tuff adhesive, which is a trademark of Hardman Inc. of Belleville, New Jersey, that exhibits excellent bonding to both polychloroprene rubber and Lexan® can be employed. One or more additional washer-like disks (not shown) of any appropriate material, such as rubber, polyurethane, neoprene or the like, can be attached to the front, rear or both sides of washers 24 for acoustic tuning purposes. The additional washers may have variable thicknesses and inner diameters according to the acoustic tuning needed, which is empirically determined for the specific design of the facemask in which assembly 10 is mounted using an acoustic frequency spectrum analyzer. The acoustic characteristics of each facemask design will differ from each other design. Thus, the inner diameter of the two washers 24 may be identical or different depending on tuning as described below. Hereinafter, reference to a single washer 24 will be understood to mean to include one or collectively all of the washers 24 employed. In addition, it must be understood that wherever the term, facemask, is used, diving helmets, facemasks and all other diving headgear are understood to be within the scope of the invention.

[0022] A bead 32 of Kalex Tuff or other adhesive is applied to the peripheral edge of supermic label 26 as shown in Fig. 2. Washers 24 are then pressed to the front and back of supermic label 26 with wires 20 lead through the inner diameter of the adjacent washer 24. Two narrow cuts or grooves 34 are cut into the adjacent washer 24 to a depth to allow the full insertion of wires 20 therein as shown in Fig. 3, one wire 20 being placed into one corresponding groove 34. Wires 20 are then laid into grooves 34 and notch 18 and at least the inner end of grooves 34 are potted or sealed with adhesive 22 as shown in Fig. 4.

[0023] A bead 36 of adhesive is laid down on the periphery of one of the washers 24, which is defined as the rear washer 24 with the opposing washer 24 being defined as the front washer 24, and a rear rubber washer 38 with an inner diameter through hole or port 40 is laid down on bead 36 as shown in Fig. 5. While a through hole or port 40 is preferred and illustrated, it is also within the scope of the invention that in some applications hole or port 40 may be a blind hole with a thin membranous bottom surface. Rear washer 38 has an outer diameter greater than port 30 defined by the inner diameter of washers 24 and hence provides a perforated cover for one side of transducer assembly 10. The opposing front side of transducer assembly 10 is preferably left open, but in some applications may be provided with a perforated cover or completely covered by a membranous or porous surface as may be desired in the specific application.

[0024] Wires 20 are twisted together as a pair to minimize stray pickup and nickel wire 28 or other stiffener is laid parallel to wires 20 and around washers 24 in the interlying space between washers 24, which is defined by providing a slightly larger outer diameter for washers 24 than for supermic label 26. Nickel wire 28 thus forms an enclosing reinforcement completely around supermic label 26 and washers 24 and is led away from assembly 10 parallel to wires 20 for a predetermined length as shown in Fig. 6. The arrangement is also illustrated in the top plan view of Fig. 7. Wires 28 thus allow assembly 10 to be positioned in the facemask by bending wires 28 as needed.

[0025] Heat shrink tubing 42 is then telescopically disposed over wires 28 and wires 20 as shown in Fig. 8 and heated air applied to shrink tubing 42 tightly onto wires 20 and 28. Transducer assembly 10 is thus complete and is ready for mounting in a conventional manner in or on a facemask, which is accomplished by attaching wires 28 is a mounting bracket or other mechanical attachment means and bending wires 28 to position the front surface of transducer assembly 10 in a free standing position within the facemask near or just lightly touching the diver's lips. Similarly, when used as an earpiece, wires 28 are mechanically attached to the facemask or its straps, and wires 28 bent to position the front surface of transducer assembly 10 in a position near or just inside the diver's ear.

[0026] One novel feature of this transducer assembly 10 is the particular ease by which it can be acoustically tuned, This is an important advantage. For instance, in

a diver's full-face mask, there are other acoustic properties that affect the acoustic response of any microphone mounted on or in the mask. By adjusting the port size 30 or inner diameter of washer 24, the resulting installed microphone can be configured to exhibit a response that suppresses the muffled effect that is a result of the mask's acoustic Helmholtz effect. Usually the acoustic Helmholtz effect causes a rising response of the microphone as the frequencies moves toward 0 Hz or DC levels. To counter the acoustic Helmholtz effect, the transducer assembly 10 when used as a microphone is "ported" or constructed with washers 24 of selected thicknesses and inner diameters 30 as shown in Figs. 1-8 such that its acoustic response is exactly opposite than that of the facemask cavity. Because all facemasks are not the same, there is a need to adjust the microphone acoustic response in a way that suppresses the mask's acoustic peaks and valleys. If a greater rising frequency response in needed, additional porting can be applied to the front of the transducer assembly 10.

[0027] Nickel wire 28 is used in transducer assembly 10 as a means of reinforcement and to allow positioning of transducer assembly 10. It is both noncorrosive as well as flexible allowing the user to position the transducer assembly 10 if used as a microphone close to the diver's lips when employed as a microphone or ear(s) when employed as an earpiece.

[0028] When used as a microphone, transducer assembly 10 exhibits a high degree of noise cancellation because of its gradient characteristics. The degree of cancellation is controlled by the dimensions of the port 30 defined by the inner diameter of washers 24 applied to the front, rear or both (if used) of supermic label 26. If the acoustic path to supermic label 26 is made to be longer in the back of supermic label 26 than the front, because the rear port 30 has an added length, acoustic energy close the front of supermic label 26 will tend to produce a large electrical signal. However, if this energy comes from a greater distance, then the signal tends to cancel out. This is a conventional method by which noise canceling microphones operate. What is unique in the disclosed embodiment is the ease by which the amount of cancellation as well as acoustic response is controlled via simple rubber ports 30 defined by washers 24. This in turn makes the design a very flexible assembly 10 that can be easily configured to sound best in a wide variety of full-face masks.

[0029] It is to be expressly understood as well that the diameter of port 30 of the front and rear washers need not be identical. Typically, the diameter of port 40 is less than that of port 30. Stepped acoustic tuning may be achieved, for example, by providing a series of rear washers 24 with decreasing diameters of port 30. In addition rear or front washers 24 need not be restricted to a cylindrical shape as depicted in Figs. 1 - 8, but may instead have a conical inner surface or a surface with another shaped contour chosen according to the desired acoustic performance.

[0030] The laminated assembly process eliminates the need to completely encapsulate the front and rear of the element assembly. That in turn saves considerable manufacturing time and expense.

[0031] In can now be appreciated that in the prior art, acoustic transducers were encapsulated using potting compounds like silicone resin or urethane. This requires special potting equipment and facilities. In the disclosed design the use of a small amount of urethane to cover the notch area where, the wires emerge from the piezoelectric element is preferred, but this requires is a small amount of labor compared to complete encapsulation.

[0032] Other prior art diver's microphones use bladders filled with air to cover the microphone. The bladder collapses with depth, pressure compensating the microphone, but eventually stops compensation because the air in the bladder is compressed to a volume smaller than the microphone. When the air inside the bladder is compressed to this point, the microphone ceases to operate.

[0033] A unique feature of the transducer assembly 10 of the invention is that it doesn't have any bladders or for that matter any air space whatsoever. Accordingly it can go to the bottom of the deepest ocean and function unaffected by depth and pressure.

[0034] Since assembly 10 is a transducer, it will also function as an underwater earphone or speaker if rear porting offers the correct acoustic resistance in water is employed. Current speaker designs use air-backed elements that are subject to pressure effects and therefore have limited depth capability. The free flooding, self-cleaning, tunable and solid design of the invention does away with these problems.

[0035] Transducer assembly 10 can be used as both a waterproof and pressure proof microphone. Its simple design provides a simple means to manufacture a variety of divers' microphones and/or earphones. It solves the problems experienced by current designs where air backed or balloon devices are needed for pressure compensation.

[0036] Another advantage to this invention is the laminated structure that waterproofs the active piezoelectric element 14 without the need to encapsulate it.

[0037] In addition to the above, instead of using nickel wires, one may design a plastic mounting structure or the like for the purposes of mounting the assembled transducer in a mask or helmet. The groove intended for the nickel wire is used in conjunction with a smaller opening in such a plastic structure whereby the thickness of the plastic comprising the periphery of the circular opening replaces the thickness of the nickel wire and is used to hold the transducer.

Claims

1. An underwater acoustic transducer (10) comprising:

a laminated waterproof and sealed active

acoustic element (14) for transducing sound and electrical signals;
a front and rear housing element (24) disposed on each side of the active acoustic element (14) to define a corresponding front and rear acoustic chamber on each side of the active acoustic element (14), each housing element (24) defining a corresponding port (30) therethrough to provide free flooding acoustic chambers; **characterized in that** said corresponding ports (30) are of a predetermined diameter and thickness to provide tuning of the corresponding acoustic chamber and that a rear cover (38) is disposed on the rear housing element (24) and defines a corresponding port (40) therethrough of a predetermined diameter and thickness to provide further tuning of the corresponding rear acoustic chamber while maintaining the free flooding characteristic of the rear acoustic chamber.

Patentansprüche

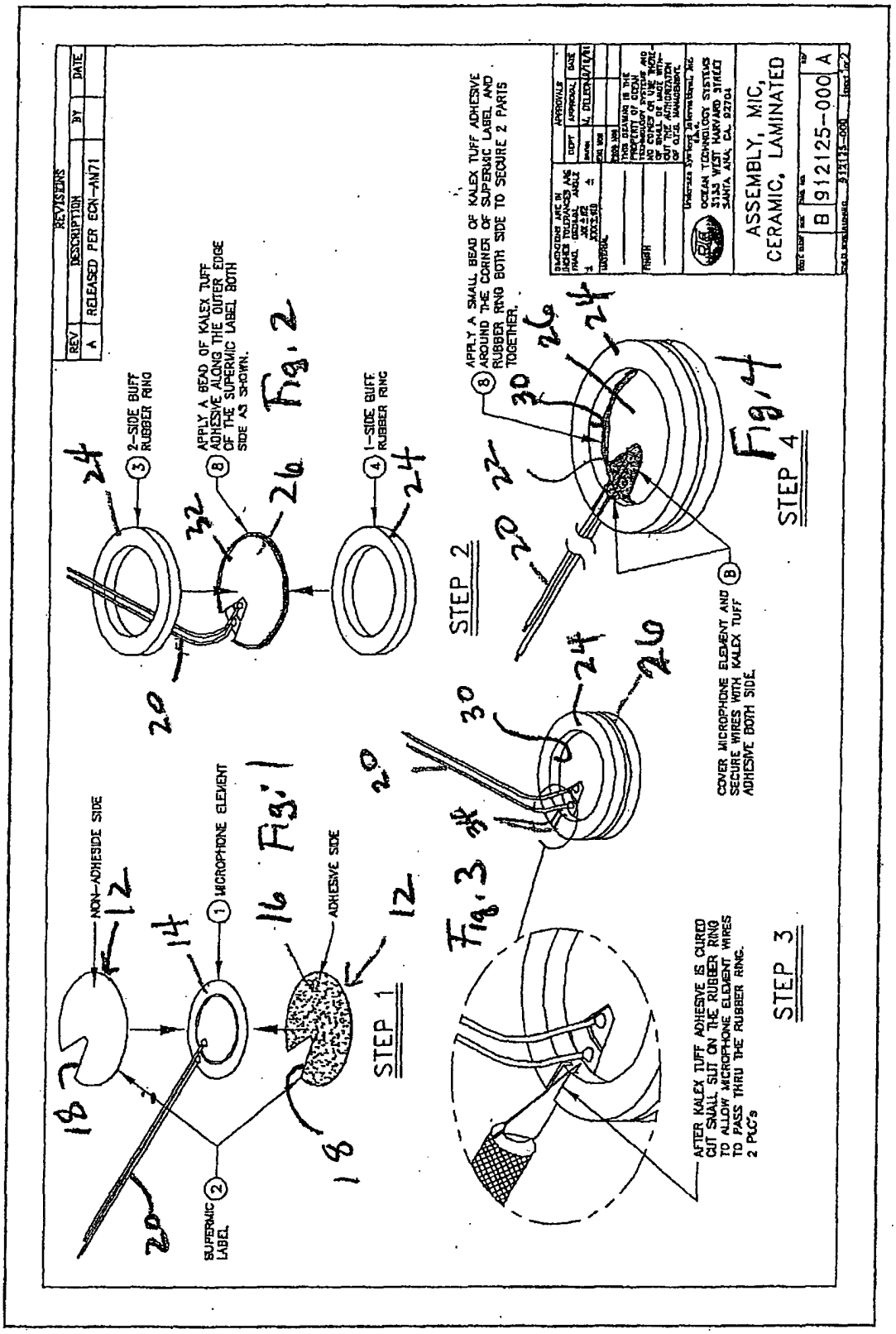
1. Ein Unterwasser-Akustik-Wandler (10), aufweisend:

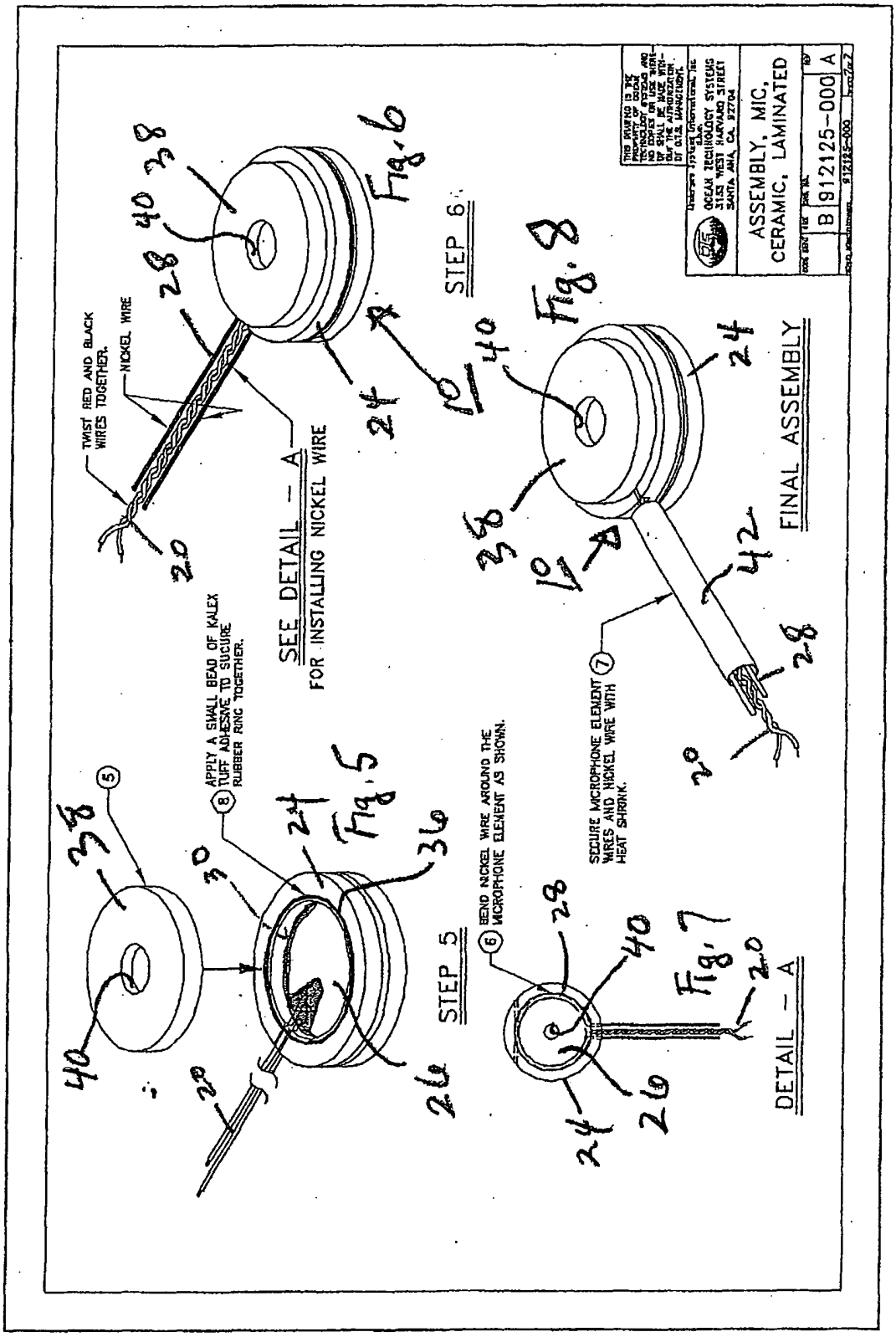
• ein beschichtetes, wasserdichtes und versiegeltes aktives akustisches Element (14) zum Umwandeln von Geräuschen und elektrischen Signalen;
• ein vorderes und ein hinteres Gehäuse-Element (24), die auf jeder Seite des akustischen Elements (14) angeordnet sind, so dass jeweils eine vordere und ein hintere akustische Kammer auf jeder Seite des aktiven Elements (14) definiert ist, wobei jedes Gehäuse-Element (24) einen entsprechenden hierdurch hindurchgehenden Einlass (30) definiert, so dass frei durchflutbare akustische Kammern bereitgestellt werden;
• **dadurch gekennzeichnet, dass** die genannten entsprechenden Einlässe (30) von einem bestimmten Durchmesser und einer bestimmten Dicke sind, so dass eine Abstimmung der entsprechenden akustischen Kammer bereitgestellt wird und dass eine hintere Abdeckung (38) an dem hinteren Gehäuse-Element (24) angebracht ist und einen entsprechenden hierdurch hindurchgehenden Einlass (40) von einem bestimmten Durchmesser und einer bestimmten Dicke definiert, um ein weiteres Abstimmen der entsprechenden hinteren akustischen Kammer bereitzustellen, wobei die Freidurchflutungs-Charakteristik der hinteren akustischen Kammer aufrecht erhalten wird.

Revendications

1. Transducteur acoustique sous-marin (10) comprenant :

un élément acoustique actif (14) étanche à l'eau et hermétique stratifié pour transformer des signaux sonores et électriques ;
des éléments de logement (24) avant et arrière disposés de chaque côté de l'élément acoustique actif (14) pour définir des chambres acoustiques avant et arrière correspondantes de chaque côté de l'élément acoustique actif (14), chaque élément de logement (24) définissant un orifice (30) correspondant à travers celui-ci pour réaliser des chambres acoustiques à débordement libre ; **caractérisé en ce que** lesdits orifices (30) correspondant ont un diamètre et une épaisseur prédéterminés pour réaliser l'accord de la chambre acoustique correspondante et **en ce qu'**un couvercle arrière (38) est disposé sur l'élément de logement arrière (24) et définit, par ce moyen, un orifice (40) correspondant d'un diamètre et d'une épaisseur prédéterminés pour réaliser en outre l'accord de la chambre acoustique arrière correspondante tout en maintenant la caractéristique de débordement libre de la chambre acoustique arrière.


REVISIONS
REV
DESCRIPTION
BY
DATE
A
RELEASED PER ECN-AN71
NON-ADHESIDE SIDE
12
14
1 MICROPHONE ELEMENT
16
ADHESIVE SIDE
18
20
2 SUPERMIC LABEL
STEP 1
Fig. 1
3 2-SIDE BUFF RUBBER RING
24
8 APPLY A BEAD OF KALEX TUFF ADHESIVE ALONG THE OUTER EDGE OF THE SUPERMIC LABEL BOTH SIDE AS SHOWN.
32
26
4 1-SIDE BUFF RUBBER RING
STEP 2
Fig. 2
8 APPLY A SMALL BEAD OF KALEX TUFF ADHESIVE AROUND THE CORNER OF SUPERMIC LABEL AND RUBBER RING BOTH SIDE TO SECURE 2 PARTS TOGETHER.
30
22
STEP 3
Fig. 3
AFTER KALEX TUFF ADHESIVE IS CURED CUT SMALL SLIT ON THE RUBBER RING TO ALLOW MICROPHONE ELEMENT WIRES TO PASS THRU THE RUBBER RING.
2 PLCS
8 COVER MICROPHONE ELEMENT AND SECURE WIRES WITH KALEX TUFF ADHESIVE BOTH SIDE.
STEP 4
Fig. 4
APPROVALS
DEPT
APPROVAL
DATE
M. DILLEN
10/10/01
THIS DRAWING IS THE PROPERTY OF OCEAN TECHNOLOGY SYSTEMS AND CANNOT BE USED OR REPRODUCED IN WHOLE OR IN PART WITHOUT THE EXPRESS WRITTEN PERMISSION OF OCEAN TECHNOLOGY SYSTEMS, INC.
OCEAN TECHNOLOGY SYSTEMS
3133 WEST HARVARD STREET
SANTA ANA, CA. 92704
ASSEMBLY, MIC, CERAMIC, LAMINATED
B
912125-000
A


TWIST RED AND BLACK WIRES TOGETHER.
NICKEL WIRE
SEE DETAIL - A
FOR INSTALLING NICKEL WIRE
Fig. 6
STEP 6
Fig. 8
FINAL ASSEMBLY
APPLY A SMALL BEAD OF KALEX TUFF ADHESIVE TO SECURE RUBBER RING TOGETHER.
Fig. 5
STEP 5
BEND NICKEL WIRE AROUND THE MICROPHONE ELEMENT AS SHOWN.
SECURE MICROPHONE ELEMENT WIRES AND NICKEL WIRE WITH HEAT SHRINK.
Fig. 7
DETAIL - A
OCEAN TECHNOLOGY SYSTEMS
3153 WEST HARVARD STREET
SANTA ANA, CA. 92704
ASSEMBLY, MIC, CERAMIC, LAMINATED
B
912125-000
A

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 3909529 A **[0004]**
- US 5812496 A **[0005]**
- GB 1546521 A **[0005]**