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(54) A method of manufacturing a hydrophone

(57) The hydrophone includes at least one detector unit 1 comprising a casing made up of two cups 2a, 2b supported one against the other by means of a peripheral rim 3, each having a central, flexible portion supporting a piezoelectric element 4 on the external face thereof. A flat, recessed centring element 6 made from a deformable material is designed to be nested along an axial plane of a rigid tube 9 and has an internal groove 8 in which the peripheral rim of the two cups 2a, 2b of the casing is located. A coating of protective sealant 11 encloses the detector unit 1 and a part of the internal face of the tube 9.

During manufacture, once the centring element 6 has been inserted in the tube, the substance forming the coating 11 is injected into the thin space left free around the centring element by a two-brached moulding piece 13a, 13b which is nested in the tube.

FIG.4

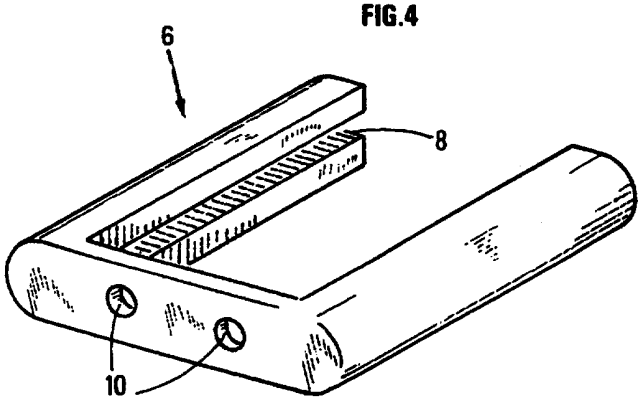
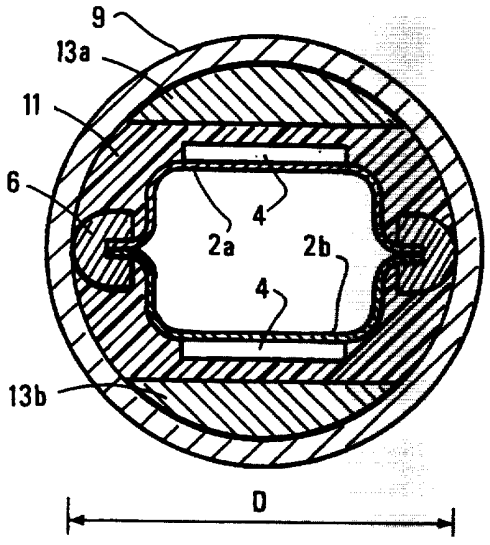


FIG.5



GB 2 312 808 A

FIG.1

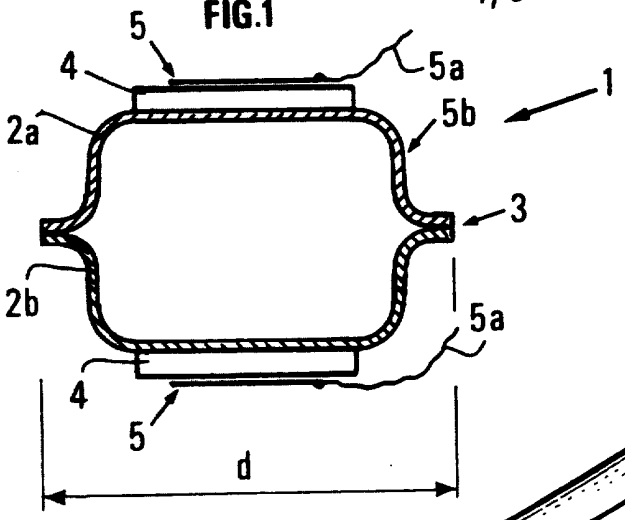


FIG.2

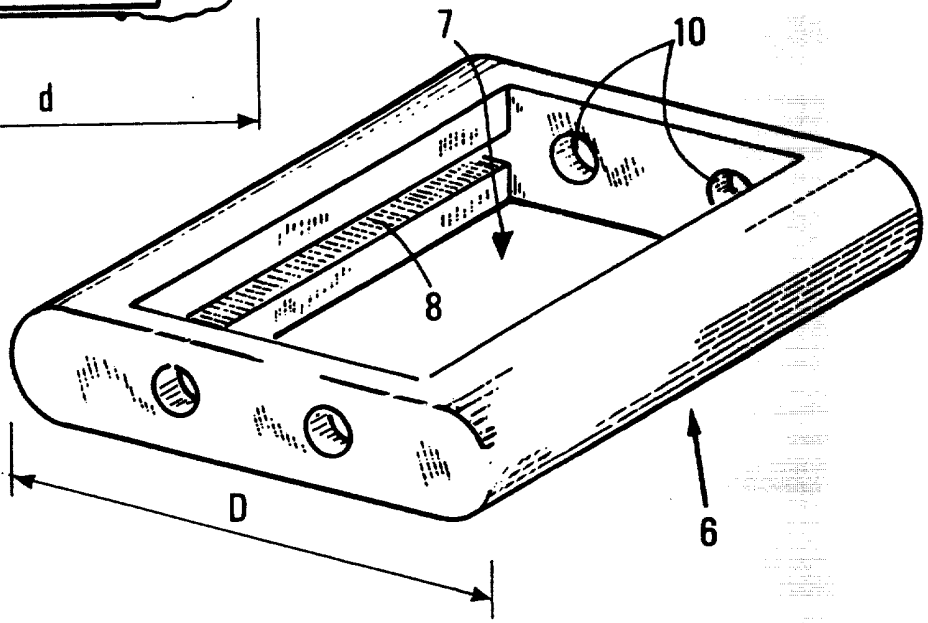


FIG.3

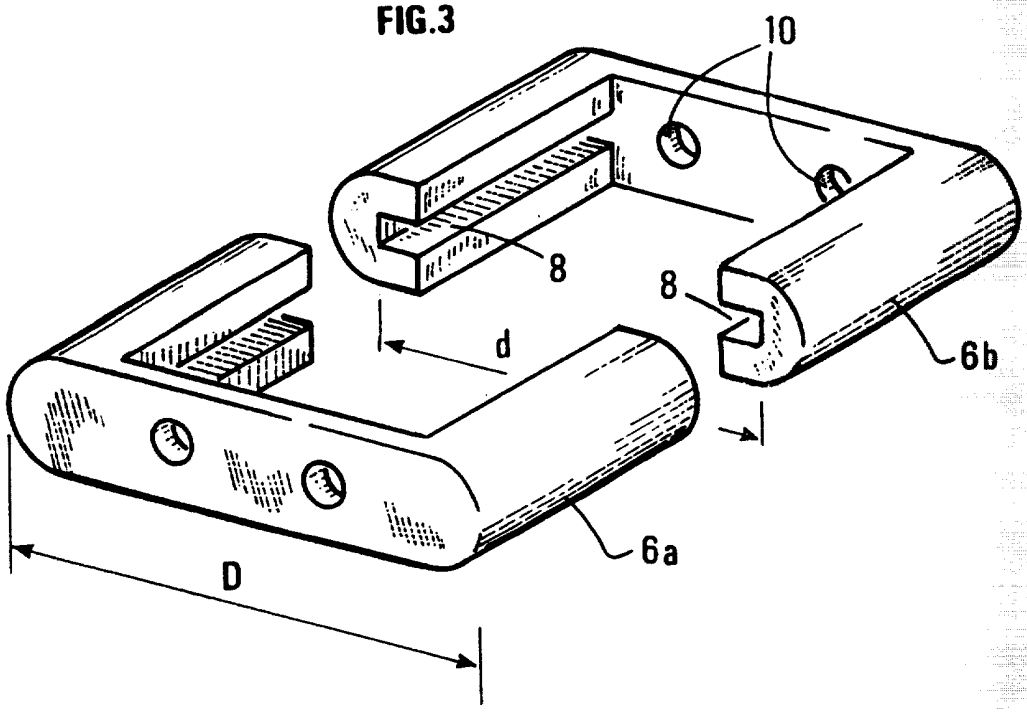


FIG.4

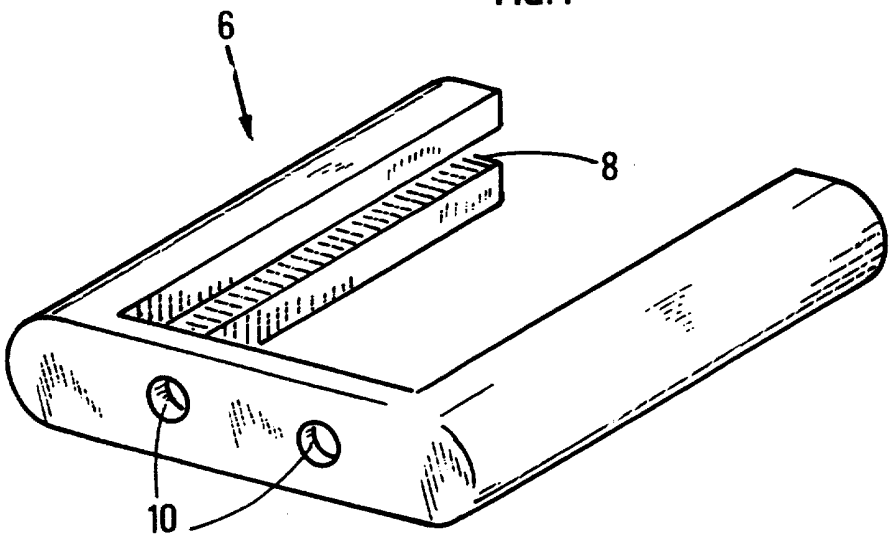


FIG.5

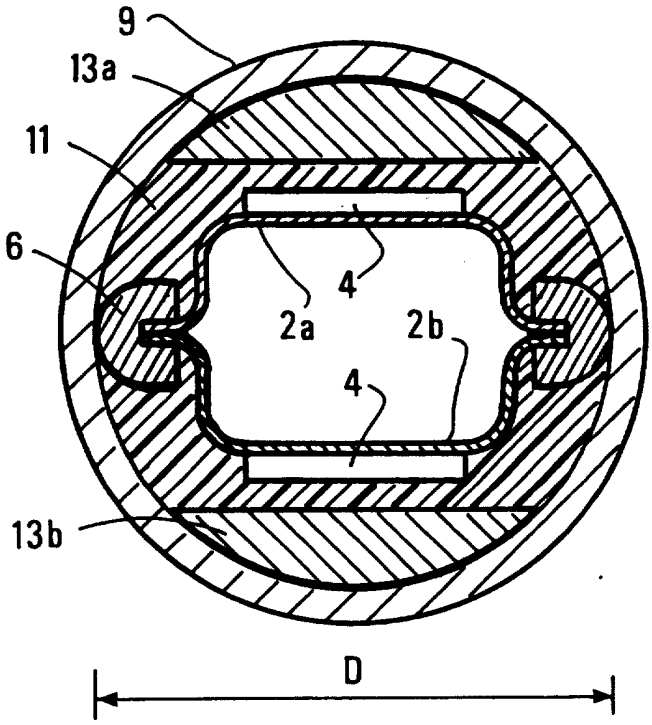


FIG.6

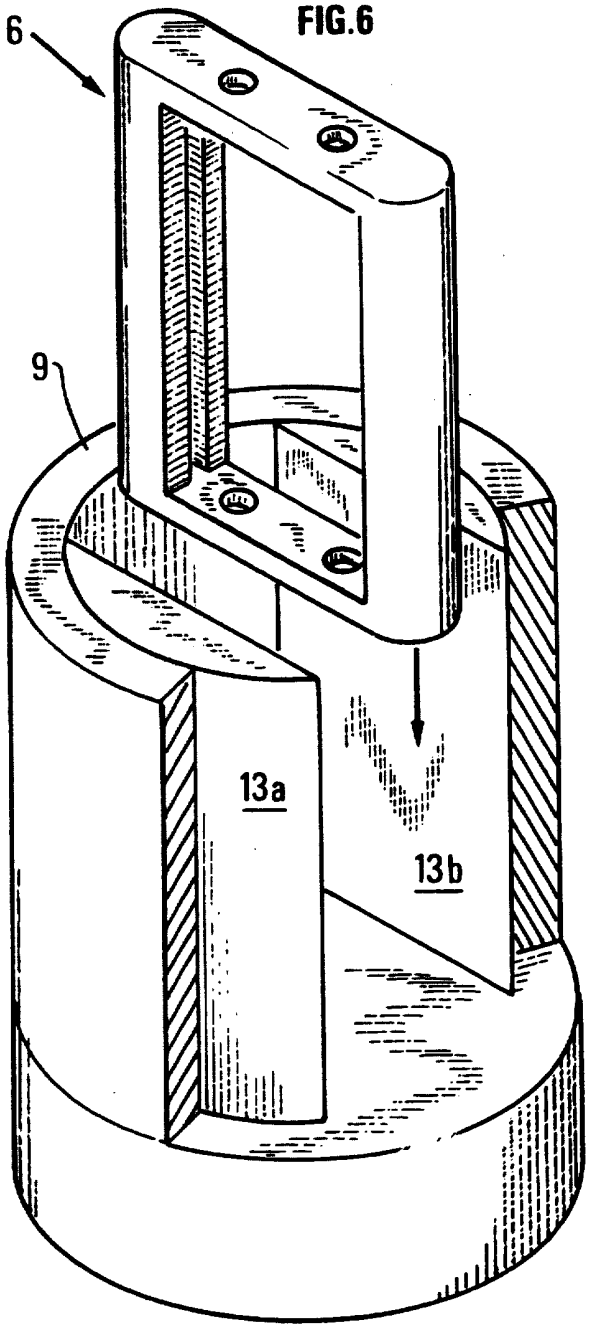


FIG.7

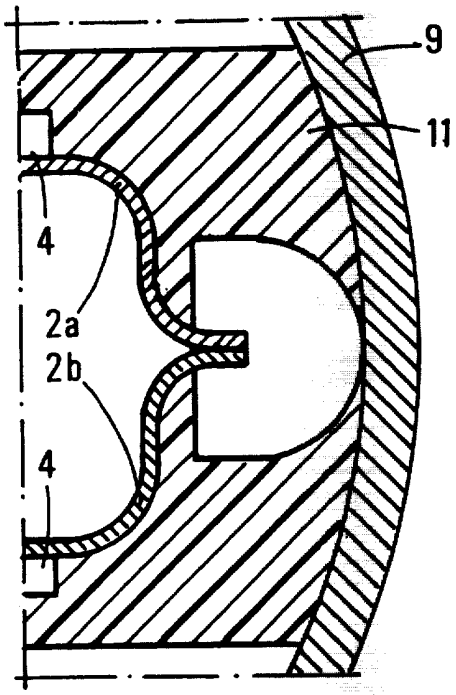
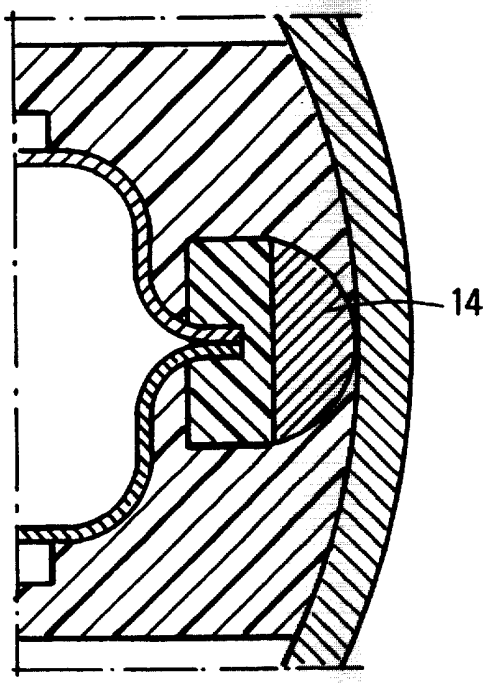


FIG.8



HYDROPHONE AND A METHOD FOR MANUFACTURING IT

The present invention relates to a hydrophone which can be used specifically for detecting acoustic or seismic waves and a method for manufacturing it.

A known method of making hydrophones is to assemble elements that are sensitive to pressure, each consisting of a disk made from a piezo-electric ceramic linked to a pair of electrodes arranged on either side. Each disk is bonded to a flexible support such as a diaphragm, one of the faces of which is exposed to the pressure variations to be measured.

The flexible support is shaped like a cup, for example, which can be supported by a rigid housing or alternatively supported by an identical cup, which in turn supports one or more sensitive elements, the two cups being placed in contact with one another by means of a rim to delineate a casing. The flexible support is the central portion of a plate, for example, the peripheral part being reinforced and rigid. The casing may be formed by two identical plates supported one against the other by means of their thicker, peripheral portions and each bearing a sensitive element. The electrodes of the two sensitive elements are electrically inter-connected so as to compensate for parasitic effects due to accelerations.

When the external static pressure increases, the two plates flex until they come to rest against each other. The spacing between them is selected so that their maximum deformation when placed one against the other remains within the limits of elastic deformation. This being the

case, the sensor is protected from accidental over-pressures. Made in this way, the casing may be coated with a layer of material that is transparent to acoustic waves.

The sensitive elements may be fixed externally to the casing, which means that there will be little variation in their sensitivity (less than 10% for a static pressure of 10 MPa, for example) as the hydrostatic pressure varies. Generally, the sensitive elements are covered with a protective coating (such as a layer of araldite coated with a varnish) so as to maintain adequate electrical insulation between the electrodes. Very sensitive detectors can be made at a relatively low cost using this design.

In another known design, the sensitive elements are fixed onto the internal faces of the cups and are therefore inside the casing, which ensures that they are well protected from the external environment. With this arrangement, however, the piezo-electric sensitive elements, which are sintered ceramic disks, are relatively fragile and are therefore prone to crush damage when the hydrostatic pressure increases, causing them to be pushed against each other by the plates as they bend. Furthermore, their sensitivity has been found to decrease sharply as the hydrostatic pressure rises, due to the fact that they are fixed to a face which becomes convex. In addition, since the sensitive elements are on the interior, it is necessary to provide sealed ducts through which to run the electric wires connected to the electrodes, a factor which increases manufacturing costs.

It has also been found that the sensitivity of hydrophones whose sensitive elements are inside the casing tend to be less sensitive. To overcome this problem, manufacturers have been forced to extend the surface area of the sensitive disks and consequently the diameter and thickness of the supporting cups.

A method is also known whereby one or more of these casings enclosing one or more sensitive elements are placed inside a rigid tube, into which elastomer centring and acoustic decoupling wedges are inserted. In sub-sea monitoring applications or seismic prospecting, these tubes are distributed in large numbers inside a flexible sheath or seismic streamer, often of a considerable length, which is filled with kerosene or mineral oil and towed submersed from a vessel. In order to protect the casings from the filler liquid, a known option is to place the casings in protective housings and then cast a protective material into each tube.

Different piezo-electric sensors are described in patents FR 1.556.971 and 2.122.675 and patent application FR 95/05331, for example, all filed in the name of the present applicant, or from patents US 3.970.878, 4.336.639 or 4 296 397.

The objective of the method of the invention is to manufacture a hydrophone having at least one receiver unit designed to be housed inside a rigid tube, each receiver unit consisting of a casing made up of two cups, each of which has a support face placed against a matching support face the other cup, each of these having a flexible

central portion, and at least one sensitive element linked to electrodes and joined to the central portion of at least one of the cups, as well as electric conductors connected to the electrodes and each sensitive element. It is characterised in that it involves the following steps in succession:

- fitting at least one casing in a flat, rectangular centring element designed to be supported by two of its opposite sides against the internal wall of the tube;
- inserting the centring element containing the said casing in the rigid tube;
- inserting moulding pieces in the rigid tube, designed to fill the greater part of the remaining volume inside the rigid tube on either side of the centring element except for a specifically determined thickness of space on either side of the centring element; and
- injecting a material inside the rigid tube into the said space around the centring element to form a protective sealing sheath.

The method includes removing the centring element after the protective sheath has been formed, for example, so as to prevent any direct coupling between the receiver unit and the rigid tube.

In a first embodiment, a sealing material is injected into at least a part of the space left behind when the centring element is removed, delineated by inserting moulding pieces, in order to isolate each receiver unit. A

vibration damping material may be used for this purpose, so that each receiver unit will be acoustically decoupled from the rigid tube.

In another embodiment, a centring element made from a vibration damping material is used and the said housing in its centring element is embedded in the injected material which forms a protective sealing sheath.

The hydrophone of the invention, therefore, consists of at least one detection unit consisting of a casing formed by two cups, each having a support face supported against a matching support face of the other cup, each of them having a flexible central portion, and at least one sensitive element linked to electrodes, which is joined to the central portion of at least one of the cups, as well as electric conductors connected to the electrodes of each sensitive element.

It is characterised in that it has an external rigid tube, means to position and seal at least one casing in a diametral plane of the tube, produced by injecting a sealant material to form a coating of a controlled thickness for the detection unit and a part of the internal wall of the rigid tube.

In one embodiment, the sealing and positioning means comprises two recesses in a diametral zone of the rigid tube containing the support faces of the cups, at least one part of which is filled with a vibration damping material.

In another embodiment, the positioning and sealing means consists of a flat, recessed centring element

designed to be supported by two of its opposite sides against the internal wall of the rigid tube in an axial plane thereof, this element being provided with a recess for at least one casing and a protective sealant coating of a controlled thickness around this centring element.

It is to advantage to provide the centring element with an internal groove in which to insert a peripheral rim of the two cups of the housing. It may be made from one piece or in two pieces, between which the housing is retained or alternatively from a single U-shaped piece with two branches between which the casing is held.

Each receiver unit has two sensitive elements each associated with two cups of each casing. The cups are made using a moulding process, in particular stamping.

The design of the unit and the method used to manufacture it are such that the hydrophone of the invention is of a small dimension, has good sensitivity and high resistance to variations in the external static pressure and can be mass-produced at reduced manufacturing costs.

Other features and advantages of the device of the invention and the method used to manufacture it will become clear from the following description of embodiments, described by way of illustration and not restrictive in any respect, and with reference to the appended drawings, in which:

- Fig. 1 is a schematic illustration of a receiver unit in section;
- Fig. 2 represents the centring element into which the

casing of the receiver unit is clipped;

- Fig. 3 illustrates an embodiment of the centring element in two parts;
- Fig. 4 illustrates a variant of the embodiment of figure 2 with one end open;
- Fig. 5 is a schematic illustration of the device with its tube containing the receiver unit;
- Fig. 6 illustrates the manufacturing method, whereby the moulded piece is inserted in the tube to confine a space for injecting around the clipped-in box;
- Fig. 7 illustrates an embodiment in which the centring element is removed after the substance forming the sheath has been injected and set; and
- Fig. 8 shows a variant of the previous embodiment in which a part of the space freed by removing the centring element is closed off by moulding pieces 15.

The device consists of one or more receiver units 1, each comprising (figure 1) a casing made up of two symmetrically arranged identical cups 2a,2b, one supported against the other by the periphery, provided with a support edge or rim 3, for example. The two cups may be machined or produced using a moulding process, in particular stamping. Bonded to the face of the central, flexible portion of each of the cups 2a, 2b is a sensitive element such as a disc made from piezo-electric ceramic, for example, linked to two electrodes 5, each of which is electrically connected to a conductive film inserted between the sensitive disc and the support face of the cup 2a, 2b or a conductive face thereof against which the disc

is applied. By preference, in a conventional mode, the electrodes 5a, 5b of the two sensitive elements are respectively inter-connected.

Linked to each receiver unit 1 (figures 2, 3) is a thin, flat centring element 6, made from a plastics material, with a central recess 7, the dimensions of which match that of the casing 2a, 2b. Two opposite edges of this central recess 7 are provided with grooves 8 of spacing d between which the edges 3 of the cups are slotted. The centring element may be made from a single piece (figure 2) or in two pieces 6a, 6b provided with complementary grooves 8 in which the rim 3 is located (figure 3).

Two opposite edges of the centring element 6 are rounded. Their spacing D matches the internal diameter of a rigid tube 9 (figure 5) in which the centring element 6 will be located once it has been inserted in the casing 2a, 2b. The other two edges of the centring element have orifices 10 crossing through them.

In the embodiment illustrated in figure 4, one of the two edges is dispensed with and the centring element 6 is left open at this side.

Once it has been placed in the tube 9, the centring element 6 with its inserted receiver unit 1 is embedded (figure 5) in a sealing sheath 11 of a controlled thickness. To this end, a U-shaped moulding piece 12 (figure 6) is joined to the unit (1, 6) in its rigid tube 9. The two branches 13a, 13b of this U are designed so that they will nest inside the tube 9 on either side of

the assembly 1, 6 leaving a space of a determined thickness around it. An acoustically transparent plastics material is injected through the orifices 10 arranged in the ends of the centring element into the space left free around the unit 1, 6. After it has set, by polymerisation for example, and the moulding piece 12, 13 has been removed, the coating will provide a sealed sheath around the receiver unit 1 inside its centring element 6, conforming with the internal wall of the rigid tube 9 (figure 5).

In the embodiment of figure 7, the two parts 6a, 6b are removed from the centring element (see embodiment of figure 3) once the protective sheath has set. Consequently, there is no possibility of any direct contact between the casing (2a, 3b) and the external rigid tube 9 which might be a source for the direct transmission of vibrations. This freed space 14 may remain empty but it may also be filled either partly or completely by injecting in a plastics material, preferably with vibration damping properties (figure 8), inserting moulding pieces 14 before injecting, in order to improve the damping of parasitic vibrations applied to the cups 2a, 2b which might interfere with the signals.

The embodiment described has a cylindrical rounded rigid tube. This type of tube is particularly well suited to applications in which the receiver units need to be distributed at regular intervals in a seismic streamer that will be towed by a vessel for sub-sea detection applications or seismic prospecting. It would not be a

departure from the scope of the invention if any other container were used whose shape was more suitable for the proposed use.

An embodiment has also been described in which the cups 2a, 2b of each casing are provided with rims 3 and the centring element 6 is provided with grooves 8 to accommodate these rims. It would not be a departure from the scope of the invention if cups were used which did not have rims placed one against the other at the periphery and a centring element 6 were adapted to accommodate one or more casings adequately during the subsequent stages of insertion in the tube 9.

CLAIMS

1. A method of manufacturing a hydrophone having at least one receiver unit designed to be inserted inside a rigid tube, each receiver unit consisting of a casing made up of two cups each having a support face placed against a matching support face of the other cup, each of them being provided with a central, flexible portion, and at least one sensitive element linked to electrodes, which is joined to the central portion of at least one of the cups, and electric conductors linked to the electrodes of each sensitive element, wherein it consists of the following steps in succession:

- fitting at least one casing in a flat, rectangular centring element designed to be supported by two of its opposite sides against the internal wall of the tube;
- inserting the centring element containing the said casing in the rigid tube;
- inserting moulding pieces in the rigid tube, designed to fill the greater part of the remaining volume inside the rigid tube on either side of the centring element except for a specifically determined thickness of space on either side of the centring element; and
- injecting a material inside the rigid tube into the said space around the centring element to form a protective sealing sheath.

2. A method as claimed in claim 1, wherein it includes removing the centring element after the

protective sheath has been formed in order to prevent any direct coupling between the receiver unit and the rigid tube.

3 A method as claimed in claim 2, wherein it consists in injecting a sealant material into at least a part of the space left behind when the centring element is removed, delineated by inserting moulding pieces, in order to isolate each receiver unit.

4 A method as claimed in claim 3, wherein a vibration damping material is chosen as the sealant material so that each receiver unit is acoustically decoupled from the rigid tube.

5 A method as claimed in claim 1, wherein it incorporates the use of a centring element made from a vibration damping material, the said casing in its centring element being embedded in the injected material which forms a sealing sheath.

6 A hydrophone having at least one detector unit consisting of a casing made up of two cups, each having a support face placed against a matching support face of the other cup, each of them being provided with a central, flexible portion, and at least one sensitive element linked to electrodes, which is joined to the central portion of at least one of the cups on a face thereof which becomes concave when subjected to an increase in the external static pressure, electric conductors linked to the electrodes of each sensitive element, wherein it has an external rigid tube, a means for positioning and sealing at least one casing in a diametral plane of the

tube, produced by injecting a sealant material to form a coating of a controlled thickness for the detector unit and a part of the internal wall of the rigid tube.

7 A hydrophone as claimed in the preceding claim, wherein the positioning and sealing means has two recesses in a diametral zone of the rigid tube containing the support faces of the cups.

8. A hydrophone as claimed in the preceding claim, wherein a part of the two recesses is filled with a vibration damping material.

9. A hydrophone as claimed in claim 6, wherein the positioning and sealing means is a flat, recessed centring element designed to be supported by two of its opposite sides against the internal wall of the rigid tube in an axial plane thereof, this element being provided with a recess for at least one casing and a protective sealant coating of a controlled thickness around this centring element.

10. A hydrophone as claimed in claim 9, wherein the centring element is provided with an internal groove for locating a peripheral rim of the two cups of the casing.

11. A hydrophone as claimed in one of claims 9 or 10, wherein the centring element is made in a single piece.

12. A hydrophone as claimed in one of claims 9 or 10, wherein the centring element is made in two parts between which the casing is retained.

13. A hydrophone as claimed in one of claims 9 or 10, wherein the centring element is made as a single U-

shaped piece with two branches between which the casing is retained.

14. A hydrophone as claimed in one of claims 9 to 13, wherein each receiver unit has two sensitive elements linked respectively to the two cups of each casing.

15. A hydrophone as claimed in one of claims 9 to 14, wherein the cups are made by a forming process, in particular by stamping.

16. A method substantially as hereinbefore described with reference to the drawings.

17. A hydrophone substantially as hereinbefore described with reference to the drawings.

The Patent Office

15

Application No: GB 9708405.7
Claims searched: 1 to 15

Examiner: Peter Easterfield
Date of search: 16 June 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4J (JAB, JCE, JDQ)

Int Cl (Ed.6): G01V 1/20; H04R 1/44, 17/00, 17/02

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A,E	GB 2306848 A	(SYNTRON)	
A	US 4431873 A	(DUNN et al)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.