MINIATURE DIRECTIONAL HYDROPHONE

Filed June 26, 1969 2 Sheets-Sheet 1

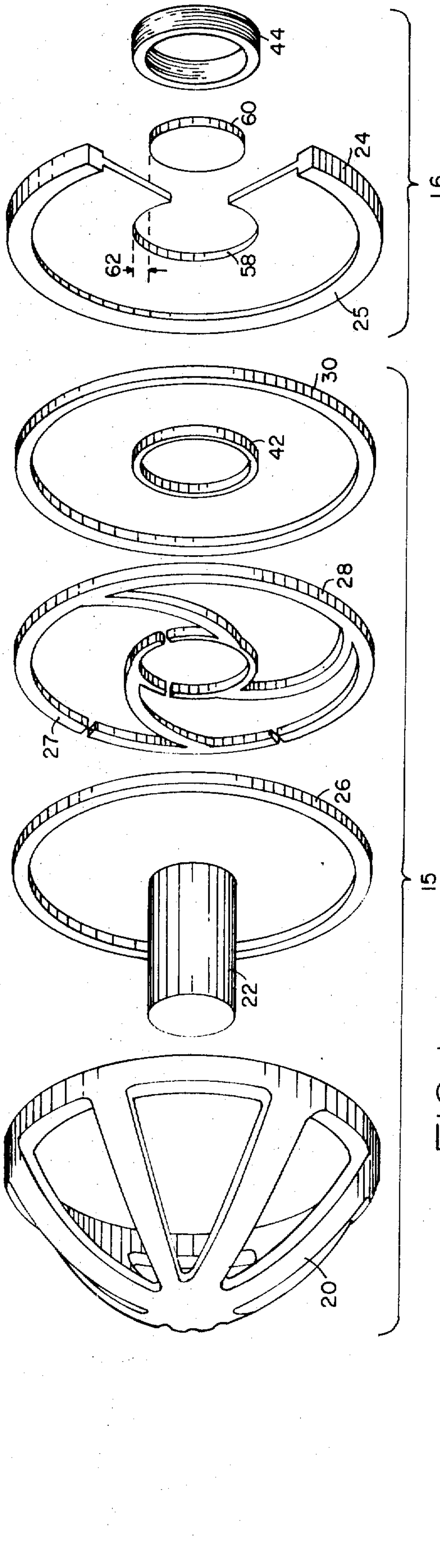


FIG. I

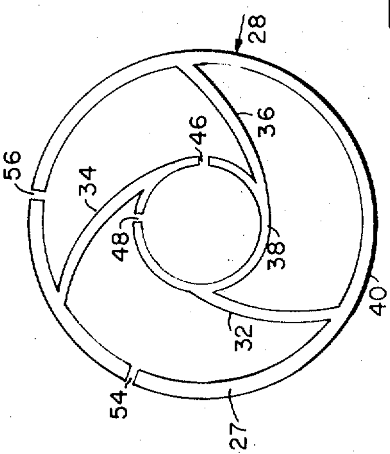


FIG. 2

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MINIATURE DIRECTIONAL HYDROPHONE

Filed June 26, 1969 2 Sheets-Sheet 2

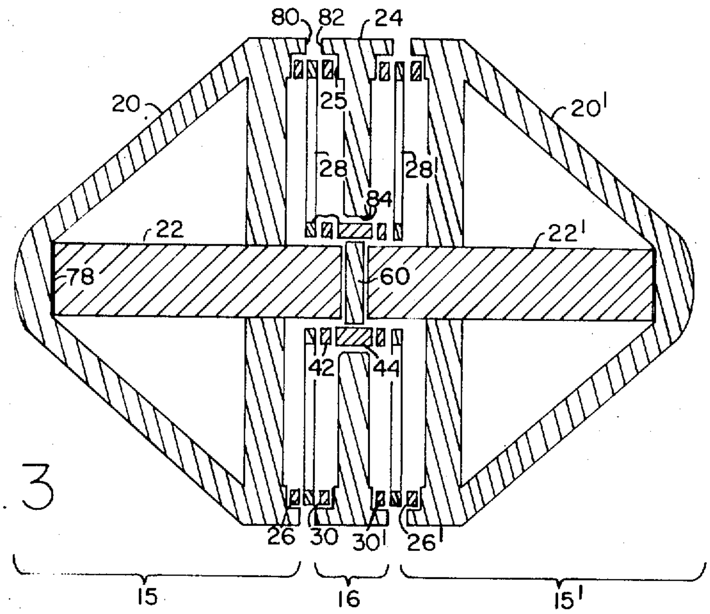


FIG. 3

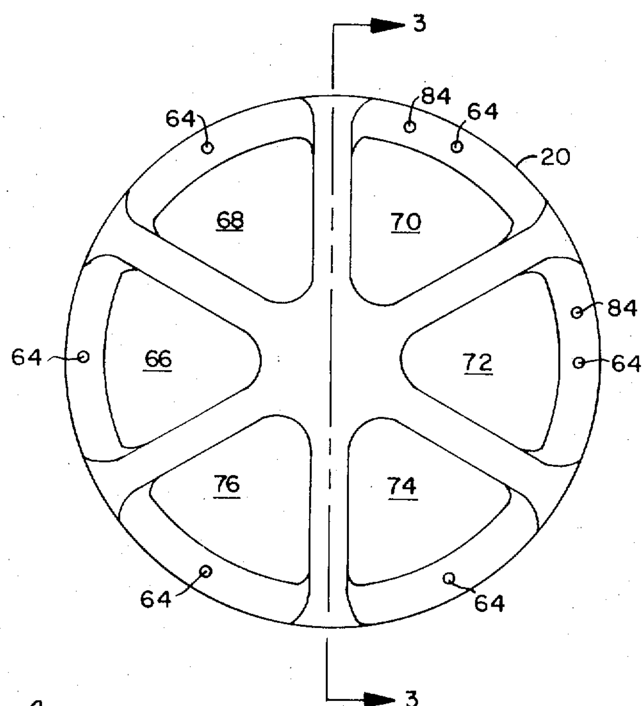


FIG. 4

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United States Patent Office 3,550,072
Patented Dec. 22, 1970



3,550,072

# MINIATURE DIRECTIONAL HYDROPHONE

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Filed June 26, 1969, Ser. No. 836,789
Int. Cl. H04r 9/04
U.S. Cl. 340—13 10 Claims


## ABSTRACT OF THE DISCLOSURE

A hydrophone for detecting acoustic waves in a fluid comprises a magnetic circuit assembly providing a fixed magnetic field and a wave actuated resilient spring coil assembly moveable relative to the magnetic field, which coil assembly is driven by pressure waves. The magnetic circuit assembly includes, in part, a bell shaped housing structure having openings in the surface for the passage of the acoustic waves, and an improved magnetic member to establish the magnetic field.


## FIELD OF THE INVENTION

This invention relates to devices in the field of acoustic detection; more particularly to hydrophones that respond mechanically to sound pressure waves thereby generating electrical signals which are representative of these waves.

## THE PRIOR ART

In directional hydrophones of the prior art, the electrical and mechanical parameters have largely determined the overall size of the hydrophone. More specifically, to achieve a predetermined output signal, a moveable sensing coil must cut across a magnetic field in an air gap of a magnetic circuit. Alternatively, for a given sensing coil, the value of the output signal is directly proportional to the density of the magnetic field, and the density of the field is also related to the efficient use of magnets; that is, the use of magnets which will produce the desired magnetic flux when they are operated within their maximum energy region. Thus, when hydrophones are small they generally exhibit less magnetic and electrical efficiency and, when they are efficient, they are very large and heavy.

In addition, the size of a hydrophone bears a direct relationship with noise that is generated in the electrical signal during the operation thereof; that is, noise generated by the drag of the hydrophone as it moves through the water or as water flows around a stationary hydrophone. This noise is minimized as the overall size of the hydrophone is decreased.

A further problem in the hydrophone art is caused by a failure of electrical leads that interconnect the spring-coil assembly and a terminal post of the hydrophone housing. Because the lead must move with the coil, electrical faults, such as a shorting out or a break in the lead, develop after excessive oscillatory movement thereof.

## SUMMARY OF THE INVENTION

Accordingly, it is a primary object of this invention to provide a novel and improved hydrophone.

An additional object of this invention is to provide a hydrophone having a magnetic field contained therein which is equal to the field found in larger conventional hydrophones.

Another important object of this invention is to provide a hydrophone in which a spring suspending a coil also serves as a lead interconnecting the coil and terminal posts on the hydrophone housing.

It is a further object of this invention to provide a hydrophone having relatively low flow resistance and



which responds with relatively uniform noise to pressure wave signals from any direction.

According to this invention, these and other objects which will become apparent upon reading the specification are embodied in aparatus comprising a magnetic assembly which includes a permanent magnet member composed of Alnico–9 material. The magnetic member provides a magnetic field across an air gap in a magnetic circuit contained in a vented housing; and the magnetic assembly further contains a transducer means which is moveable in the air gap containing the magnetic field, which transducer means is driven by pressure waves.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an exploded isometric of the left-hand assembly and the center section, with a section removed, of the hydrophone of this invention;

FIG. 2 is a schematic presentation of the S-spring embodiment of this invention;

FIG. 3 is an exploded sectional view of the hydrophone assembly in its assembled state taken along lines 3—3 of FIG. 4;

FIG. 4 is an end view of the hydrophone assembly.

## DESCRIPTION OF PREFERRED EMBODIMENTS

A hydrophone apparatus embodying the invention is illustrated in FIGS. 1 and 3, and includes a substantially identical left and right hand magnetic field producing assemblies **15** and **15′** which produce additive magnetic field components across an air gap space **62**. A coil **44** is positioned in air gap **62** for axial movement along a central axis common to both the right and left hand assemblies. When the hydrophone assembly is submerged in water, coil **44** responds to sound pressure waves propagating through the water to move axially according to the intensity and frequency of the sound pressure waves to thereby generate an electrical signal representative of the waves.

As mentioned previously the left and right hand assemblies are substantially identical and like components are designated by like reference numerals which are unprimed and primed for assemblies **15** and **15′**, respectively. Therefore, only left hand assembly **15** will be described in detail. Common to the left and right hand assemblies **15** and **15′** is a ferromagnetic outer pole disc **24**, a coil **44**, and a ferromagnetic inner pole disc **60** collectively shown as subassembly **16**.

Referring to both FIGS. 1 and 3, assembly **15** is shown to include an end bell housing **20**, a permanent magnet **22**, a clamping ring **26**, a resilient S-spring **28**, and a spacer **30**. The housing **20** and magnet **22** are combined to form one subassembly, and ring **26**, spring **28**, and spacer **30** are connected to one side of outer pole disc **24** to form part of a second subassembly.

The cylindrical shaped permanent magnet **22** is mated with the inside of the closed surface of housing **20**, and the longitudinal axis of magnet **22** is substantially aligned with the axis of housing **20**. For purposes of aligning the magnet **22** within the housing **20** and to minimize losses in the magnetic field, inner surface **78** of housing **20** may be machined to assure that mating surfaces of magnet **22** and housing **20** are properly interfaced.

The ferromagnetic outer pole disc **24** interconnects housings **20** and **20′**, and additionally forms one edge of air gap space **62** and will be subsequently explained. Further, as previously explained, clamping ring **26**, S-spring **28** and spacer **30** of the left and right hand assemblies **15** and **15′** are secured to outer pole disc **24**. The clamping ring **26** is positioned against side **27** of S-spring **28** with spacer **30** being positioned against the other side of spring **28**. These three components (**26**, **28** and **30**) are positioned against ridge **25** of outer pole disc **24**, and are secured thereto by any suitable means, for example, a plurality of fastening screws to form a subassembly. The clamping ring **26** and spacer **30** are preferably made from non-conducting material to electrically isolate S-spring **28** from the other components.

The S-spring **28**, illustrated in FIGS. 1 and 2, is shown to have an outer element **40** and an inner element **38** suspended from the outer element by means of three curved fingers **32**, **34** and **36**. Preferably, one of the fingers is isolated from the other two and forms a segment of the electrical leads for coil **44**. The method of isolating this finger will be explained subsequently. A coil spacing ring **42** preferably made of non-conducting material, is secured to the side of the inner element **38** towards spacer **30** by any suitable means, for example, a cement or bonding composition. Coil **44** is then cemented or otherwise secured to the opposite side of coil spacer **42**.

Outer pole disc **24** contains a central bore **58** which receives a ferromagnetic inner pole disc **60** when the hydrophone is assembled. Inner pole disc **60** is mounted between the ends of magnets **22** and **22'**, and the disc **60** may be secured to either or both magnets by any suitable means, for example with cement. The outside diameter of disc **60** is less than the diameter of bore **58**, and the distance between the edge of disc **60** and bore **58** defines annular air gap **62**. Coil **44**, secured to spacing ring **42**, is then positioned within air gap **62** for axial movement along a central axis common to magnets **22** and **22'**.

A feature embodied in the present invention is to use one of the fingers of S-spring **28** as a segment of the lead which will interconnect coil **44** and a terminal post **84** (FIG. 4) on housing **20**. For example, finger **34**, illustrated in FIG. 2, is easily isolated from fingers **32** and **36** after subassembly **16** is assembled, that is, clamping ring **26**, S-spring **28**, spacer **30**, spacing ring **42**, coil **44** and the prime designates, are secured to the outer pole disc **24**. Once the components are assembled, outer element **40** of S-spring **28** is cut at points **54** and **56** and inner element **38** is cut at points **46** and **48**. One end of coil **44** is then connected to the isolated section of inner ring **38** by any suitable means, such as soldering, and the isolated section of outer element **40** may be connected to terminal post **84** by a lead wire or other means well known in the art. In addition, one finger of S-spring **28'** (right hand assembly) becomes a segment of the second electrical lead for coil **44**. Alternatively, a lead wire may be directly connected between coil **44** and terminal post **84**, but since the leads are subject to oscillatory movements they tend to fracture after extensive use causing a malfunction in the unit.

The hydrophone, illustrated in FIG. 3, comprises the left hand assembly **15**, the center assembly and the right hand assembly **15'** with the sections fastened together by any suitable means, for example, bolts and nuts extending through a plurality of holes **64** located in the outer circumference of sections **20**, **20'** and **24** as seen in FIG. 4.

FIG. 3 further illustrates appropriate design techniques to minimize the loss of magnetic flux in the hydrophone package. For example, the surface area **80** of housing **20** and the corresponding mating surface **82** of outer pole disc **24** are substantially identical, that is, the surfaces are parallel and the sharp edges are coplanar. In addition, edges leading to surface **84** of bore **58**, outer pole disc **24**, are beveled so that surface **84** is substantially identical in area and width to the outside surface of the inner pole disc **60**. This assures that the magnetic field is concentrated within the active air gap **62**, thereby enhancing the efficiency of the hydrophone.

The magnetic field that is established within the air gap **62** is the sum of the magnetic field components of the permanent magnets **22** and **22'**. The path for the field components of the left hand assembly **15** extends from the permanent magnet **22** into the closed end of housing **20**, radially through the fingers of housing **20** to outer pole disc **24**, radially through outer pole disc **24** and across



air gap **62** into inner pole disc **60** and then back to magnet **20**. The magnetic path for the right hand assembly extends through the corresponding prime numbered components. In addition, design procedures will provide for the use of components or cements that will minimize the loss of the resultant magnetic field.

Another feature embodied in the present invention is the use of Alnico-9 magnetic material for the permanent magnets. Since Alnico-9 magnetic material possesses very high flux density characteristics, the performance characteristics of the described hydrophone are only achieved in the hydrophones of the prior art that are four or five times in size. Conversely, the size, weight, and volume of the described hydrophone are substantially reduced. For example, the dimensions of the preferred hydrophone are approximately 2.25 inches in length, 2.20 inches in diameter at the center and weighs approximately four-fifths (0.80) of a pound.

In operation, the assembled magnetized hydrophone is immersed in a fluid which completely surrounds and fills any vacant chambers that exist in the hydrophone, the fluid entering the hydrophone structure through the vents or openings **66** and **76** in housing **20** and **20'**. When a sound or vibration occurs in the monitored area, the compression waves produced by the vibrations are vented through openings **66** to **76** varying the pressure within the hydrophone, and causing coil **44** to move. Thus, coil **44** is driven back and forth through the magnetic field in air gap **62** in response to the magnitude of the sound pressure variations, and as a result of this movement through the magnetic field, a signal is generated in the coil **44**. Springs **28** and **28'** act in concert to restrain the movement of coil **44** due to variations of pressure, more particularly, to respond to coil motion by introducing a restoring force. The hydrophone described herein is directional, that is, the signal generated in coil **44** is a function of the cosine of the angle between the common axis of the hydrophone or the axis of the coil motion and the direction of the motion of the sound source. Thus, a resultant signal which is comprised of the signal generated in coil **44** and signals from other similar hydrophones in a unit will indicate the direction of the source. This resultant signal may be connected to any suitable electronic apparatus, for signal analysis.

The assembled hydrophone will produce a signal for analysis providing that either the left or right hand magnetic assembly is properly functioning. In particular, the signal generated by coil movement in the magnetic field produced by one assembly will be greater than one-half of the signal produced in a field generated by both assemblies, and the strength of the signal is great enough to permit detection. Thus, the hydrophone will perform its intended function providing that at least one section is producing a magnetic field.

It should be appreciated that the above-described structure may be used in apparatus other than a hydrophone placed in the ocean, for example, it may be part of a unit which is placed in the ground to detect earth vibrations.

The above description relates to specific principles of this invention, and it is to be understood that this description is made by way of example only, and not as a limitation thereon, for one skilled in the art may make modifications thereto, but still be within the true spirit and scope of this invention as set forth in the appended claims.

What I claim is:

1. The combination, comprising:

magnetic circuit means having an air gap and including permanent magnet means of Alinco-9 composition for providing a magnetic field within said gap;

said magnetic circuit means including a first and second ferromagnetic disc, said first ferromagnetic disc having a section removed substantially in the center thereof defining an aperture and said second ferromagnetic disc being smaller than and having substantially the shape of said aperture, said first and second ferromagnetic discs being arranged to form said air gap,

vented housing means enclosing said magnetic circuit means, coil means responsive to sound pressure waves for producing electrical signals, and

suspension means positioning said coil means in said air gap.

2. The combination in accordance with claim 1, wherein

said housing means includes first and second bell shaped members each having a closed and open end and each having its open end secured to said first disc.

3. The combination in accordance with claim 2, wherein said magnet means includes two substantially cylindrical shaped members each extending from the closed end of said bell member towards said first disc, said cylindrical member being coupled to said second disc.

4. The combination in accordance with claim 1, wherein

said suspension means includes a first and second S-shaped spring assembly having an inner and outer element, said inner element being secured to said coil and said outer element being secured to said housing means.

5. A miniature permanent magnet hydrophone assembly, comprising

first and second ferromagnetic housing members, each having a closed and open surface,

first and second permanent magnet members of Alinco-9 composition coupled to and extending from said closed surface to said open surface of said first and second housing members respectively, said first and second magnetic members being substantially aligned on a common axis,

a first ferromagnetic member connecting said open surface of said first housing member to said open surface of said second housing member, said first ferromagnetic member having a section removed therefrom defining an aperture,

a second ferromagnetic member connecting said first magnet member to said second magnet member, said second ferromagnetic member being positioned within said aperture,

said first and second magnet members in combination with said housings and said ferromagnetic members providing a magnetic field across the space between the wall forming said aperture and said second ferromagnetic member,

coil means responsive to sound pressure waves for producing electrical signals, said coil means being driven along the axis of said first and second magnetic members in said space, and

suspension means secured to said housing members positioning said coil means in said space, said suspension means includes a first and second S-shaped spring assembly having an inner and outer element, said inner element being secured to said coil means and said outer element being secured to said housings.

6. A miniature magnetic hydrophone assembly, comprising:

first and second bell shaped housing members, each having a closed end and an open end,

a first magnetic member extending substantially from the center of said closed end of said first housing member towards said open end, said magnetic member being substantially aligned with the center axis of said first housing member,

a second magnetic member extending substantially from the center of said closed end of said second housing member towards said open end, said magnetic member being substantially aligned with the center axis of said second housing member,

said first and second magnetic members being comprised of Alnico-9 magnetic material,

a first spring assembly being adjacent to said first housing member,

a second spring assembly being adjacent to said second housing member,

a first ferromagnetic member being adjacent to said first and second spring assemblies, said first ferromagnetic member having a section removed therefrom defining an aperture,

means to connect said first housing member to said first spring assembly, said first spring assembly to said first ferromagnetic member, said first ferromagnetic member to said second spring assembly, and said second spring assembly to said second housing member,

a second ferromagnetic member connecting said first and second magnetic members, said first and second magnetic members being substantially on a common axis, and said second ferromagnetic member being positioned in said aperture,

said first and second ferromagnetic members being positioned to form a gap therebetween,

said first and second magnetic members in combination with said first and second housing members and said first and second ferromagnetic members providing a magnetic field across said gap, and

means responsive to sound pressure waves for providing an electrical signal that is a function of said waves, said means responsive being suspended between said first and second spring assemblies in said magnetic gap, and said means responsive being free to move in a plane substantially parallel to said common axis of said magnetic members.

7. A hydrophone in accordance with claim 6, wherein said first and second magnetic members are cylindrical elements.

8. A hydrophone in accordance with claim 6, wherein said first and second housings include a plurality of vent openings, said openings being arranged around the axis of said first and second magnetic members.

9. A hydrophone in accordance with claim 6 wherein said means responsive includes a coil assembly having externally accessible leads attached thereto for sensing the current in it.

10. A hydrophone in accordance with claim 9, wherein said first and second spring assemblies includes an inner and outer metallic element, said inner element being supported from said outer element by at least three metallic supporting members,

means for electrically isolating one of said supporting members from the remaining of said supporting members and said inner and outer elements, and

means connecting said isolated support member to said coil.


**References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 2,311,079 | 2/1943 | Parr, Jr. | 340—13X |
| 2,533,249 | 12/1950 | Henson, Jr. | 340—17X |
| 2,751,573 | 6/1956 | Millington | 340—17 |
| 3,018,467 | 1/1962 | Harris | 340—17X |
| 3,242,459 | 3/1966 | McCollum | 340—17 |
| 3,412,376 | 11/1968 | Johnson III | 340—17 |



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U.S. Cl. X.R.

340—17