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A Review Paper on Hydrophones

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Abstract: **Previously, the technology was confined to the Lithospheric phenomena, but now the technology is trying to extend its hand to discover the oblivion wonders of Hydrosphere. So, here we discuss about a technology called Hydrophone which is a combination of Hydro (i.e. water) and Phone (i.e. sound) which helps us listening to the underwater sounds and vibrations. This paper includes the Types, Construction, Working, Application and Advantages of the Hydrophone. It also focuses on the use of Optical Fiber as the sensing element which not only detects the pressure waves but also the temperature changes under the water. If this device is used in proper direction, it can prove itself to be a huge prodigy to the mankind.**

INTRODUCTION

A transducer is an electronic device that converts one form of energy into another form to measure and transfer the information in sensing applications. For underwater sound sensing, we use Hydrophones. The hydrophone was earlier known as Fesseden oscillator. It was invented by the Canadian inventor 'Reginal Fesseden', in 1929. Then, the technology was taken over and re-designed by the France during World War II to detect the German sappers. A Hydrophone converts acoustic waves into electrical signals. Hydrophone is marine equivalent of a microphone. So, it has similar operation as a microphone which was used primarily for detecting sound waves coming from an underwater source, like submarine. This device is used in sonar apparatus and in underwater weapons. An array of hydrophones can be used instead of a single hydrophone for the better detection.

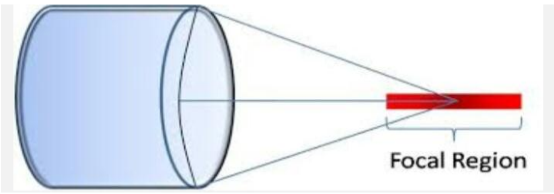
Types: There are two types of hydrophone which are as follows:

- Omni-directional Hydrophones:-The Omni-directional type detects sound from all the directions with equal sensitivity.

- Directional Hydrophones:- It has higher sensitivity to signals in a particular direction. Directional hydrophones are usually built from scores of Omni-directional hydrophones, but can also be created from hydrophone arrays. The enhanced sensitivity is due to two basic techniques:-

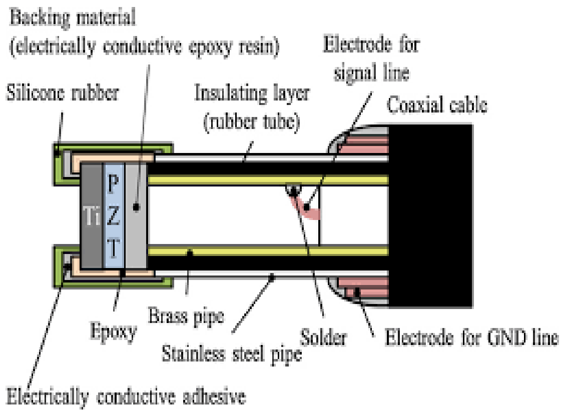
1. Focused transducer
2. Hydrophone array

Focused transducer: The old hydrophones used to use a transducer with conical shaped sound reflector to focus the signal. This type of hydrophone can be developed using a low cost Omni-directional type hydrophone. These could be used in stationary position as the reflector impedes its movement through the water. The new way is to use a spherical body around the hydrophone. The advantage of directivity spheres is that the hydrophone can be moved within the water, ridding it of the interferences produced by a conical-shaped element.

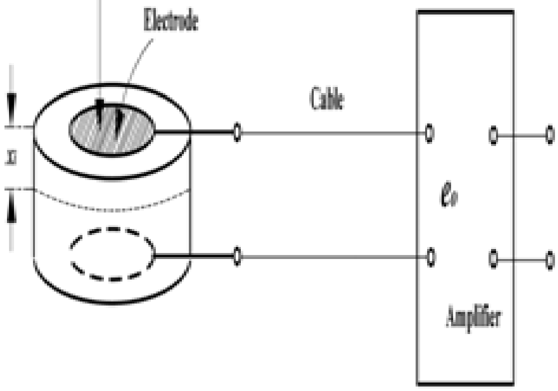


Hydrophone Array: An array of hydrophones can be used instead of a single hydrophone for the better detection. The Hydrophone array is created by connecting many hydrophones in different but known locations. The sound waves reach different hydrophone at a different instance of time, depending on the origin of the source. The difference between the sound arrival time intervals can be used to calculate the direction that the sound is coming from. Simple arrays with only two hydrophones can be used to detect the origin of the sound. A simple array can be created using only two hydrophones to detect the origin of the sound. Arrays work more efficiently than single hydrophone because they are able to filter out most of the noise from the other directions. This arrangement also increases the signal-to-noise ratio, which allows us to hear hard to detect signals. A hydrophone array is used in most of the sensors to detect acoustic sounds.

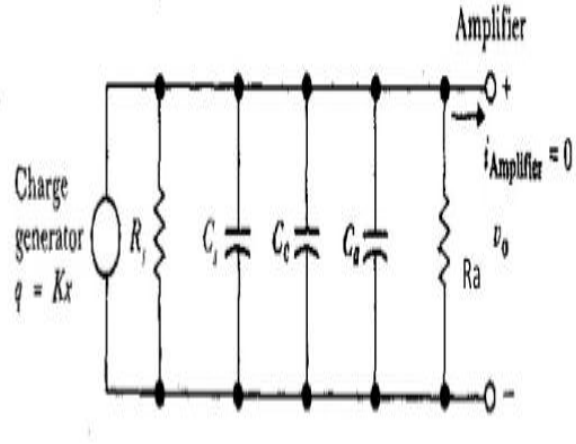
Structure: A hydrophone comprises a casing within which a conductive substrate is mounted and a piezoelectric crystal (Ceramic or Polyvinylidene Fluoride, PVDF) is mounted on the exterior of the substrate. The conductive substrate increases the mass and limits the ringing at the resonant frequency of the piezoelectric crystal. A piezoelectric crystal is used due to the fact that the acoustic impedance matches with the impedance of the crystal. So, it facilitates its use in underwater applications. The volume between the casing and the substrate is always filled with a liquid. Preferably oil is used. If there is one or more bubbles of air in the volume between the casing and the conductive substrate. It will permit vibration of the substrate and the piezoelectric element.



Working: A Hydrophone works on piezoelectric effect. Piezoelectric effect is the ability of a material to produce an electric charge in response to applied mechanical stress. One of the unique characteristics of the piezoelectric effect is reversibility i.e. a material exhibiting the piezoelectric effect (generation of electric field when stress is applied) also exhibits the converse piezoelectric effect (the generation of stress when electric field is applied). Hydrophones depend upon piezoelectricity to detect the underwater vibrations and pressure differences. Piezoelectric materials can change their shape and converts the mechanical energy into electrical energy. Sound is a form of pressure wave that physically moves particle. It produces a mechanical force as it comes in contact with a hydrophone. Due to the presence of air bubbles between the hydrophone casing and conductive substrate, it permits vibration of the substrate. Consequently, there is a vibration in the piezoelectric crystal. It is required for hydrophones to have a flat frequency response. That is, the output voltage should be of same amount as the amount of acoustic excitation. So, the output voltage is basically proportional to acoustic pressure input. This technique works really well and also results in the desired flat frequency response up to a level where the piezoelectric crystal begins to have a resonanceThis crystal now produces a voltage signal and the voltage signal is proportional to the spatial average of acoustic pressure sensed at the active element. The output voltage can be acquired and analyzed using an oscilloscope. Another method is to use the fiber optics, to detect the change in refractive index from the acoustic pressure wave in the water. This method was developed to withstand the high acoustic pressure waves.



Equivalent electrical circuit:



q = Charge produced from applied pressure
R_s = Resistance of the piezoelectric crystal
C_s = Capacitance of the piezoelectric crystal
C_c = Capacitance of the cable
C_a = Capacitance of the preamplifier
R_a = Resistance of the preamplifier

Optical Fiber Hydrophone: The fiber optic hydrophone is the next generation of hydrophone technology. Optical fiber hydrophone is developed by combining the on hand hydrophone design techniques with the most up-to-date optical system and component. A fiber optic hydrophone is a sensor that uses an optical fiber either as a sensing element or as a means for regulating signals coming from a remote sensor to the electronic device that process the signals. Optical fibers are mostly used in remote sensing which is due to its small size and also no electrical power is required at remote location. Optical fiber sensors are also resistant to electromagnetic interference and do not carry out the conduction of electricity. These can be used in places with high voltage electricity or combustible material. Optical fiber sensors can be used to bear up high temperatures. The advantage of optical fiber hydrophone is that it can be used to determine temperature and pressure, at the same time and the same point in a measuring environment. This makes a direct correlation between pressure and thermal change. Hydrophones based on the interferometry method are mostly used. Interferometry is family of techniques in which waves (usually EM waves) are superimposed. It cause the development of inference phenomena which helps in extracting the original information. There are two types of the optical fiber hydrophones:

1. A plane tipped sensor for optimal sensitivity (it has less uniform frequency response).

2. A tapered tipped sensor for optimal frequency response (it has a little lower sensitivity).

Structure and Working of Optical Fiber Hydrophone:

Optical fiber hydrophone consists of mainly five layers made up of different materials-

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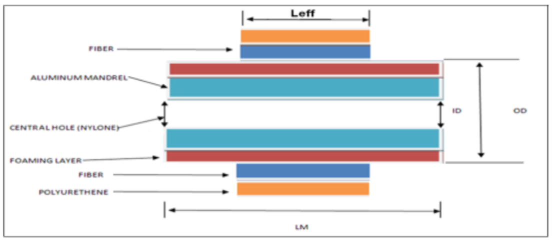
- Basic layer of Nylon with the thickness of 0.25Cm.
- The core layer is of Aluminum (Al) with the thickness of 2Cm.
- Foaming layer with the thickness of 1 Cm
- Optical fiber
- Elastic Polyurethane coating of 1 Cm thickness.



When an acoustic wave strikes and makes impact on the effective length (L_{Eff}) of sensor, the pressure exerted by the acoustic wave on the sensor is firstly experienced by the elastic polyurethane coating and this makes a proficient impact of stress & strain on the optical fiber which causes the deformation on the fiber. Hence, the optical path length changes and we get the information about the original pressure wave.

Applications:

- Detection of mammals
- Detection of submarines and icebergs
- Subsea gas leakages
- Natural phenomena such as earthquakes, underwater volcanic eruptions
- Navigation, underwater mapping and communication
- Oceanography
- Seismology
- remote sensing
- surface profiling
- Measurement of mechanical stress/strain

Advantages:

- Waterproof
- Do not require a power source
- Less expensive to operate
- More accurate sound detection than other devices
- High sensitivity
- Low noise
- Double output: single/differential
- Calibration input
- High materials quality
- Robust
- Small and light

Selection criteria of a hydrophone:
The selection should be done on the basis of some main factors. These are:-

1. Sensitivity versus effective area: the amplitude of the voltage is proportional to the area of the active element. The larger the sensing area, the more will be the sensitivity.

2. Interference with the acoustic field: Generally, we prefer to use sensors that do not affect the parameter being measured. But, we choose a hydrophone depending upon the nature of the acoustic field.

3. Fragility: Hydrophones are very fragile, especially near the sensing element, because it has high sensitivity to transient pressures waves.

4. Immersion: The water is a relatively aggressive solvent. It even can pass through plastics. For this reason, the hydrophone must be taken out of the tank when it is not actively used.

5. Size: Needle hydrophone has the smallest size and it is followed by the capsule design, and membrane type hydrophones are extremely large as compared to the sensing element.

6. Cost: The membrane devices are more costly, followed by capsule and then needle hydrophones. The smallest devices are the most difficult to make and hence are the most expensive.

CONCLUSION:

Hydrophones are essential devices that are configured to pick up underwater sound and convert it into audio signals that can be translated into measurable data by using a piezoelectric transducer that is water tight. The hydrophone can be encased in some sort of material to provide protection for the device but it never interferes with the reception of audio input signal. The casing is usually like a long tube which is flexible in design and can be used for the underwater surveys.

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