ULTRA-SONIC WAVES

by

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GENERAL PROPERTIES OF THE ULTRA-SONIC WAVES.

The ultra-sonic waves are elastic longitudinal vibrations of higher frequency than the sounds audible to our ear.

The range which they embrace has no upper limit, while it has a minimum value roundabout 20 kHz.

As compared with audible sounds the ultra-sonic waves possess very interesting properties which alone justify the preference given them in submarine signalling. These properties may be enunciated as follows :

a) With equal dimensions of the emitting source, the propagation of ultra-sonic waves is particularly directive as compared with that of (audible) sound-waves.

This property is enhanced as the ratio between the dimensions (diameter) of the ultra-sonic projector and the length of the ultra-sonic wave increases. In other words with the increase in the frequency of the transmitter the transmission becomes more and more directive.

It is obvious that this property should warrant soundings with an accuracy which, a few years ago, it was impossible to obtain on shoals of irregular character.

The propagation of the elastic longitudinal vibrations in sea water is very easy, and it is this facility which, many years ago, enabled FESSENDEN to construct the first laminated oscillator with a frequency of 500 kHz which was such a success in enabling satisfactory hydrographic soundings to be obtained with great rapidity.

The accuracy of the data obtained drew the attention of navigators and scientists to these low-frequency signalling apparatus. It was, however, noticed that on shoals (a few tens of metres), these soundings gave indistinct and inaccurate echoes, especially if the ocean bottom presented marked irregularities.

The propagation of the direct and reflected wave, in the case of undirectional emission, can, in actual fact, give superimposed indistinct successive echoes, which render impossible an accurate determination of the depth. The emitted sound travels by spherical waves which, on striking against some obstacle, or the bottom itself, are reflected afresh as spherical waves. This fact explains how superimposed indistinct echoes are produced if the bottom is not smooth, due to the circular reflection of these waves.

It was necessary, to eliminate this drawback, to find a directional transmission capable of affecting but a small area of the bottom exactly under the ship's keel.

Ultra-sonic waves with positive directional properties tend, for this reason, to be substituted in practice for audible sounds in the transmission for maritime soundings.

Before touching upon the question of the practical application of the ultra-sonic waves in the apparatus with piezo-electrical projector in use in the Royal Navy, let us review the other properties of these :

b) The energy transmitted by a thin plate for either audible or for ultra-sonic waves is proportional to the square of the amplitude of vibration and to the square of the frequency.

This means that with an increase in frequency, in passing from the audible to the ultra-sonic waves, the transmitted energy increases considerably.

c) Because of the losses (by internal friction and heat), the transmitted energy decreases in accordance with an exponential law given by a coefficient which is proportional to the square of the frequency.

This means that the absorption of energy increases greatly with the frequency and that, due to this, a given value thereof must not be exceeded or illusory ranges will ensue, even with high-power transmitting apparatus.

The two properties *b)* and *c)* show therefore that, for the propagation of ultra-sonic waves in water, there exists an "optimum" frequency with which it is possible to obtain maximum range and good incoming energy (after reflection) for making the necessary determinations.

Naturally the choice of this frequency is made taking into account, besides properties *b)* and *c)*, property *a)* also, as well as the characteristics which it is desired to give the transmitter and the results to be obtained.

d) From the measurements which it has been possible to effect on the absorption, reflection and refraction of the ultra-sonic waves, it has been determined that the ratio between the reflected and refracted energy depends on the impedance which the mediums oppose to the propagated ultra-sonic wave.

From the determinations of these impedances in various mediums, it has been found that it is possible to obtain a good reflection from the sea bottom, or from ships' metal hulls, and that the reflection is negligible for ice. It has been actually ascertained that a super-sonic beam striking the separation surface of two mediums of different density is partly reflected and partly transmitted. The reflected portion is given by the formula. $\left(\frac{\delta v - \delta' v'}{\delta v + \delta' v'}\right)^2$, in which v and δ are respectively the velocity and the density in the first medium, v' and δ' the velocity and density in the second medium.

It has thus been found that the ultra-sonic waves lend themselves badly to the search for icebergs, whereas they present real advantages for the determination of the sea bottom or the location of submerged wrecks.

THE ULTRA-SONIC WAVES IN THE NAVY.

The properties enumerated up to now reveal clearly the reason for the preference given the ultra-sonic waves for oceanic sounding.

The problem of the generation of ultra-sounds is one of those which has been occupying a great number of scientists for many years.

The practical solution thereof has been found by LANGEVIN who had the idea of making use of the piezo-electrical property of quartz for transmitting vibrations of suitable frequency through the water. In the attempts which had preceded this application, efforts were made to transmit these vibrations using thin metal plates in contact with the medium, like the armature of a condenser interposed in a circuit traversed by a high-frequency current. The great power required, the high tension necessary between the plates of the condenser, have caused this solution to be discarded.

The piezo-electrical phenomenon of quartz is well known. It is known, as a matter of fact, that a sheet of quartz adequately cut, subjected to a given difference of potential, suffers a mechanical deformation which is proportional to that tension. The phenomenon is reversible and, with a sheet mechanically actuated in the direction of its thickness a difference of potential may be brought about proportional to the actuating pressure (positive or negative).

The application of these properties, using in place of a sheet a mosaic of small sheets, sandwiched between steel armatures of adequate thickness, so that the frequency utilized is the fundamental resonance frequency of the condenser formed by the two steel plates and the quartz mosaic sandwiched between them, has enabled us to obtain a practical solution of the problem by constructing what is commonly called the ultra-sonic piezo-electrical quartz projector.

In taking a sounding with this projector we use it both as transmitting and receiving apparatus for the ultra-sonic energy produced.

The transmitting apparatus which supplies the energy to the projector is a spark or a continuous-wave radio-apparatus.

Other types of ultra-sonic apparatus for sounding, especially used by the Navy, have a magnetostriction projector made of a bar of nickel in place of the quartz projector.

These bars, under the action of the magnetic field, undergo mechanical deformations which are transmitted to the water, like those of a quartz projector.

Having come to this point, it would appear unnecessary to go further into details of the manner in which the various ultra-sonic apparatus used in the Navy are constituted.

It will suffice to say that these apparatus have given the navigator practical trustworthy means to navigate and that nowadays there no longer exists a ship of any size of the Navy or the Mercantile Marine which does not possess an ultra-sonic apparatus.

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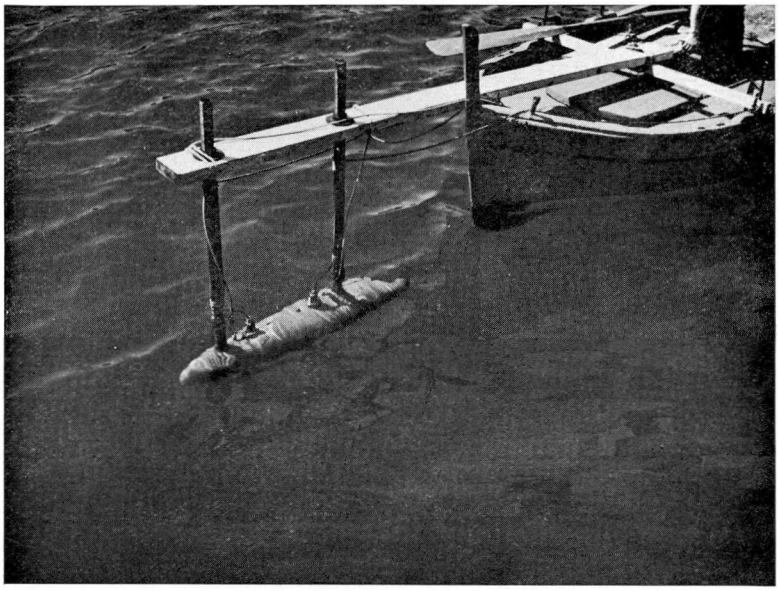
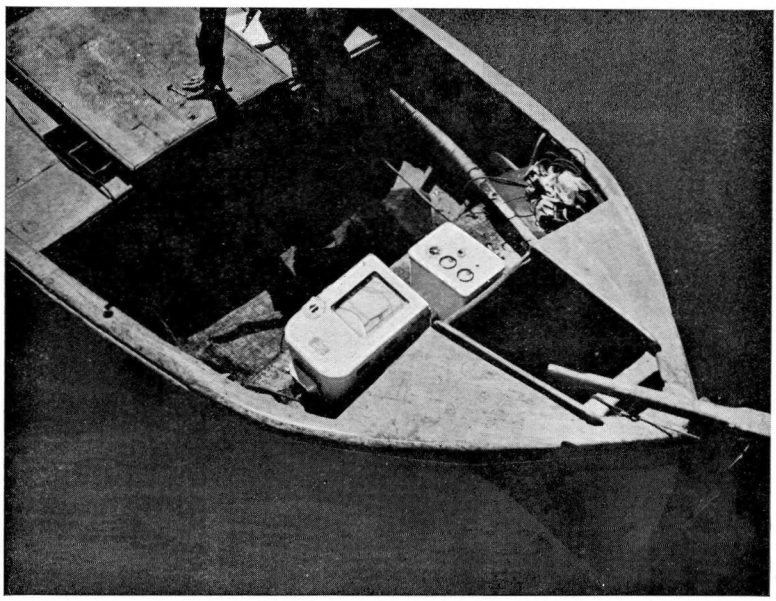


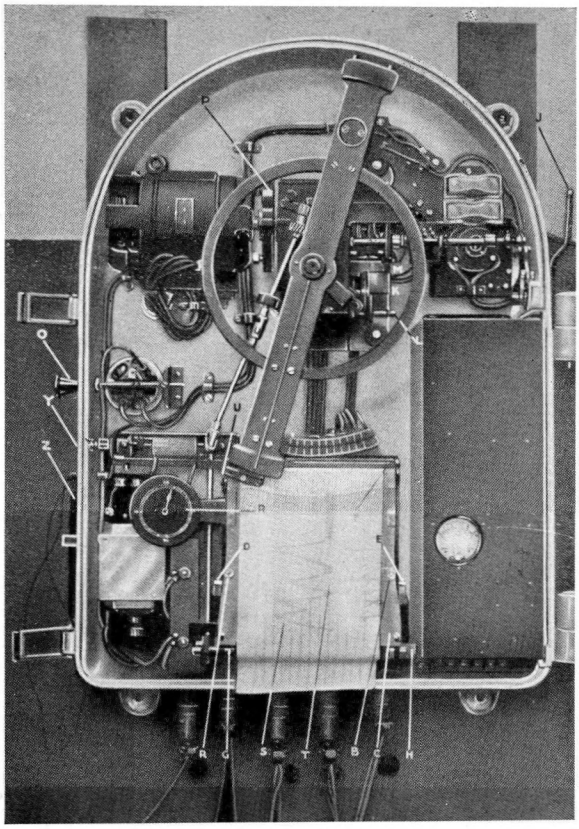
HUGHES ECHO-SOUNDER.

(Outboard oscillator. — *Oscillateur hors-bord*).



HUGHES ECHO-SOUNDER.

(Demonstration Rig. — *Dispositif de démonstration*).



Hughes Recorder, with rotating arm.

Enregistreur Hughes, à bras tournant.