ECHO SOUNDING APPARATUS

(Report of the German Hydrographic Institute, Hamburg, in response to the circular-letter No. 12-H of 28/11/1947 from the International Hydrographic Bureau, Monaco).

I.—COMMERCIAL SOUNDING APPARATUS.

In Germany several types of echo-sounders were produced in large series. Their state of development may be marked as follows :—

1. Low-frequency-echo-sounders.

Low-frequency-echo-sounders have displaced almost entirely the former echo-sounders with impact effect, which only could be applied in small and medium depths. The transmission of an audible sound in comparison to producing impulses by impacts has the advantage, that the sound receiver may be tuned into the frequency of the sound transmitter. Thus a considerable increase of sensitiveness is gained, which enables to take soundings in largest oceanic depths. Originally low-frequency-echo-sounders were produced for a frequency of 1050 cycles. That proved inexpedient : The sensibility of the human ear is maximally indeed for 1050 cycles, but this frequency is lying within the acustic disturbances of the ship, caused by the ships engines and other sources, the most substantial range of which is extending between 500 to 1500 cycles. Therefore the frequency of modern low-frequency-echo-sounders was placed on 3.000 cycles. With this arrangement at the German Northatlantic Expedition in 1938 regulary three echos following one another were heard even at a depth of 6000 meters. That amounts to 6 times 6000 meters or 36 kilometers of way the sound was travelling.

Manufacturers : Firm Atlas-Werke, Bremen; Firm Electroacustic, Kiel.

Technical datas : Weight of the complete instrument : appr. 110 kilogramm ; Primary need of power: 1,2 kilowatts; Oscillator output (electric): 400 watts; Efficiency (electric-acustic): 50%; Accuracy of measure: 1% at a maximum fluctuation of voltage of ± 5% ; Scale of indication: 0 to 1000 meters and multiples of this.

Range of application : Medium and large depths.

2. High-periodic-echo-sounders.

High-periodic-echo-sounders are a valuable completion of the low-frequency-echo-sounders. They are operating with inaudible frequencies, and have the following considerable advantages in comparison to low-frequency-echo-sounders.

(a) The directed radiation of inaudible sound waves delivers the true depths below keel. With low-frequency-echo-sounders in comparison only echo distances are received. As it is known, the values they give are too little at ditches and slopes, as each plane being nearest to the transmitter already reflects the arriving acustic waves ;

(b) The high-periodic-echo-sounder delivers continuous soundings, therefore the impression of a " fixed indication " and of a comfortable reading is given ;

(c) The high-periodic-echo-sounder is the ideal sounder for shallow waters. Smallest measurable depths below keel already 0,5 to 1,0 meter (at the low-frequency-echo-sounder about 5 meters) ;

(d) The high-periodic-echo-sounders cause no difficulties in installing the swings even at ships with small draught. Length of base between the transmitter and receiver swing only about 1 meter ;

(e) The high-periodic-echo-sounders work noiseless.

High-periodic-echo-sounders preponderant are manufactured as magnetostriction sounders, seldom as piezoelectric sounders. They have an operating frequency of 30 000 cycles. The indication is worked either by means of rotating glowing lamps (neon lamps), which illuminate at arrival of echo (firm Atlas-Werke) or by means of sluices of light electro-magnetically controlled (firm Electroacustic).

Manufacturers : Firm Atlas-Werke, Bremen (magnetostriction sounders) ; Firm Electroacustic, Kiel (magnetostriction sounders) ; Firm Debeg, Berlin (piezoelectric sounders).

Technical datas: Weight of the complete instrument: appr. 55 kilograms; Primary need of power : appr. : 1 kilowatt ; Oscillator output (electric) : 200 watts ; Efficiency (electric-acustic) : 30 % ; Accuracy of measure : 2,5 per mille at a maximum fluctuation of voltage of ± 5%; Scale of indication: 0 to 125 meters and multiples of this.

Range of application : Small and medium depths.

3. **Universal sounders.**

The echo sounding apparatus described under 1) and 2) also have been combined and were manufactured in large series (firm Atlas-Werke, firm Electroacustic) under the denomination " Universal Sounders ".

II.—RESULTS OF THE WORK OF DEVELOPMENT.

Numerous systematic researches lead to the knowledge, that the distance ranges of ultra sound waves are succumbed under the distance ranges of audible water-sound frequencies on account of stronger absorption and dispersion on the inhomogeneousness of sea water.

By means of high frequency sounders depths up to 600 meters reliably could be sounded; only in extreme cases echo indications of depths up to 1000 meters could be received.

With regard to the considerable advantage of high-periodic-echo-sounders compared with low-frequency-echo-sounders, as referred to under 1,2), trials were made to meet efficaciously this single disadvantage of the ultra-sonorous sound waves. The aim was to develop a high periodic sounding apparatus applicable also for soundings in oceanic depths. What steps may be taken for that purpose ?

Physically it is possible first to increase the output of the transmitter swings. Yet theoretical considerations proved, that the needed increase of transmitter output, in order to reach up to enlargened distance ranges, is very high, and therefore sounding apparatus build on this principle would be uneconomical and would need a high instrumental expansion of the whole apparatus. For this reason the matter was dropped.

Yet H. Gabler has declared a method, by which a considerable increase of sensitiveness is gained at the high-periodic-echo-sounders by simple arrangements on the receiver part. The instruments developed and manufactured after this method are named.

High-periodic-superposed-echo-sounders.

1. **Principle of method.**

The echo reflected from the bottom of the sea produces an ultra-sonorous periodical oscillation of 30 000 cycles within the receiver, which after an advanced reinforcement may have grown up to the amount $H. \cos \omega_H . t$. Within the receiver amplifier an auxiliary oscillation of about the same amplitude, but of deviating frequency is superposed to this oscillation, the auxiliary oscillation being produced by a small oscillator step. The superposed frequency may have the amount $\ddot{U}. \cos \omega_{\ddot{u}} t$. What analytical form and physical consequence has the amount C, which originates from the superposition of these two oscillations ?

$$\ddot{U} \cos \omega_{\ddot{u}} t + H \cos \omega_H t = C \tag{1}$$

with

$$H \cos \omega_H t = H \cos \left(\omega_H - \omega_{\ddot{u}} + \omega_{\ddot{u}}\right) t =$$

$$H \cos \left(\omega_H - \omega_{\ddot{u}}\right) t. \cos \omega_{\ddot{u}} t - H \sin \left(\omega_H - \omega_{\ddot{u}}\right) t. \sin \omega_{\ddot{u}} t. \tag{2}$$

after inserting into (1), and after some convertions and substitutions the searched amount C is received as follows :—

$$C = \ddot{U}. \cos \omega_{\ddot{u}} t + H \cos \omega_H t$$

$$= \sqrt{H^2 + U^2 + 2 H \ddot{U}. \cos \left(\omega_H - \omega_{\ddot{u}}\right) t}. \cos \left(\omega_{\ddot{u}} t + \varphi\right) \tag{3}$$

$$= A. \cos \left(\omega_{\ddot{u}} t + \varphi\right).$$

the amount A and φ being

$$A = \sqrt{H^2 + \ddot{U}^2 + 2 H \ddot{U}. \cos \left(\omega_H - \omega_{\ddot{u}}\right) t}.$$

$$\operatorname{tg} \varphi = \frac{H. \sin (\omega_H - \omega_{\ddot{u}})\, t}{\ddot{U} + H. \cos (\omega_H - \omega_{\ddot{u}})\, t}.$$

Result : According to (3) the physical consequence of superposing these two not modulated oscillations is one single modulated oscillation, the medium value of which is periodically fluctuating with a modulation frequency, which, according to (4), is equal to the difference $(\omega_H - \omega_{\ddot{u}})$ of the two not modulated oscillations.

2. **Sensitiveness.**

If 31 000 cycles are chosen as an auxiliary frequency, a frequency of 1 000 cycles arises after rectifying the modulated oscillation. It corresponds with the maximum sensitiveness of the ear, and can be made audible by a multistage low-frequency-amplifying. With this method an improvement of the amplifying balance is reached up to three tenpotential-functions. At this the low frequency acustic disturbances of the ship are completely suppressed, as the receiver swing is tuned in to the ultra-sonorous frequency of 30 000 cycles. Therefore a considerable improvement of sensitiveness of the echo sound receiver is obtained. The added low frequency amplifying unobjectionably may be driven very high, as the superposed frequency of 1 000 cycles will be well audible on account of the excellent ear-selection even at relative high own disturbances of the amplifier (rustling of valves).

3. **Testing results.**

A high-periodic-superposed-echo-sounder provisionally was built by the firm Atlas-Werke and the firm Electroacustic each according to the instructions of H. Gabler, and by applying the method described above. They were put to a thorough test during the German Northatlantic Expedition in 1938. The results of the soundings reached the expected values founded on the base of theoretical considerations. With both arangements depths up to 4 000 meters reliably could be sounded. A further rise of the measurable range of depth with certainty may be received with high-periodic-superposed-echo-sounders. For this an optimal dimensioning of the amplifying value of the receivers is necessary.

Development of these instruments was carried on during war, especially was aspired to an improvement of indication. The firm Electroacustic in 1944 has concluded the construction of a high-periodic-superposed-echo-sounder with depth-gauge-indication. Instead of the rotating neon lamps respectively sluices of light at the indicator of this new " Magnetic Sounder " a window is placed, through which the sounded depth may be read as on a gauge. The indication is transmitted by application of a principle of statistic selection, which is capable of dividing the arrival of true echo impulses with constant time-intervals from casual disturbing impulses. For this purpose a magnetic coupling of the gauge drive is set to action. During war it was not possible to test the first model of this " Magnetic Sounder " in larger depths.

The required descriptions and drawings on the Echo Sounding Apparatus developed in Germany since 1939 are lost for the greatest part. The attempt could be made by the German Hydrographic Institute to restore detailed reports, if such are of interest, and if the German Hydrographic Institute would get an order from the Controlling Authorities concerning the subject.