ECHO SOUNDING

IX

In continuation of the series of descriptive articles published in the *Hydrographic Review* on Echo-sounding Instruments (1), a few notes are given below concerning the following sounding-machines :-

1. The LANGEVIN-FLORISSON Ultra-sonic Sounding Machine, small model, fitted with Echo-meter.
2. "Graphic Acoustic Sounder" of the U. S. Navy.
3. "Indicating Acoustic Sounder" of the U. S. Navy.
4. British Admiralty "Echo Sounder" - Mark IV.

1. *THE LANGEVIN-FLORISSON ULTRA-SONIC SOUNDING MACHINE, small model, fitted with Echo-meter* (Manufactured by the *Société de Condensation et d'Applications Mécaniques*, 42, Rue de Clichy, Paris, 9e). (2)

This apparatus is the latest improvement to the LANGEVIN-FLORISSON sounding machine, which has already been described in previous numbers of the *Hydrographic Review*. First let us briefly recall the basic principles of echo-sounding :-

The name ultra-sonic waves has been given to the inaudible elastic vibrations of higher frequency than that of sounds which can be detected by the ear.

These vibrations travel in water at the same speed as audible sounds, and like the latter they are reflected from obstacles ; but, in addition to their inaudibility, they possess the further great advantage of making directional transmission and reception possible.

The LANGEVIN piezo-electric projector, which is fitted to the ship's hull, is energised by means of a special small high frequency electric current emitter.

This projector produces, during a very small fraction of a second, ultra-sonic vibrations which are directed vertically to the sea-bottom.

These vibrations are reflected by the bottom and on their return as echos affect the projector (the action of this apparatus being reversible) and a receiver (amplifier) which is permanently connected to the projector. Thus, in the receiver pulsations of current are produced corresponding to the transmitted signal and then further pulsations due to the "echo" reflected from the bottom.

The speed of propagation in water of ultra-sonic waves being known

(1) See *Hydrographic Review*, 1923, Vol. I, N° 1, page 71 ; 1924, Vol. I, N° 2, page 39 ; 1924, Vol. II, N° 1, page 51 ; 1925, Vol. II, N° 2, page 135 ; 1926, Vol. III, N° 2, page 75 ; 1927, Vol. IV, N° 2, page 205 ; 1928, Vol. V, N° 1, page 131 ; 1928, Vol. V, N° 2, page 107 ; 1929, Vol. VI, N° 2, pages 21, 163 and 215 ; 1930, Vol. VII, N° 1, page 99.

(2) Extracted from a booklet issued by the Société de Condensation et d'Applications Mécaniques, Paris.

(1500 metres per second), the vertical depth of water underneath a vessel can be deduced from the measurement of the elapsed time (echo-interval) between the first pulsation (corresponding to the transmitted signal), and the second pulsation (corresponding to the "echo" signal).

If we represent the "echo-interval" in seconds by t, the depth d in metres may be found by the following formula:

$$d = \frac{1500 \times t}{2}$$

This mathematical operation is carried out by means of a chronograph, called an "Analyser", from the graduated scale of which soundings can be read directly; it is reset automatically about once every second.

The Société de Condensation et d'Applications Mécaniques has realised the desirability of producing a sounding appliance which, whilst possessing all the qualities of the LANGEVIN-FLORISSON sounder, is of reduced size, more particularly intended for use in small vessels; it is for this reason that the LANGEVIN-FLORISSON Ultra-sonic Sounder, small model, fitted with the FLORISSON Echo-meter, has been constructed.

The LANGEVIN-FLORISSON Ultra-sonic Sounder (small model) includes the following parts:

A projector ;
An echo-meter ;
A 4 v. accumulator with charging board, if required ;
An 80 v. battery.

The fitting plan (fig. 1) shows the electrical connections, as well as the outside dimensions of the principal components.

Description of the component parts. — a) The projector :

This apparatus, very strongly constructed of cast steel, and water-tight, contains the piezo-electric steel-quartz-steel condenser, which produces ultra-sonic vibrations in the water, directs them vertically to the sea-bottom, and receives the echo.

The projector is firmly fixed to a steel flange, which, in turn, is attached to the hull of the vessel either by means of a cast-steel drum or in any other suitable manner.

The projector is placed in the central third of the vessel, near the keel (In a submarine it may be placed in the keel itself).

The two cables connecting the projector with the echo-meter are protected throughout by water-tight metal tubing. The length should not exceed 40 metres (130 feet) run of cable.

b) The echo-meter (Fig. 2) :

This instrument contains, in a single metallic case (outside dimensions 35 × 35 × 72 cm. or 14" × 14" × 28 ½" — weight 70 kgs, 154 lbs), the transmitter, receiver and analyser. The high-frequency emitter, which consists of a small spark installation (radio-telegraphic type, but extremely simplified) and the receiver (valve amplifier), are contained in the lower section of the case.

The emitter is tuned, once and for all, when fitting the sounder in the ship. The amplifier requires no adjustment.

The analyser is contained in the upper section of the case. This apparatus includes a fixed oscillograph, the mirror of which moves by reason of the electric impulses caused by the transmission of the signal and by the echo; and a swinging mirror moved by means of a strongly constructed and accu-

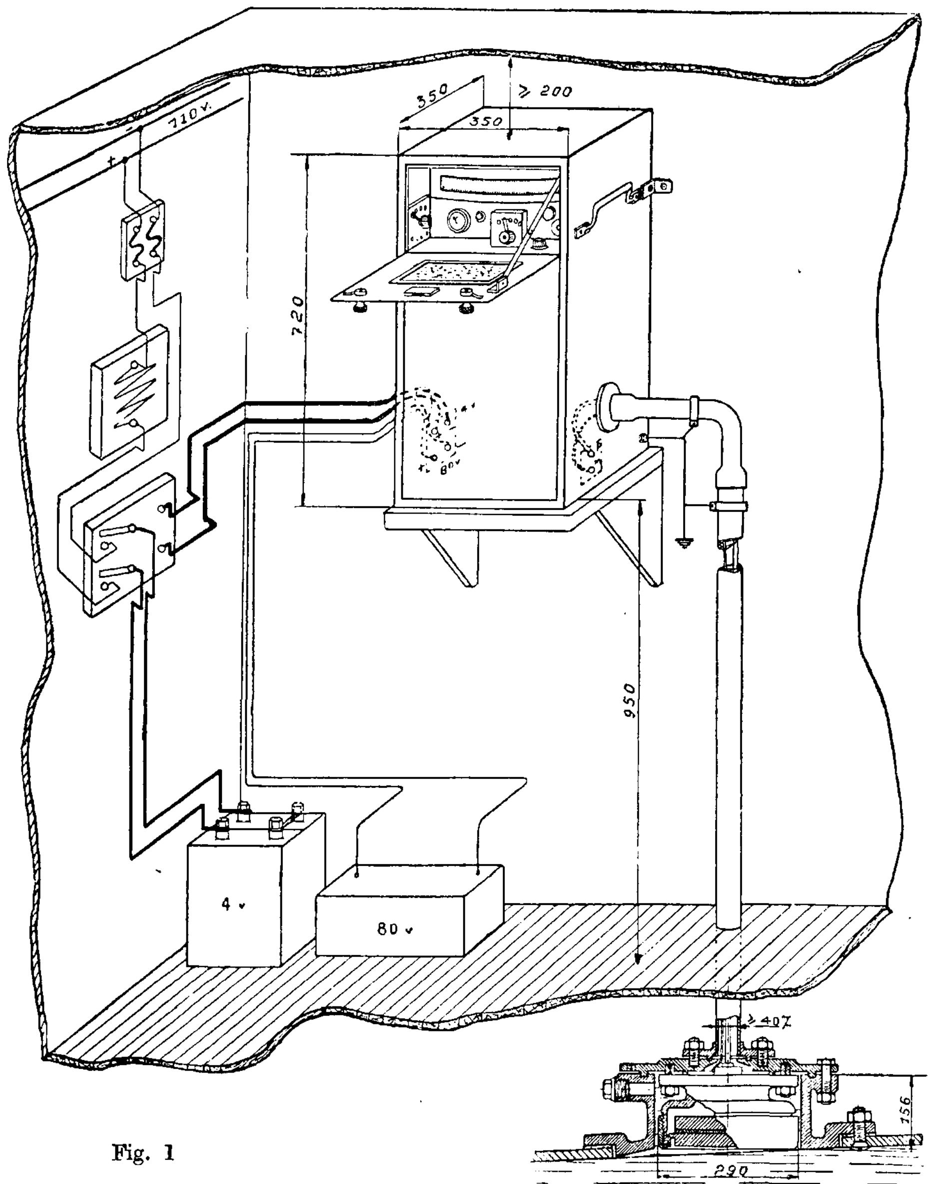


Fig. 1

rately running clock-work, adjusted in such a manner that once every second a luminous spot can be seen on the graduated scale, travelling from left to right at a constant speed, first tracing the "signal kink" (at the commencement of the graduation), and then the "echo kink" (fig. 3).

The depth can be read off the scale, with great facility, opposite the point of commencement of the "echo kink".

The chronograph movement is perfectly regular and requires no adjustment.

Fig. 4 represents the front view of the echo-meter open, and in working position.

On the top, can be seen the scale, with double graduation (from 0 to 660 metres, and from 0 to 360 fathoms); on the right, the winding stem of the clock-work movement; above, the starting and stopping knob; in the centre, the regulating switch of the oscillograph (shallow soundings, deep soundings); underneath, on the right, the filament resistance of the amplifier; on the left, the knob for regulating the height of the luminous spot on the scale, and the voltmeter with its commutator, for testing the batteries and the amplifier filament voltage.

When the instrument is not in use, the door, which is shown thrown open, is closed so as to protect the components described above.

When in service, the 4 v. battery supplies an average of 4 amps; and the 80 v. battery, 10 milliamps; thus the power consumed is 17 watts, or less than three hundredths of one horse-power.

Range and accuracy. — The LANGEVIN-FLORISSON sounder, with echo-meter, takes soundings once every second, vertically from the vessel in depths of from about 3 metres under the projector, up to 660 metres (or 360 fathoms) with accuracy within one per cent.

Characteristics and advantages of the Langevin-Florisson Ultra-sonic Sounder. — The projector serves the double purpose of transmitter and receiver The vibrations are ultra-sonic and are transmitted directionally in the form of a cone having an aperture of about 15 degrees. The ultra-sonic emission is of extremely short duration (of the order of about a thousandth of a second). There are no parasitic sounds to lengthen the emitted signal. The projector is very selective and is tuned to ultra-sonic frequency, *i. e.* beyond the frequency of the audible noises of a vessel under way. The receiver, which is permanently connected to the projector, requires no relay. It consists of triode valves, and a mirror oscillograph, a device which is free of inertia and is extremely sensitive and accurate.

2. "*GRAPHIC ACOUSTIC SOUNDER*" *OF THE AMERICAN NAVY*

(Extracted from the *U. S. Naval Institute Proceedings, Annapolis - Nov.* 1929).

An investigation was undertaken at the University of California at Los Angeles early in 1923 to determine the practicability of developing a continuously recording depth sounder. Tests were carried out aboard the U. S. S. *Maryland* in 1924.

It was felt that a depth recorder to be of the greatest use should embody the following features: it should be capable of giving continuous visual

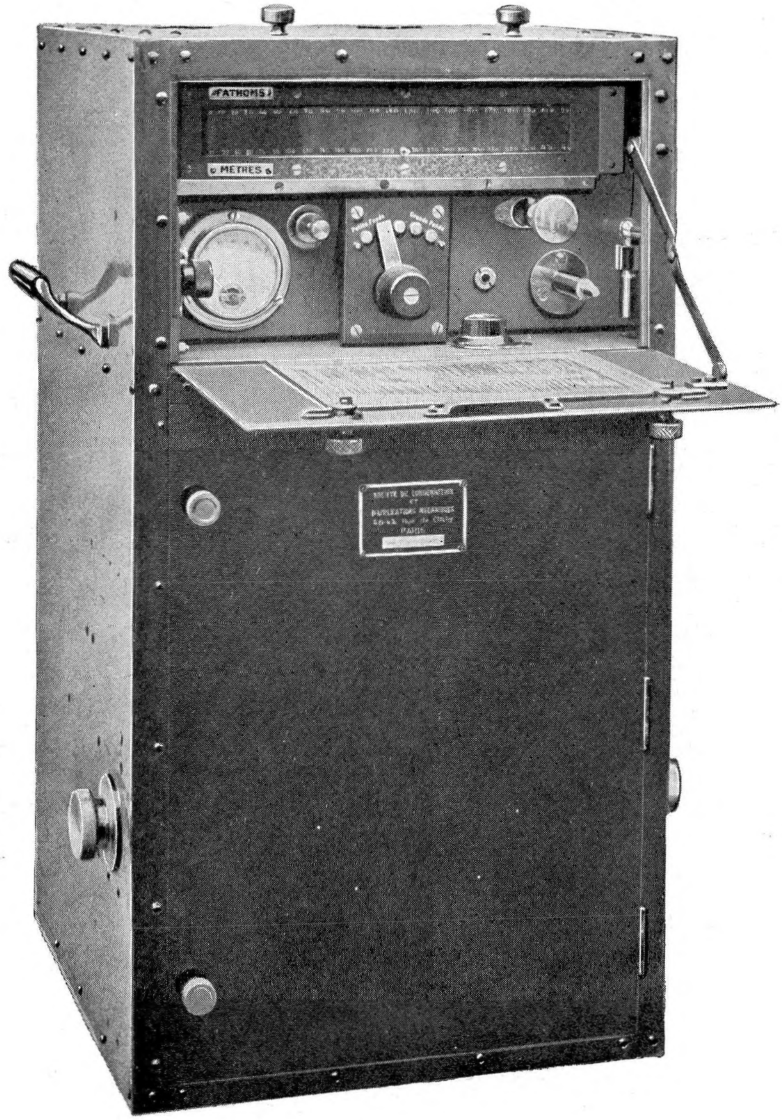

FATHOMS
MÈTRES

Fig. 2

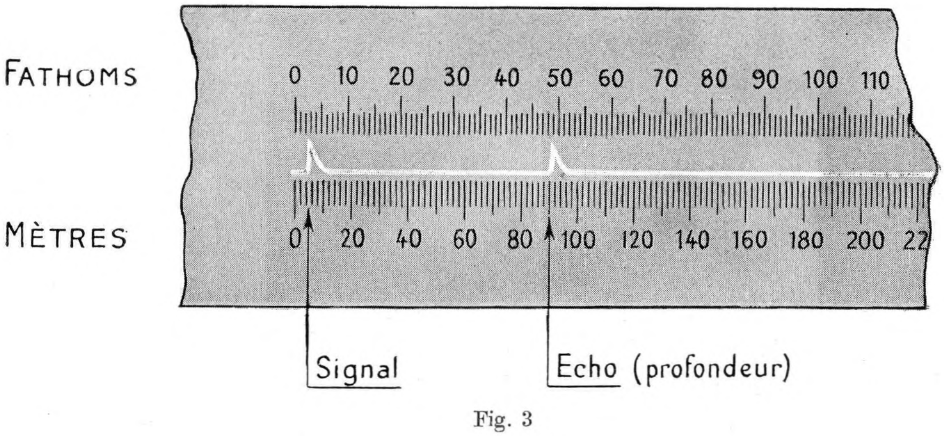

FATHOMS
0 10 20 30 40 50 60 70 80 90 100 110
MÈTRES
0 20 40 60 80 100 120 140 160 180 200
Signal
Echo (profondeur)

Fig. 3

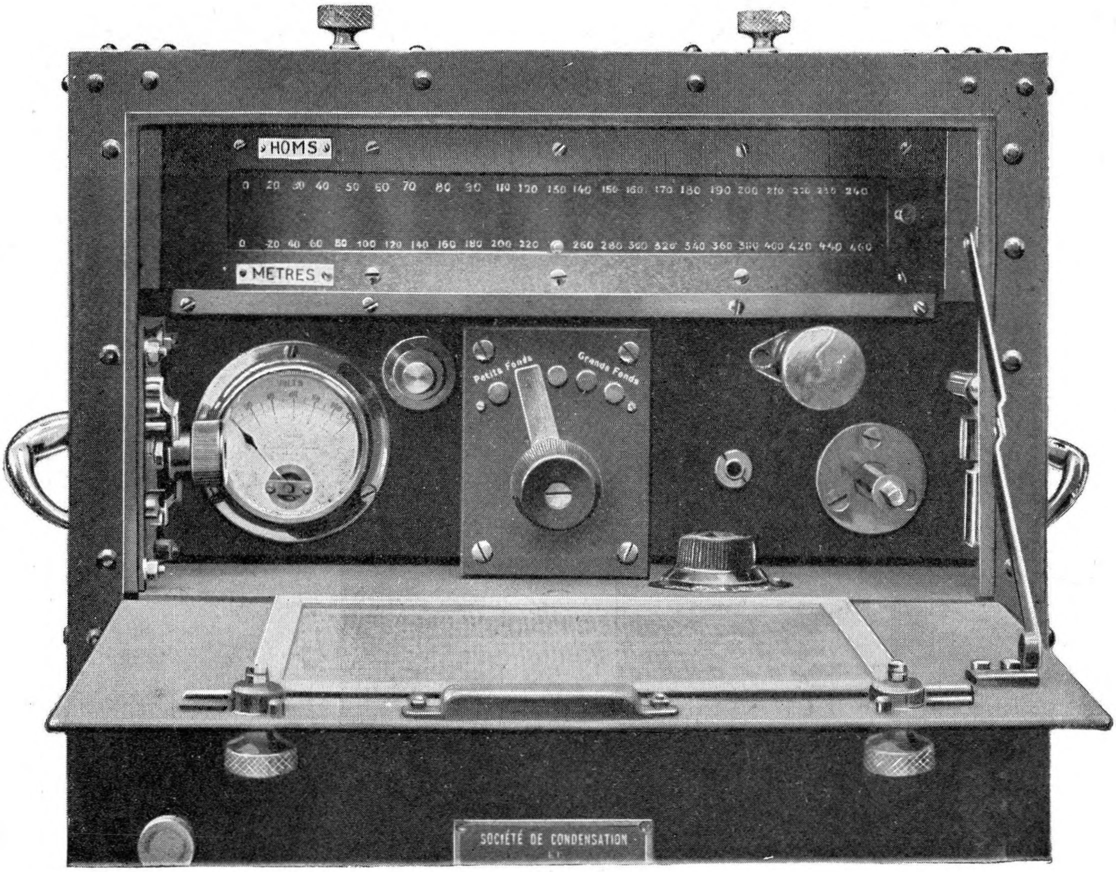

HOMS
METRES
Petits Fonds
Grands Fonds
SOCIÉTÉ DE CONDENSATION

Fig. 4

indications automatically, *i. e.* it should be direct reading and as independent as possible of the personality of the operator; it should be as rugged and free from adjustments as possible. In a word, it should be "seagoing", and capable of being maintained by the ever-changing personnel of a ship.

An experimental instrument embodying these features was then built and tried out aboard the U. S. S. *Maryland* in January 1925. This instrument is known as the "graphic acoustic sounder". It is an instrument designed to use the standard Navy installation of oscillator and microphones to give a continuous graphic record of the depth and at the same time provide a visual indication. It depends for its operation upon a measurement of the time that elapses between the arrival of a pulse of sound direct from the oscillator and of the same pulse as an echo from the bottom. It is assumed that for practical purposes the velocity of sound is constant and that the speed of the ship is slow in comparison to this velocity. The time lag of the echo may be computed as follows: if

d = the distance from oscillator to microphone center in fathoms;
h = the depth of water below oscillator-microphone line in fathoms;
v = the velocity of sound in sea water in fathoms per second;
t = the time lag of the echo over the direct sound in seconds;

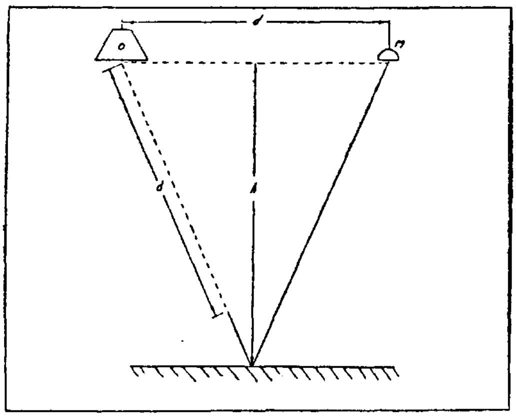


Fig. 5

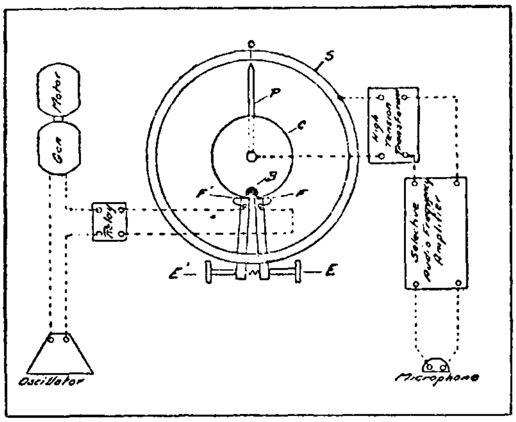


Fig. 6

then the distance the echo travels is given by:

$$2\sqrt{h^2 + \left(\frac{d}{2}\right)^2} \qquad (1)$$

This distance less d is the difference between the echo path and the direct path.

$$2\sqrt{h^2 + \left(\frac{d}{2}\right)^2} - d \qquad (2)$$

Dividing (2) by the velocity v gives the interval of time between the arrival of a single pulse of sound by a direct path and an echo path; t then is given by:

$$t = \frac{1}{v}\left[2\sqrt{h^2 + \left(\frac{d}{2}\right)^2} - d\right] \qquad (3)$$

It is evident that for a given depth, separation of microphones and oscillator, and velocity of sound, the value of t may be found. The graphic acoustic sounder is then merely a device for indicating or recording this time interval to an appropriate scale.

Description and Operation of the Sounder. — The sounder consists of the following parts: (*a*) a constant-speed, electrically governed motor; (*b*) suitable gears to drive a rotating pointer; (*c*) a three-stage audio frequency amplifier and appropriate step-up transformer. The relation of these parts to the standard oscillator and microphones is shown in fig. 6. The operation of the sounder is as follows: the pointer, *P*, in fig. 6 is driven at a constant speed by the motor. Once for each revolution of *P* and contact disc, *C*, the contact bar, *B*, is caused to pass between the contact brushes, *F* and *F'*, closing the relay circuit and then the oscillator circuit for a very short interval of time. A pulse of sound is thus emitted each revolution of the contact disc, *C*. This pulse of sound reaches the microphones by two routes, a direct one along the bottom of the ship and a reflected one from the ocean floor. Each of these is received by the microphones, amplified, stepped up through the transformer, and causes a short series of sparks to pass between the sharp pointer *P*, and the circular knife edge, *S*. The angular relation between the contact brushes, *F* and *F'* and the pointer, *P*, is so adjusted by means of the tangent screws, *E* and *E'*, as to cause the first train of sparks to begin when the pointer, *P*, is at the zero position on the scale. The second series of sparks, which is caused by the echo, will begin after an interval of time which is determined by the depth. This interval is measured from the beginning of the first series of sparks to the beginning of the second series. Since the pointer moves with constant angular velocity it will have rotated through an angle θ during this time given by:

$$\theta = \frac{360\ t}{p} \qquad (4)$$

where θ is in degrees and p is the time for one revolution of the pointer in seconds. Or substituting for t from equation (3)

$$\theta = \frac{360}{pv}\left[2\sqrt{h^2 + \left(\frac{d}{2}\right)^2} - d\right] \qquad (5)$$

From these conditions it is evident that the scale can be calibrated directly in depth for any given angular velocity. It is further evident from this equation that the scale will not be quite uniform for shallow depths but will rapidly become so as the depth increases.

In the graphic acoustic sounder the pointer is arranged to rotate at three different speeds, once a second for depths below 100 fathoms, once in 10 seconds for depths up to 1,000 fathoms and once in 50 seconds for

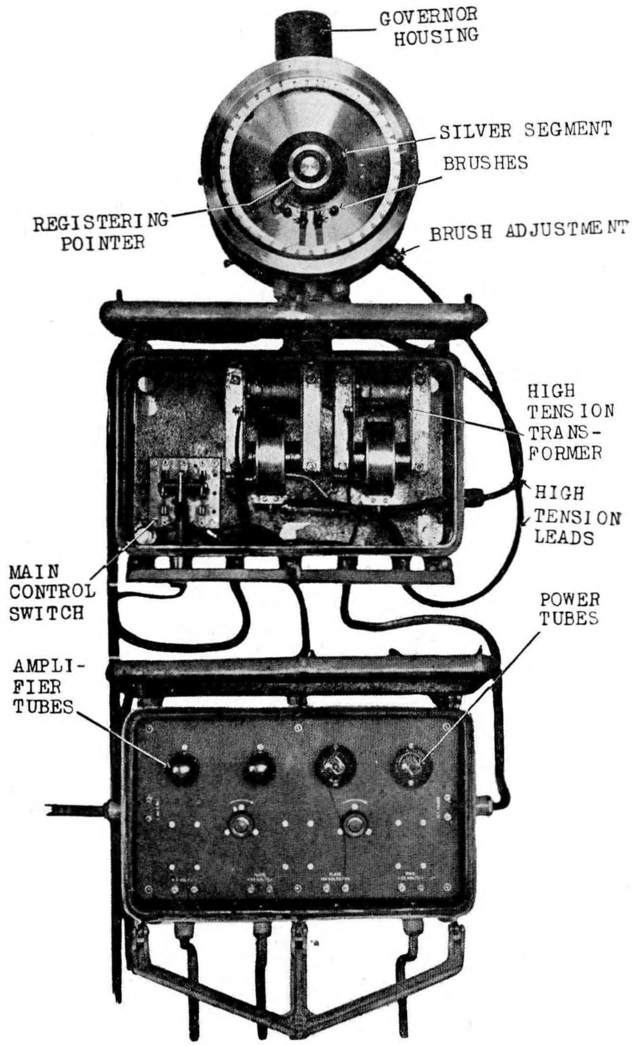


Fig. 9.

INDICATING ACOUSTIC SOUNDER.

Front view.	Vue avant.
Governor housing.	Carter du moteur de commande.
Silver segment.	Segment en argent.
Brushes.	Balais.
Registering pointer.	Aiguille enregistreuse.
Brush adjustment.	Réglage des balais.
High tension transformer.	Transformateur haute tension.
Hight tension leads.	Conducteurs haute tension.
Main control switch.	Interrupteur principal.
Power tubes.	Lampes de puissance.
Amplifier tubes.	Lampes amplificatrices.

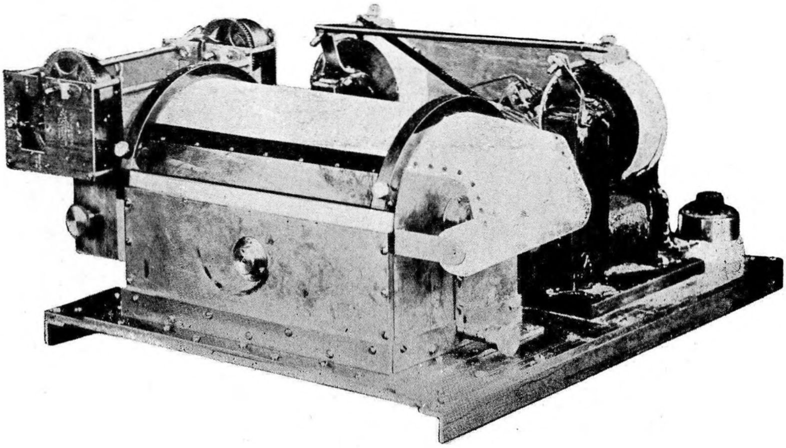


Fig. 8.

Graphic Acoustic Sounder.

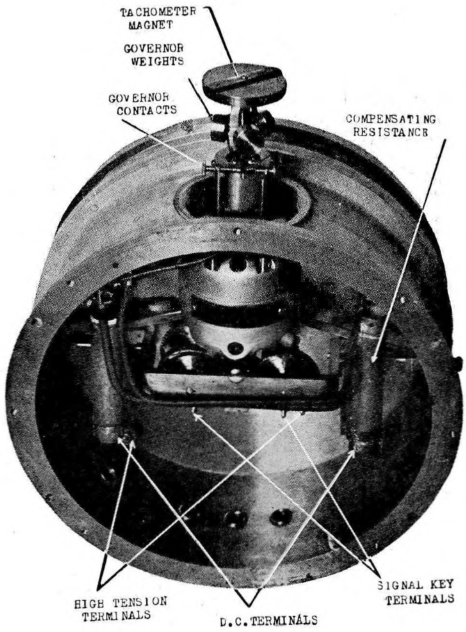


Fig. 10.

Indicating Acoustic Sounder.

Rear view.	Vue arrière.
Tachometer magnet	Barreau aimanté du tachymètre.
Governor weights.	Boules régulatrices du moteur de commande.
Governor contacts.	Contacts du moteur de commande.
Compensating resistance.	Résistance compensatrice.
High tension terminals.	Bornes haute tension.
D. C. terminals.	Bornes du courant continu.
Signal key terminals.	Bornes de la clé de manœuvre.

depths above 1,000 fathoms; p then has the value 1, 10, and 50. The relation between angle θ and depth for $p = 1$, and $v = 800$ fathoms per second, now simplifies to:

$$\theta = \frac{9}{20}\left[2\sqrt{h^2 + \left(\frac{d}{2}\right)^2} - d\right] \qquad (6)$$

where h and d are expressed in fathoms and θ is in degrees. If d is small, for a depth of 100 fathoms it is evident that θ will be 90°.

To provide a continuous graphic record a paper chart is drawn by clockwork between the knife edge, *S*, and the pointer, *P*. Each series of sparks perforates the moving paper and provides a permanent record of depth against time.

The Constant-Speed Motor Governor. — Since the device depends for its operation on the pointer moving with constant angular velocity, an electrical governor has been provided which maintains the speed within narrow limits. Under normal fluctuations of the supply voltage the speed is maintained within 1 per cent of the correct value, and even with a drop of 50 per cent in the line voltage the speed does not drop more than 1 ½ per cent. The operation of the governor is as follows:

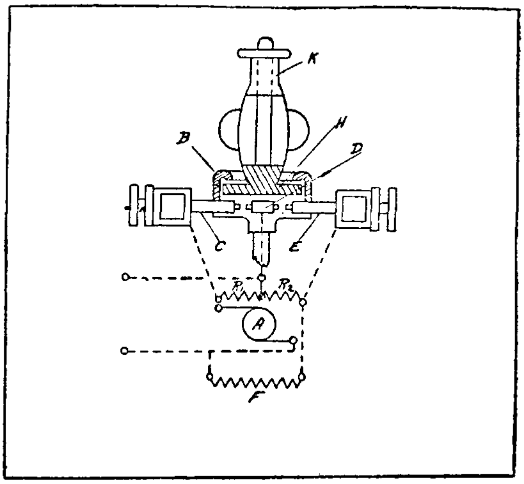


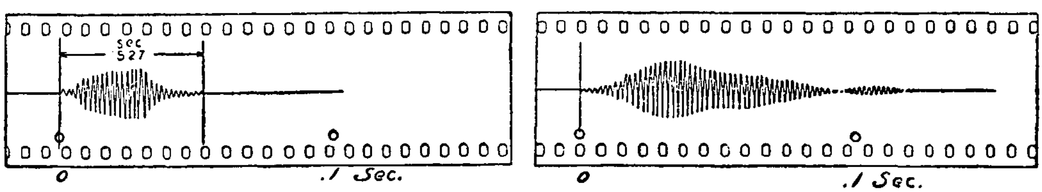
Fig. 7

In fig. 7, *A* is the armature and *F* the shunt field of a 110-volt D. C. motor. The contact, *D*, and the friction ring, *B*, are attached to the same support. *D* is arranged so that it may vibrate between the contacts *C* and *E*. When the motor is not running, contacts *C* and *D* are held together by a light spring not shown in the figure. A resistance R_1 in series with the armature, is shunted by contacts *C* and *D*. A resistance R_2 in series with the shunt field is shunted by contacts *D* and *E*. When the motor is started the governor balls are driven out radially by the centrifugal force, causing the friction disc, *H*, to approach the friction ring, *B*. If in proper adjustment the disc, *H*, will bear on the ring, *B*, with sufficient force to cause *B* to rotate slightly and separate the contacts *C* and *D*. This action includes resistance R_1 in the armature circuit, which decreases the armature current and consequently the torque, and tends to decrease the speed. Should the speed, however, further increase, the contact *D* is driven over until it closes with contact *E*. This action cuts out the resistance R_2 from the shunt field circuit, thus strengthening the field and further tending to slow the motor. When operating normally contact *D* vibrates between *C* and *E* and maintains a uniform speed. An adjustment nut *K* is provided to regulate the speed at which the motor is to operate. A reed tachometer is provided as a ready check on the motor speed. The reeds are actuated by a small bar magnet fixed to the motor shaft. The center reed is tuned to exactly 30 vibrations per second, the right one 1 per cent above this value, and the left one 1 per cent below. By this arrangement it is possible to check the speed at a glance prior to obtaining a sounding.

3. "*INDICATING ACOUSTIC SOUNDER*" *OF THE AMERICAN NAVY*, (Extracted from the *U. S. Naval Institute Proceedings, Annapolis Nov.* 1929.)

It was felt that the graphic feature would find its greatest use for charting purposes, and that for purely navigational use an indicating instrument would suffice. An instrument of this type was built aboard the U. S. S. *Holland* in December, 1926. It has been in constant use since then.

In this instrument two speeds are provided. The pointer can rotate clockwise once a second, or in the reverse direction once in ten seconds. This arrangement permits depths up to 400 fathoms to be read from one scale and up to 4,000 fathoms on the other. The shallow limit of both sounders is fixed by the minimum duration of sound that can be produced by the particular oscillator used. The last depth readable is reached when the train of sparks due to the echo begins to overlap with that due to the direct sound. Fig. 11 illustrates this point: *a*) is an oscillogram of the current



a) Current through Oscillator *b)* Direct Sound through Oscillator

Fig. 11

flowing through the oscillator when the circuit is closed for a very short interval; *b*) is a record of the direct sound from the oscillator as received by the microphones. It should be noticed that the sound persists in this type of oscillator for a considerable time. It is possible, however, by using the directional property of the compensator, to eliminate some of the interference. With a 540-cycle oscillator the shallow limit is twenty fathoms, while with a 1,050-cycle oscillator it is five fathoms. The shallow limit is thus fixed by the damping of the oscillator. The maximum depth is limited by the intensity of the oscillator signal, the type of bottom, and the amplification used. With a 540-cycle oscillator and three stages of amplification it is possible to obtain visual indications or graphic records as deep as 2500 fathoms.

In order to test these instruments over an extended period of time and under actual operating conditions at sea, four have been built by the Washington Navy Yard. They are to be placed on various types of naval vessels. The results of the tests should definitely establish the practicability of these instruments.

4. *BRITISH ADMIRALTY "ECHO SOUNDER" MARK IV.*

We have already published in the *Hydrographic Review* certain information on the British Admiralty Echo Sounder Mark IV (*See Hydrographic Review*, Vol. VII, N° 1, 1930, page 100). The makers of this apparatus, Messrs Henry HUGHES & SON, Ltd., 59, Fenchurch Street, London, E. C. 3, have forwarded the following information on further developments introduced in the apparatus.

The outline of the Transmitter and Hydrophone has been improved, and the whole of the Receiving Box and Gear has been perfected in order to facilitate the reading and increase the accuracy of the echo soundings obtained. The makers are also working out a special Recording Gear to be attached to the Receiving Gear, so that the operator may leave the machine permanently running and obtain on a sheet of paper the record of the contour of the bottom of the sea. This method is assuredly the best if at the same time it is possible to take a check of the depth recorded by the headphone attached to the machine. This arrangement is realized to advantage in the British Admiralty pattern.

A certain number of big liners and merchant ships are being fitted with the Mark IV machine. The services rendered by the apparatus on board are highly satisfactory; much of the water noise that was heard formerly and which made it so difficult to perceive with the ear the return of the echo, has been nearly completely damped out, so that it is now possible for a trained ear to pick up the return of the echo in depths of less than 150 fathoms.

In these liners, the Echo Sounder has been used in conjunction with the KELVIN Tube, and the Shallow Water Echo Sounder Mark IV permits to follow the bottom, both when making land and when running off shore, long before and long after the THOMSON Sounder. One may thus make the land much before having reached the 100 fathoms line : for example, when making land on the English coast coming from America, the Mark IV apparatus allows accurate soundings to be taken two hours before the liners reach the 100 fathoms line, which is certainly valuable in thick and bad weather.

Detailed information concerning the various types of British Admiralty Sounders are supplied on request addressed to Messrs Henry HUGHES & SON, Ltd., 59, Fenchurch Street, London, E. C. 3.