THE BBT-NEYRPIC CURRENTOGRAPH

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1. The experience acquired by BBT in the construction of Idrac current recorders has been profitably applied in the designing of a new instrument showing, compared with its predecessor, improvements on three principal points which are as follows:

— more accurate measurements of headings and speeds;

— more legible records, easier to analyse, and for which the reading errors should be less than the measurement errors;

— ease in handling, lowering and lifting.

General Description:

With the exception of the Dumas impeller for the measurement of current velocity, all the parts of the currentograph are enclosed in a watertight container, streamlined in such a way as to interfere as little as possible with the field of current velocity. The Dumas impeller is located forward at the end of a rod and its rotation is protected by a circular guard. At the back a tail piece is fixed fitted with fins ensuring sufficient steadiness of heading while preserving great sensitiveness of orientation to the current (Fig. 2 and 3, Pl. 1).

The body proper of the instrument is 28 cm. in diameter and 115 cm. in length; but the total length from the head of the meter to the extremity of the tail is 206 cm. It is constructed in a lightweight alloy for immersion in depths up to 250 metres and the apparatus thus weighs only 90 kilograms, so that two men can lower and raise it without using either a davit or tackle.

For greater depths, the body of the instrument is in bronze and the total weight increases to 170 kg.

The body, or watertight container, carries on its upper and lower parts two projections fitted with two swivels equipped with ball bearings, which gives the instrument entire freedom to follow the direction of the current. The upper swivel carries in addtion a spring shock-absorber which as far as possible safeguards the instrument from the recoil of the suspension.

By means of this arrangement, the currentograph can be used with a buoy by fixing it in the buoyage moorings at the required depth for the record. Selection of the volume of the buoy depends entirely on the weight of the moorings used, determined by the depth of the sea at the anchoring place and by the horizontal force due to the action of wind and current on the buoy; actually, the action of the current on the streamlined body of the currentograph can be practically neglected.

The apparatus can also be suspended at a given depth, at the stern of an anchored boat.

The body of the instrument is essentially composed of a hollow cylindrical-conical part, closed in the rear by a screwel bullet-shaped cap with watertight joint. When the cap is removed, all the mechanical parts, as well as the batteries, can be inserted in or withdrawn from the container. The batteries include 5 solid-electrolyte elements of 40 A.H. capacity (No. 5, Fig. 4, Pl. II), which ensures an eight-day (200 hour) autonomy. The mechanism and the batteries are carried on a strong frame (Fig. 4, Pl. II) fitted with rollers which run along the interior longitudinal grooves of the body so that moving the frame in and out is very easy; moreover, the grooves contribute towards increasing the resistance of the container to water-pressure. Finally, in order to absorb the shocks the lowering or lifting of the currentograph may produce on the mechanism, the frame rollers are mounted on a shock-absorber, the frame rests against the forward cone of the body by means of rubber rings, and pressure is applied by the rear cap by means of a spring.

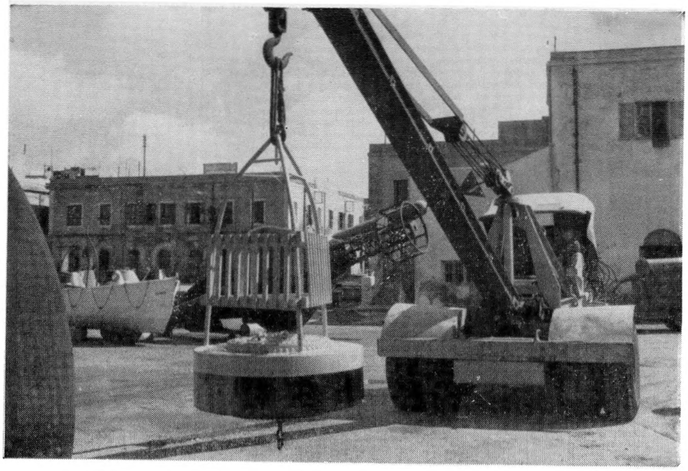
The records of current velocity and direction are made on a strip of waxed paper having a useful width of 120 mm. driven at 15 mm. per hour by a clockwork movement capable of running uninterruptedly for eight days; this period, which is equal to the operations period of the battery corresponds to the unwinding of about three metres of paper (No. 7, Fig. 4, Pl. II).

We shall now examine in more detail the two arrangements constituting the essential new features of the currentograph: the recording of the headings and the recording of velocities.

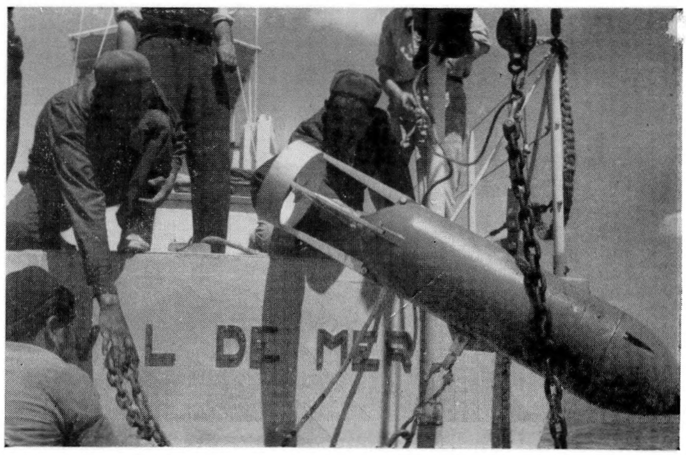
3. *Device for Recording Headings:*

The heading of the apparatus is obtained by means of a liquid magnetic compass with a 100 mm.-diameter rose and a plastic bowl which is located on the front of the frame (No. 9, Fig. 4, Pl. II).

A direct current reversing electric motor is geared to the position of the rose; it therefore turns in ratio to the angular displacements of the rose referred to the bowl and consequently to changes of heading of the apparatus orientated by the action of the current. By means of appropriate reduction gearing the motor drives an endless metallic tape (No. 8, Fig. 4, Pl. III), the length of which is three times the useful width of the diagram; this tape carries, at equal intervals, 3 recording styluses, only one of which — that which is on the forward part of the tape — is in contact with the paper, where it traces the graphs of the headings in terms of time. The 120 mm. useful length of the paper corresponds to 360° of the compass card, so that the scale of the headings is 1 mm. for each 3 degrees; the slope of the graph gives the direction of rotation of the current and, thanks to the 3 styluses, which can succeed each other in the recording, inscription is possible even if the current makes more than one complete turn in the same direction.



TRANSPORT DE LA BOUÉE
A BORD DE LA VEDETTE



MANŒUVRE DE MISE A LA
MER DU COURANTOGRAPHE
B.B.T.-NEYRPIC

AMARRAGE
DU COURANTOGRAPHE
A LA CHAINE DE LA BOUÉE ET
A LA CHAINE DE MARNAGE

NEYRPIC · GRENOBLE

The servo-mechanism, which must have a good follow-up speed (in fact 180° in 6 minutes), which must provide a sufficient degree of accuracy (errors less than ± 3°) and which, finally, must be exempt from servo-mechanism oscillations, deserves a detailed description. The difficulty of obtaining complete response from a compass card, the torque control of which is always relatively feeble, lies in the fact that it is necessary to compare the position of the rose with that of the bowl without disturbing the equilibrium position of the rose in the magnetic field. In the case under consideration, success was attained by measuring the intervening angle discontinuously on the one hand, and on the other hand on an intermediary device, and not on the card itself.

For this purpose, a magnetized needle mounted between two pivots and floating in a small bowl filled with xylene (No. 1, Fig. 4, Pl. II) is placed on the compass in such a way that its axis prolongs that of the card; the needle, comparatively long, possesses a low magnetic mass and a low moment of inertia; it therefore always tends to orientate itself parallel to the S-N line of the card. If separated from the latter its reaction on the magnets of the card is slight; when released, it very quickly resumes its equilibrium position, its oscillations being absorbed by the liquid in which it floats.

The compass bowl is controlled by the servo-motor, which is operated in the following way. The bottom of the bowl contains two conductor sectors of slightly less than 180 degrees, separated by two small insulating spaces: a small electro-magnet (No. 2, Fig. 4, Pl. II) placed above the bowl, works at a certain periodicity a rod which traverses the cover of the bowl and which presses the needle on the bottom; according to the relative position of the bowl and of the needle, the latter comes in contact with one of the conductor sectors or with an insulating space; as each of the sectors is electrically connected to a relay starting the motor in one direction or another, and as the needle itself is connected to the other pole of the battery, it is seen that the working of the electro-magnet results in starting the motor in the desired direction to bring an insulating space back under the needle. For this system of operation, a rate of 5 seconds has been adopted, the electro-magnet being excited during one second and interrupted during 4 seconds. Moreover, the speed of the motor and gear ratio have been chosen so that, for the second during which the needle is in contact with a sector, the bowl turns by 2°.5, whence it results that the average speed of response is 2.5/5 = 0.5 degree per second and also that the accuracy of the control is ± 2°5 since, if the bowl is at the limit of its equilibrium position at the instant when it is blocked by the electro-magnet, the bowl will still cover 2°.5, the needle resuming its equilibrium position during the four seconds following. Since, besides, the insulating space covers less than 2 degrees, it is seen that the servo-mechanism will oscillate by a total angle of 2°.5 if the body remains immobile in space. It was possible to confirm on a rotating table that the servo-mechanism error is less than ± 1°.5, i.e. ± 0.5 mm. at recording scale.

With this system and for the same follow-up speed, by reducing the periods of attraction and release of the electro-magnet, the servo-mechanism error can be theoretically reduced in the same proportion, but practically the blocking of the needle always tends to make it deviate slightly from its direction and nothing is to be gained by descending below the rate chosen.

The periodical excitation of the blocking electro-magnet at this rate is obtained by means of a sensitive relay (No. 6, Fig. 4, Pl. II) connected to the terminals of a condenser which is charged through a resistance. A certain attraction delay is therefore necessary in order that the tension of the terminals be sufficient to draw the blade. For each attraction, the relay shuts off the condenser charge which is then discharged into the relay winding and into a regulating resistance; the blade will therefore remain attracted during a certain time (relaxation delay) before falling again and before resumption of the cycle. As the periods of time are steadier when the attraction delay (1 sec.) is small compared to the relaxation delay (4 sec.), an auxiliary relay is used to excite the blocking electro-magnet during the attraction delay. The duration of each of the two periods of the cycle can be adjusted separately by means of rheostats.

It would have been possible to cause the periodical blockage of the magnetized needle to be controlled by the clockwork movement of the paper spool, but in that case it would have been necessary to place electric contacts, and consequently to provoke friction, on an axis too close to the escapement, with the risk of interfering with the latter, so that the electric solution adopted seems decidedly the more advantageous.

4. *Device for Recording Speed:*

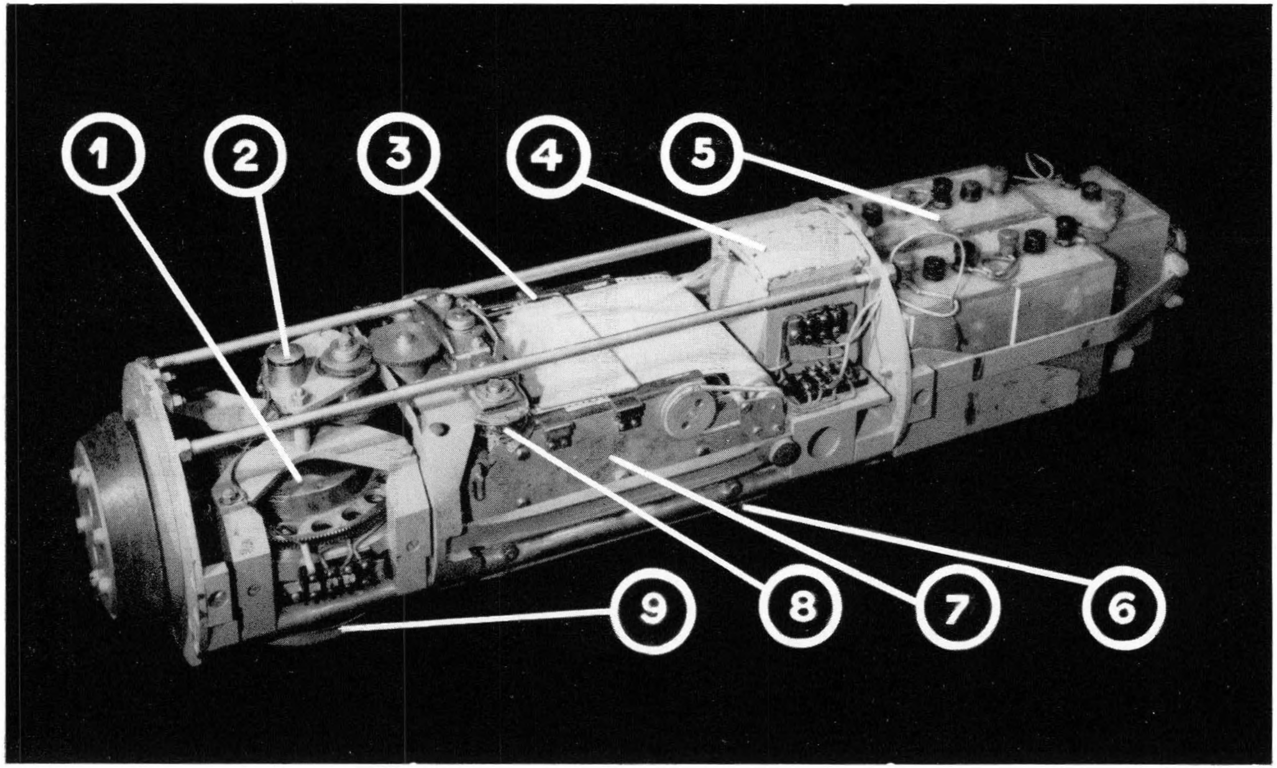
The speed detector is a Dumas impeller fitted with a helicoidal blade of 0.25 m. pitch. Turning under the effect of the current, the blade drives a contact cam which closes an electric circuit each time that the blade has effected a certain number of revolutions. Thanks to the insertion of gearing, which can be changed by a simple dismounting operation, the number of revolutions can be fixed at 10, 20 or 40, acording to the strength of the velocity to be measured.

The electric impulses thus produced are directed every 15 minutes onto an impulse meter (No. 4, Fig. 4, Pl. II) during a 150-second metering period. In this connection, the clockwork movement carries a shaft making one revolution in 15 minutes and on which is fixed a small collector having a conductor sector of 50°; in this way a circuit is closed for about 155 seconds every 15 minutes. In order to improve this first approximation of the metering period, a second shaft making one revolution every 3 minutes also carries a conductor sector on which slide two brushes a hose angular shift can be regulated in such a way that the time during which the contact is closed is 150 seconds to within nearly a second (here 1 second corresponds to 2°). The contacts of the two shafts are connected in series and inserted in the circuit connecting the impeller contacts to the impulse meter; consequently the metering time and the frequency of the meterings are accurately adjusted.

The impulse meter is composed of a wound rotor revolving between the pole-shoe tips of a permanent magnet; the rotor makes one-quarter of a revolution when influenced by the current coming from the Dumas impeller and is brought back to its equilibrium position by a spring when the circuit is open. It carries a 48-tooth ratchet wheel which meshes with a quadrant carrying the speed-recording stylus; this sector turns 5/6 of a degree per impulse; on a maximum it can describe 60° corresponding to 72 impulses. A few seconds after the end of the metering period, an auxiliary contact carried by the shaft making one revolution in 3 minutes, excites a zero-return electro-magnet which raises a counter-ratchet and so permits the stylus to be brought back to the position corresponding to zero speed by means of a counter spring.

COURANTOGRAPHE

VUE DU MÉCANISME



1 BOITIER DE BOUSSOLE D'ASSERVISSEMENT — **2** DISPOSITIF DE FRAPPE — **3** CADRE DE RELEVAGE DU STYLE DES VITESSES — **4** TOTALISATEUR D'IMPULSIONS DE VITESSE — **5** BATTERIE D'ACCUMULATEURS **6** BOITIER DES RELAIS - **7** TABLE DÉROULEUSE - **8** DISPOSITIF INSCRIPTEUR DE CAPS - **9** COMPAS PRINCIPAL

The speed-recording stylus (No. 3, Fig. 4, Pl. II) thus describes on the recording strip a curvilinear ordinate in 150 seconds, then abruptly returns to zero. The length of the curvilinear ordinates depends on the number of impulses received during this time. For 72 impulses, the ordinate occupies the whole useful length of the paper; consequently this length corresponds to velocities of 1.2 ór 2,4 or 4,8 metres/second according to the gear ratio used (one impulse per 10, 20 or 40 revolutions of the blade) (1). Each ordinate is separated from the following by 15/4 = 3.75 mm. The current velocity curve in terms of time is therefore not traced continuously, but it is clearly represented by the extremity of the successive ordinates. The tracing of headings and that of the velocities show very different aspects, so that the whole width of the diagram may be used for each of the records without risk of confusion; however, in order to avoid the two styluses interfering with each other, directions and speeds relating to an identical instant are recorded with abscissae 60 mm. apart.

Errors in the Recording of Velocities:

The relative error in the recorded velocity is the sum of the relative errors affecting the duration of the metering period, the calibration of the Dumas impeller and finally the method of measurement itself.

The first is less than 1/150 since it is possible to regulate the metering time to within less than a second.

The calibration error of the Dumas impeller can be reduced to a very small value, if the calibration curve established experimentally in the laboratory for each screw is used. This precaution, however, is not indispensable when it is desired to measure the velocity of sea currents — an operation which does not require extreme accuracy; in this case it suffices to take an average pitch for all the screws of the same model with the same gearing; the relative error introduced by dispersion due to manufacture and assembly does not appear to exceed 3 %.

Finally the principle itself of recording velocities implies a certain error, since during the metering period the impeller turns any number of revolutions while the stylus records only a whole number of impulses. According to the position of the contact at the beginning and at the end of the metering period, the absolute maximum error is one impulse too many or too few, i.e. 1/72 of the maximum velocity that can be recorded with the gearing used; arising from this fact, the absolute error for measured velocities is therefore less than 1.7 or 3.3 or 6.7 cm./sec. depending on whether the impulses correspond to 10, 20 or 40 revolutions of the impeller.

From this point of view it is therefore always useful to adopt a gearing such that the greatest velocity to be measured during the period of immersion of the currentograph may be as near as possible to, while remaining less than, the maximum velocity that can be recorded with this type of gearing. This results in the absolute error as to the measurements being diminished. It is for this reason that, in spite of the complication to which it gives rise, the instrument includes a set of 3 reducing gears.

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(1) For particular problems where the velocities to be measured exceed 4.80 m./sec., it would suffice to diminish the metering time by a certain amount by changing the lag of the brushes on the axis making 3-minute revolutions, and the recording speed would be increased in the same ratio.

The method of recording velocities involves therefore an absolute error whose upper limit can be determined, but the relative error as to velocity can be very great in the case of a small velocity; however, if one takes the case of a measured velocity equal to half the possible maximum velocity with the gearing considered (36 impulses in the metering period as against 72), the absolute maximum error being one impulse, the relative error does not exceed 1/36, i.e. less than 3 %. The normal screw does not begin to turn until the current reaches nearly 4 cm. per second; so that when it is necessary to measure very small velocities, it is better to use a screw of a smaller pitch, 10 cm. instead of 25 cm.; the scales are divided by 2, 5, but the absolute metering error is reduced in the same proportion.

Measurment of Velocities in Swell.

Generally the currentograph is suspended from a buoy which follows the movement of the swell; it therefore shifts according to a periodical movement of less amplitude than that of the movement of the buoy; the ratio between these amplitudes depends on the depth of immersion of the instrument and the depth of the sea. Moreover, the particles of water near the instrument are themselves animated, under the influence of the swell, by circular movements the amplitude of which depends on the depth of recording. Consequently the angular speed of the screw of the Dumas impeller is constantly proportional to the resultant of the various speeds which intervene: speed of the permanent current, circular speed of the water particles, speed opposed to the displacement speed of the currentograph; the recorder indicates the integration during 150 seconds of the resultant of these speeds. In practice, however, the result is only a negligible error in the measurement of the permanent current. In fact, if the buoy is not too heavy, it follows without any remarkable phase-lag the movements of the swell, to the extent that the displacements of the apparatus and the circular movement of the water particles nearby will generally almost completely compensate one another; besides, as the period of the speeds due to swell is of the order of 6 to 20 seconds, if one examines the most unfavourable case of a half-period of circular movement added to the permanent current, the supplementary current, which will have lasted from 3 to 10 seconds, will be distributed in the record over the 150 seconds of metering time and consequently will intervene by only a small fraction (1/50 to 1/15) of its value.

However, another error, which cannot be neglected, can result from the periodical velocities due to swell, from the fact that the impeller contacts are not polarized, i.e. that the impulses can be transmitted whatever the direction of revolution of the screw. Let us suppose that the speed of the current and the periodical speed are in the same direction as the instant of the closing of a contact, then that, immediately after opening it, the periodical speed changes direction and proves stronger than the current, so that the coil starts off again in the opposite direction and closes the contact (1); let us further suppose that, as soon as the latter is re-opened, a new change of direction occurs; 3 successive impulses will thus have been recorded while one alone should normally have been produced.

This is convenience is not peculiar to the BBT currentograph; it is common to all instruments operating with impulse meters. In the case of the BBT a

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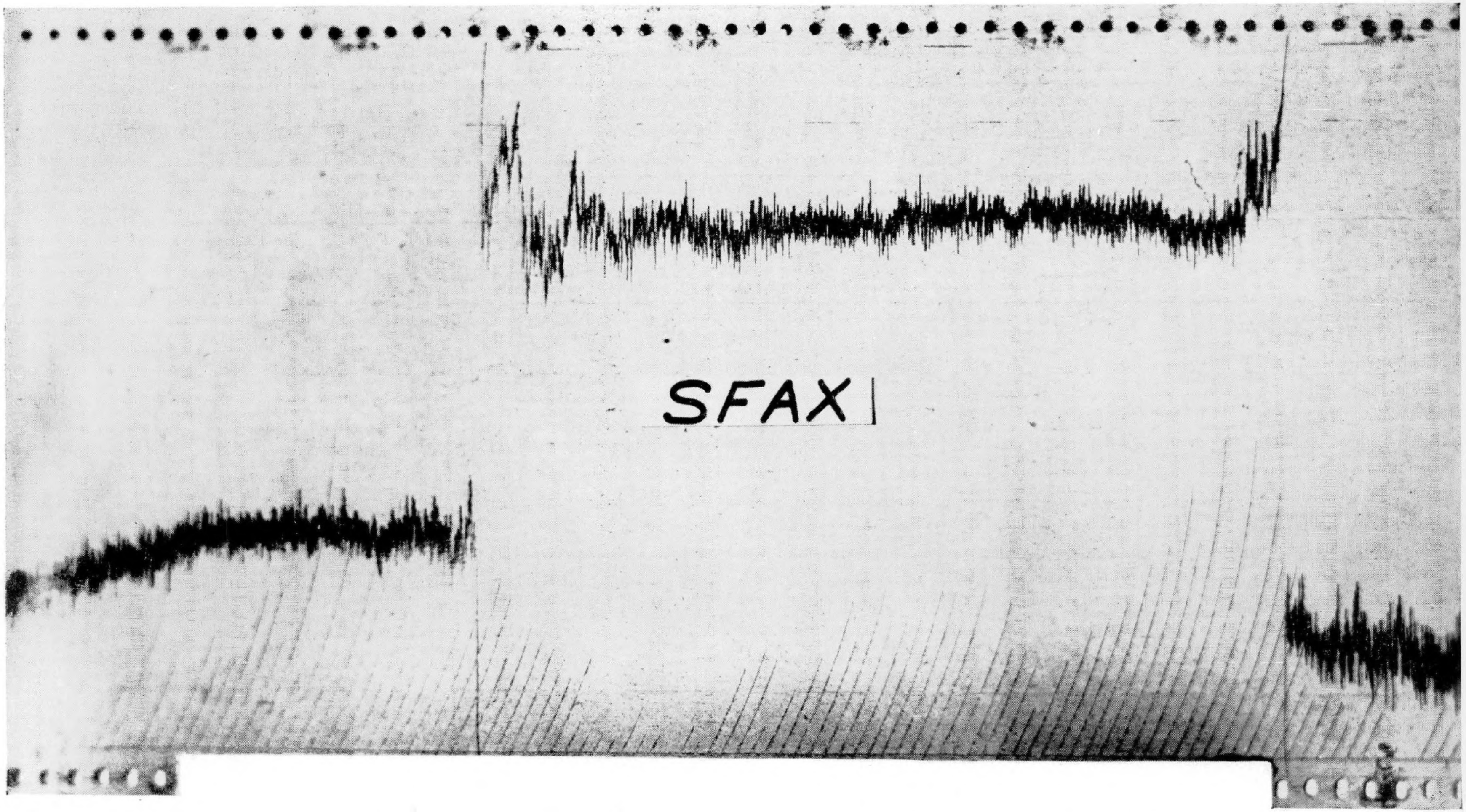
(1) Note in this connection that for gear ratio 10, the contact remains closed for one and a half turns of the screw.



ENREGISTREMENT DU 14 SEPTEMBRE 1951 DE 0 A 24 HEURES

COURANTOGRAPHE IMMERGÉ A 2 M. PAR FOND DE 4 M. — MER LÉGÈREMENT HOULEUSE
VENT MOYEN EST NORD-EST : 22 KM.-H. — AMPLITUDE DE LA MARÉE : 1,40 M.
VITESSE MAXIMUM ENREGISTRÉE : 55 CENTIMÈTRES-SECONDE ∽ 1 NŒUD

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remedy has been applied (taking for example a gear ratio of 10) by arranging a second gearing contact at 180° from the first, so that these contacts close alternately every 5 turns of the screw. The corresponding impulses, however, are not sent directly onto the impulse meter: they excite a polarized relay with a double winding, the circuits of which are such that the impulse produced by the closing of the normal contact closes the relay and that it remains closed after cessation of the impulse, until the impulse produced by the closing of the supplementary contact and directed onto the second coil of the relay opens the latter. It is closing of this relay which actuates the impulse meter. As a result, for a permanent current, the operation of the impulse meter remains the same as formerly, the only difference being that the duration of the impulses is prolonged and becomes equal to that of the interruption. On the other hand, if rotation of the screw in the opposite direction occurs shortly after the closing of the principal contact, the the rotation must exceed 5 turns and no longer 1.5 in order that the impulse be recorded, and, in addition, the reverse motion will not have given rise to a second erroneous impulse. There is no risk then of the production of erroneous impulses except for a ratio of periodic velocity to permanent current velocity three times greater than when a single impulse contact is used; the probability of any such ratio is notably less.

We have written somewhat at length concerning these risks of errors in recording velocities in swell, principally because it seemed to us that the question had not yet been thoroughly examined; it may be that up till now the insufficient accuracy of current-meters has masked this phenomenon.

5. *Diagrams.*

Figure No. 5 (Pl. III) reproduces a recording strip obtained in slight swell and for different current values. It will be noted that the oscillations enlarging the heading records show the oscillations of the instrument in its entirety under the the influence of swell around the average direction of the current. It is not difficult to follow the trace of this average direction on the diagram with the naked eye. The amplitude of these oscillations will moreover in all probability be reduced on the standard instruments in course of manufacture; the centre of pressure of these currentographs will in fact be brought nearer to the centre of suspension of the body of the instrument.

To facilitate analysis of diagrammetric records a device for examining the diagrams is given with the apparatus; it consists essentially of a plexiglas plate under which the record strip is unwound by hand.

This plate carries two sets of graduations: one for headings and the other for velocities; they are 60 mm. apart, exactly like the recording styluses, and cover the whole useful width of the paper.

The headings graduation progresses from 0 to 360° by divisions of 5°, with numbers every 30 degrees; it can be displaced by an angle representing the magnetic variation, so that the geographical headings can be read off directly.

Although the magnetic compass of the currentograph is fitted with an adjustment of semi-circular deviation, by displacement and orientaton of a permanent magnet allowing the adjustment to be made to nearly $\pm$ 2°, the plate of the analyser has been frosted along the headings graduation so that it may be possible to note when needed the residual deviations so that they may be taken into account in the analysis.

The velocities graduation is divided into 24 sections covering the width of the strip; the interval of two divisions therefore corresponds to 5, 10, or 20 cm./sec. according to the gearing used. The graduations have been so constructed as to give true velocities according, therefore, to formula V = a + bn for the first range, V = b'n for the two others; these laws represent in fact the mean calibration curve of the impeller blades in terms of the number of revolutions « n », the coefficients a b and b' being constants for one individual lot of blades.

Finally, it is possible to establish the exact times of the records even if a distortion of the waxed diagram paper has taken place, since the curvilinear ordinates are reproduced every 15 minutes. However, by means of a small auxiliary scale of the abscissae, the diagram can be shifted in front of the scales by a given time interval, without its being necessary to count these curvilinear ordinates.