ON THE RECORDING OF THE SET AND DRIFT OF OCEAN CURRENTS

DESCRIPTION OF A SELF-REGISTERING PROPELLER CURRENT-METER

by

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(Translated from the Italian)

The recording current-meter is of the propeller type, like the direct-reading current-meter which in practice have proved highly efficient: thus, as regards the measurement of the velocity it presents itself as a simple adaptation of the well-known EKMAN-MERZ current-meter; with respect to the recording of the set of the current, it approximates to the BUCHANAN-WOLLASTON current-meter: so that it embodies the characteristics of these two excellent instruments. The apparatus was built at the *Istituto Idrografico della R. Marina* at the beginning of 1936 for the study of the currents at various depths in the port of Genoa where it has been subjected to long periods of test under the most diverse conditions. From the beginning and for several months in succession its functioning has been most regular.

Fig. 1 shows the side-view of the recording current-meter; Fig. 2 shows the front-view; as a whole it has the appearance of an ordinary EKMAN-MERZ current-meter with the addition of the recording unit, but lacking the elements necessary to the original EKMAN-MERZ current-meter for the operation of the revolution counter by means of messengers, and of the compass.

DESCRIPTION (Figs. 1 & 2).

The whole of the instrument, revolvable on rustless ball-bearings about a vertical axis, is set by a vane in the direction of the current which thus acts directly on the propeller; the propeller is guarded by a protecting ring which surrounds it and is free to turn on two bearings (the front one is carried by a cross-bar which may be turned down for the easy transport of the propeller itself), by means of light easily changeable pivots. The propeller revolves, through the agency of a worm cut in its axis, a reduction gear enclosed in a rectangular casing visible in Fig. 1 and composed of two wheels: the first wheel accomplishes one revolution for every hundred revolutions of the propeller; the second, one revolution for every thousand revolutions of the propeller.

The instrument is provided with a ten-blade propeller of a pitch such that 3000 revolutions of the propeller correspond to one thousand metres run of current ; a second four-blade spare propeller, the pitch of which is such that 3240 revolutions correspond to 1000 metres; a third eight-blade propeller, interchangeable with the former, which, on the contrary, accomplishes 1000 revolutions for 1000 metres, and is adapted to the higher velocities, while offering the same sensitiveness at lower values. The axes of the propeller and of the wheels of the reduction gear rotate on agate bearings: this prevents corrosion of the pivots due to electrolysis.

The axis of the second wheel of the reducing gear carries a crank, or eccentric pivot, which causes an oscillation of the vertical arm of the balanced right-angled lever about the axis beneath the axis of the second wheel; such pivot is carried by a sheath secured to a lower support (the same as that which in the EKMAN current-meter carries the compass). The oscillation of the vertical arm of the lever, when the second wheel rotates, has a semi-amplitude of about 3° with respect to its mean position.

The horizontal arm of the right-angled lever terminates in a horizontal fork which clasps a pivot protruding about 4 cm. from the front base of the cylinder G along the horizontal axis. The cylinder G can revolve about its axis without appreciable friction; in the water it possesses a buoyancy nearly equal to its weight and is perfectly balanced around that axis. In this manner, for every revolution of the 2nd wheel, and thus for every oscillation of the right-angled lever, the cylinder G also effects a complete oscillation about its axis, of an amplitude of about 10°. All this does not in fact perturb the operation of the propeller, as has been easy to verify either in the air by means of the blow of a distant fan directed onto the propeller, or in the water, loading the propeller with or without the gearing lever.

Inside the cylindrical cavity of the oscillating cylinder *G* (Fig. 3) is enclosed the actual recorder of velocity and direction of the current, which thus has no communication of any kind with the outside. The sides of the cylinder *G* are of brass, 6 mm. (0.25 in.) thick, and the part towards the vane is hermetically sealed by a robust lid which constitutes the posterior base of the cylinder. The lid is held by 4 clamps which force it against a rubber packing (solid india rubber ring) let in the corresponding reinforced lip of the cylinder proper.

The axis of the right-angled lever and the cylinder *G* (Figs. 1 & 2) are adequately protected against any external action by strong guards.

The cylinder *G* may be taken out of its place (for opening and inspection of the contents) by removing a vertical rear cross-bar (hinged below the supporting armature); this cross-bar has in its centre a small bearing for the rear axis (in rustless steel) of the cylinder *G* secured in the lid; the other axis secured to the front base, engages in a bearing bored in the robust bridle which fixes the supporting armature to the vertical tube which embraces the rotation axis of the instrument. The whole is balanced in such a way that, in the water, the axis of the propeller is exactly horizontal. The vertical axis is provided with adequate upper and lower fixtures for securing the cables, as will be explained later.

The recording part enclosed in the cylinder *G* may be easily taken out after having removed the rear lid of the cylinder (Figs. 3 & 4), because the whole is secured to a strong frame *K* which fits, like a drawer, into two corresponding guides *I I* (Fig. 5), firmly secured to the inner walls of the cylindrical cavity of the cylinder *G*, along two generatrices of the cylinder and diametrically opposed to one another.

When the arm of the right-angled lever is in its middle position, the diameter on which these two guides *I I* are fixed is horizontal. The sleeve which carries the pivot of the right-angled lever is movable micro-metrically in its support, so that this condition may be satisfied once for all when mounting the instrument.

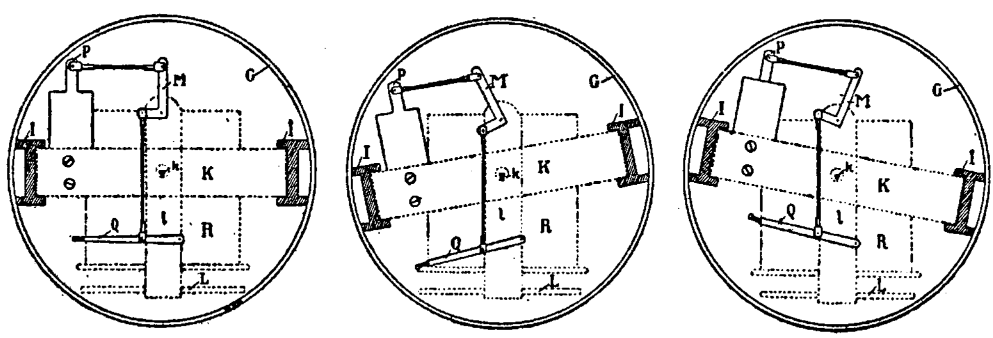

FIG. 5.

RECORDING THE SPEED OF THE CURRENT (Fig. 5).

When the right-angled lever, on the revolving of the propeller, causes the cylinder *G* to oscillate on its pivots, the frame *K* oscillates conjointly, effecting thus a complete oscillation about its horizontal position for each revolution of the second wheel of the reduction gear. The rectangular frame *K* has, corresponding with the axis of the cylinder *G*, two bearings *k k*, on which rests, by means of two uprights, in the way of a pendulum, the platform *L* which constitutes the support of the recording unit. A right-angled lever *M*, articulated on an upright *l* of the pendular support *L*, is connected, on the one side with a protruding part *P*, solid with the frame *K*, on the other side with the small recording pen *Q*, through the medium of adequate rigid articulated tie-rods, so that for each complete oscillation of the frame *K* and of the protruding part *P*, the right-angled lever *M* and the pencil *Q* (the axes of which do not take part in the oscillation of the frame *K* because they are carried by one of the uprights *l* of the pendularly suspended support *L*) effect a complete oscillation.

In this manner the pen *Q* records on the drum *R*; this drum, on which is mounted a strip of paper or a chart, is, as in the ordinary recorders, rotated by a clock-work about a vertical pivot secured in the pendular support *L*; this constitutes the main mass of the pendular system. The pen *Q* thus records a sinusoidal curve on the chart as a function of time: each complete

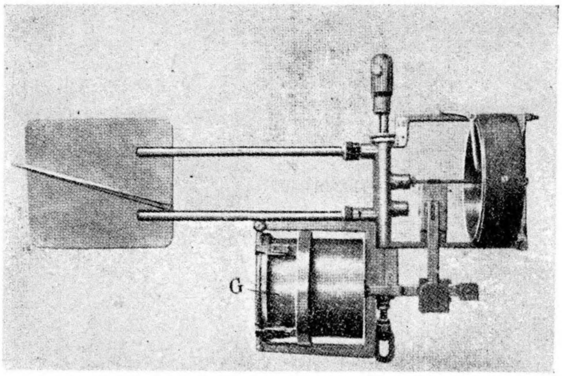

Fig. 1

Vue de côté de l'enregistreur de courant

Side view of the current meter recording device

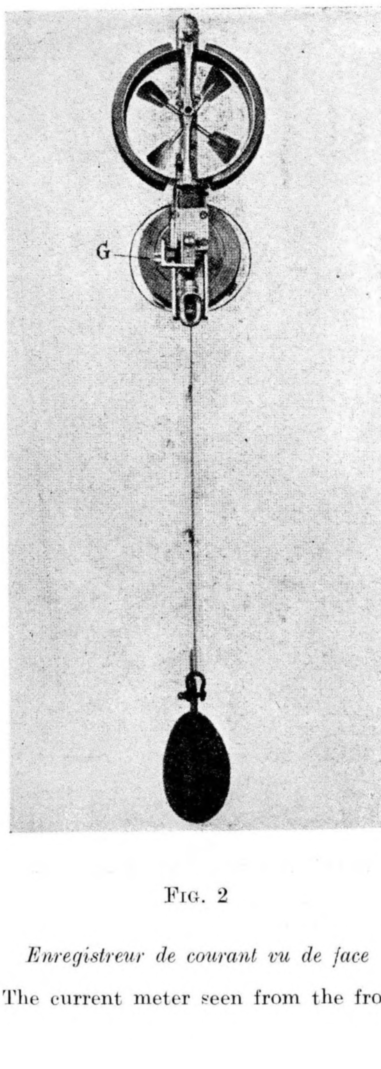

Fig. 2

Enregistreur de courant vu de face

The current meter seen from the front

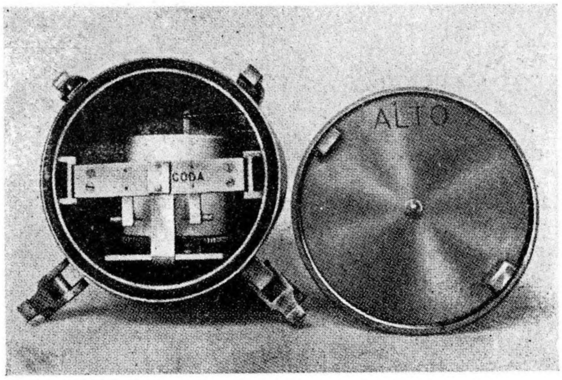

FIG. 3

Cylindre contenant le mécanisme enregistreur

Cylinder containing the recording device

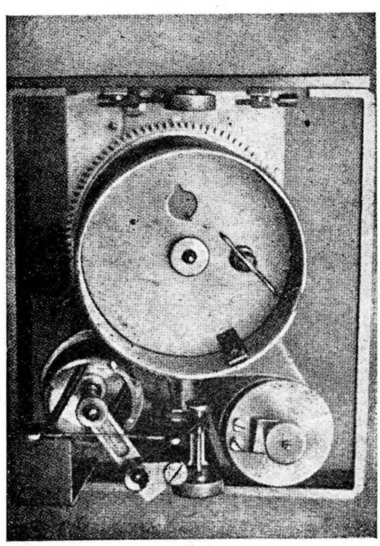

FIG. 4

Mécanisme enregistreur vu du dessus

Recording device seen from above

oscillation of this line corresponds to a revolution of the 2nd wheel of the reduction gear (and thus, in the case of the instrument shown, to 1000 revolutions of the propeller; the drum R moves the chart forward by about 1 cm. per hour). By determining the number of periods of the curve recorded on the chart during a determined interval of time, the hourly speed of the current may be easily deduced; more easily still may the elements for the calculation of the total volumes of water passing through the section of the canal be deduced.

That which has been described constitutes the *recording part for the speed of the current*; and, as has been stated, it is completely secluded inside the water-tight capacity of the cylinder and is thus able to record to any depth at which the instrument is lowered, the depth being limited solely by the resistance to pressure of the walls of the cylinder G.

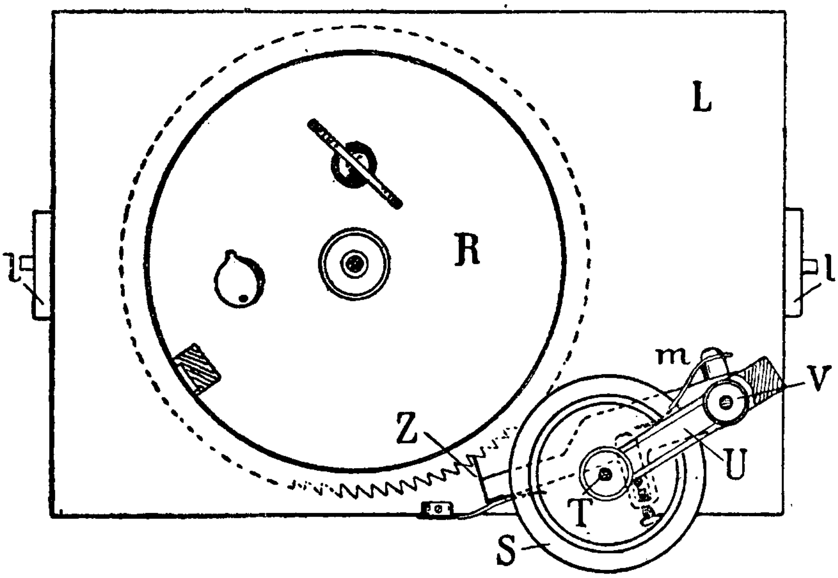

FIG. 6.

RECORDING THE SET OF THE CURRENT (*Fig.* 6).

To the pendular support L is adapted also a special recording compass: the movable part (or rose) of this compass is constituted by a small hollow aluminium cylinder S height 36 mm. (1.5 in.), diameter 33 mm. (1.4 in.) in which are embedded 4 parallel magnets for the orientation: the cylinder S revolves freely on points of an axial pivot secured to a central section of the cylinder, and is perfectly balanced around that axis. On the lateral surface of the cylinder is a helical projection which describes around its axis a complete thread of a screw of pitch equal to the height of the cylinder: on this projection is cut a helical groove of the same pitch, in which is laid a cotton thread (N° 16 for sewing machine) imbibed with stamping ink and prevented from drying-up by the addition of glycerine. The cylinder-compass S thus recalls the registering rollers of the old BECKLEY anemograph. With regard to the direction, the recording takes place in the same manner as in the above-mentioned BUCHANAN-WOLLASTON current-meter, and this gives the recording part an aspect rather similar to the same part of the latter instrument.

The axial pivot of the cylinder-compass S is held vertically by two agate bearings T T carried by an attachment U; this attachment U, in its turn, can revolve about a vertical axis V parallel to the axis of the recording drum R which is also secured to the pendular support L. The attachment U is perfectly balanced with respect to the axis V.

Normally the cylinder-compass S is entirely free to orientate itself around its vertical axis, because a light spring m compels the attachment U to keep it away from the registering drum R.

The rim of the lower base of the drum R is toothed; resting on it is a pawl Z. When the drum R rotates, the pawl Z jumps at the passage of each tooth; and, by beating on a pin Y, solid with the attachment U, it forces this attachment to revolve about its vertical pivot V, so that the attachment U, overcoming the weak resistance of the spring m (which, as has been said, tends normally to hold it away from the drum R), causes, by inertia, the cylinder-compass S to touch for an instant the chart with the helical thread impregnated with ink, and to register thus a dot, the height of which with respect to the base of the chart obviously depends on the direction of the whole of the instrument, that is, on the set of the current. The recording has scarcely taken place when the light spring *m* compels the attachment *U* to move the cylinder-compass *S* away again from the drum *R*, so that the drum *R* always answers to the orientation of the magnets.

In this manner at each jump of the pawl *Z*, a record is made of the *direction of the current* (in the case of the instrument shown in the figure, every quarter of an hour)

The cotton thread is easily changeable in its special groove; the ink with which it is impregnated is sufficient for over a week The drum *R* accomplishes one revolution per diem and, in the instrument here described, the ink will last about 7 days; the chart (about 24 cm. (10 in.) per diem) is wound on a feed roller.

A special lever on the pendular support *L* allows the recording pencil *Q* and the support *U* to move away simultaneously from the compass *S*, so that the drum *R* may be removed from its axis.

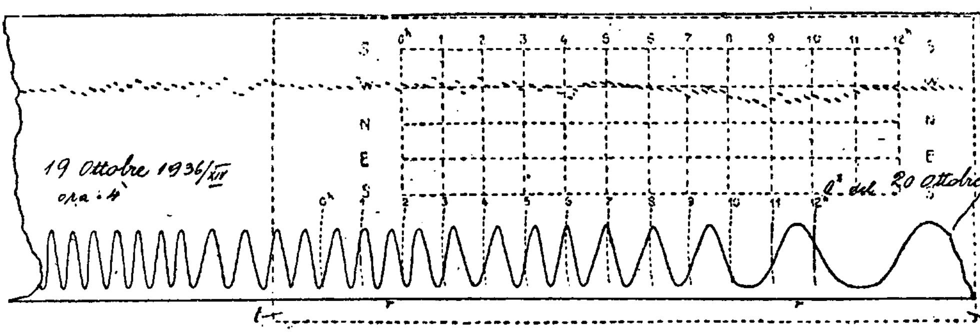

FIG. 7.

ANALYSIS OF THE RECORDS.

The analysis is effected by superimposing on the registered diagram a sheet of transparent mica *t* on which are inscribed :–

(1) a straight line (base line) *r r* to be adapted to the lower edge of the recorded diagram;

(2) a few (12) numbered arcs of circle which represent the successive geometric loci of the possible positions of the pencil *Q* at intervals of one hour; the first of these arcs is brought in coincidence with the beginning of the record of which the time has been noted;

(3) as many (12) straight lines normal to the base, and which represent the successive geometric loci of the possible records of the compass *S* at intervals of one hour; these also are numbered and correspond to the small arcs of equal numbering;

(4) perpendicularly to these straight lines are drawn parallels to the base line, the geometric locus of the records of the magnetic cardinal (and intercardinal) directions of the current, to which are given the symbols of these directions (N., E., S., W.);

(5) the speed of the current is obtained by counting the periods of the sinusoidal line recorded by the pencil *Q* included between two consecutive hourly arcs of the transparency;

(6) the direction, by observing the height of the recorded points included between the hourly straight lines corresponding to the two arcs.

Fig. 7 shows, on a reduced scale, a small section of the diagram recorded by the instrument; the diagram of the instrument is 7.0 cm. (3 in.) high; above it, in pecked lines, is reproduced the transparency *t* for the analysis, which permits the immediate reading of the hourly speed and of the corresponding directions.

PUTTING INTO OPERATION OF THE RECORDING CURRENT-METER.

The experiments carried out in the port of Genoa have proved that in *localities not too exposed*, useful and excellent records may be obtained at depths greater than 2 or 3 metres, by suspending the current-meter to a cable hanging from a pontoon firmly moored on two anchors or buoys.

In the open sea it is possible to operate as follows (vide EKMAN, l.c.) :- the axis of the instrument has two shackles; to the upper *A* is fastened the end of a cable about 1 m. long, fastened at the other end to a first float *c* (Fig. 8), the buoyancy of which is appreciably greater than the sum of the weight of the instrument in the air and that of a length of cable equal to the depth of the sea in the locality. To the lower shackle *B* is fastened the end of a cable, at least four times that of the depth in length.

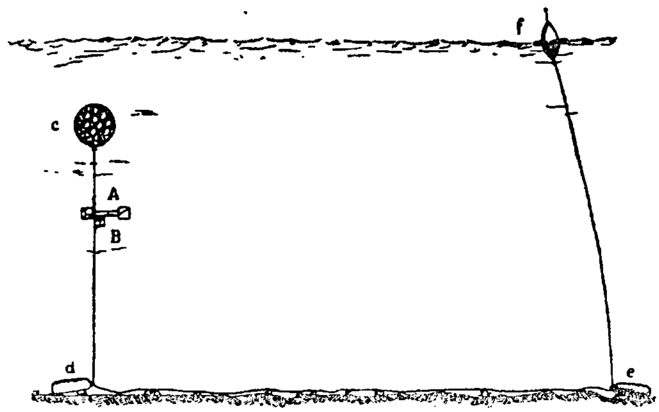

Fig. 8.

The apparatus is then lowered into the water with the first float; and while the float *c* is held as firmly as possible from a boat, and the vessel is moving slowly away, a length of cable equal to the difference between the depth of the sea at the station and the depth at which it is intended to carry out the measurement is paid out. The length paid out is gradually trailed out behind; the ship is then stopped and a first weight *d*, amply superior to the residual buoyancy of the first float, is attached along the cable. The ship now moves slowly towards the boat which holds the first float, continuing to pay out cable until the first weight pulls the first float under water and touches the bottom. The engine is reversed and, proceeding cautiously, another length of cable equal to the depth of the sea is paid out, and the ship is again stopped. Along the cable a second weight *e* is now attached, and while the ship moves slowly from the station of the current-meter, the cable is paid out until the second weight touches the bottom; the cable paid out is made fast to a reconnoitring buoy *f*, preferably a light-buoy, intended to facilitate recovery, and the whole left to itself. In this way the two cables cannot get entangled.

For the fastening of the weights along the cable, adequate clamps, which do not damage it, will naturally be used.

The exact position of the current-meter may be determined by the ordinary methods at the moment when the first float sinks.

The first float *c* having to remain immersed for a long time, and being subjected to a pressure which may be considerable, must be absolutely water-tight: thus floats made of cork or any porous material are excluded from use; preference should be given to floats formed by glass spheres like those used by fishermen to sustain their nets. (Glass spheres 13 cm. (5 in.) in diameter with a free buoyancy of about 1 kg. (2.2 lbs.) exist in the open market). The spheres are grouped in a strong hemp sack, and arranged so that the external form is round.

ADAPTATION OF THE ORIGINAL EKMAN-MERZ CURRENT-METERS.

As is clear from Figs 1 and 2, to transform an original Ekman-Merz current-meter into a current-recorder, it is sufficient to:

(1) substitute for the original revolution-counter an appliance applicable in the same manner as the revolution-counter itself;

(2) substitute for the original compass the attachment which sustains the pivot of the right-angled lever;

(3) screw on to the vertical tube which embraces the rotation axis of the current-meter the support of the above-mentioned recording apparatus *G*;

(4) adjust the position of the fork of the right-angled lever in such a manner that the cylinder *G* oscillates symmetrically with respect to the position which renders horizontal the internal attachment *K* supporting the recording unit;

(5) balance adequately the instrument so that in the water the axis of the propeller is horizontal.

The parts of the original current-meter intended for releasing and stopping the revolution-counter by means of messengers, are useless; they may however remain in place ready for operation.

REFERENCES : Publication de Circonstance N° 34 du Conseil Perm. Intern. pour l'Exploration de la Mer, 1906 (with Appendix by V. M. EKMAN).
Hydrographic Review, Monaco, 1928, Vol. V N° 2.
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