



STUDY OF THE REGIME OF COASTAL WATERS BY MEANS OF FIXED AUTOMATIC DEVICES.

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The study of the regime of coastal waters is particularly interesting from a scientific point of view, as well as for purely practical purposes (harbour construction, navigation, pisciculture, etc.). This study can only be developed slowly, owing to the lack of sufficiently perfected instruments and adequate methods of working.

At the hydrometeorologic stations of the Central Office of Marine Navigation, observations are made at intervals of 1 to 5 days, and sometimes more frequently. In spite of efforts which have been made to render these observations as systematic as possible, they are of an intermittent character, and cannot give accurate information on all details of the peculiarly variable regime of water movements. From the data obtained from these intermittent observations, it is exceedingly difficult to deduce the relation which exists between the different hydrometeorologic factors, to verify the hypotheses, and to establish laws governing these phenomena. At times, however, it is possible to obtain very important information of a practical nature; such as, for instance, the maximum speed of the currents, the volume of drifted sediments, etc. Although the data recorded by the anemographers for many years were collected, and it was known that a correlation undoubtedly exists between the currents and the winds, it was not possible, at the time when a special study was made of the currents, to deduce definitely and methodically the relation existing between them, as the data were not based on uninterrupted observations spread out over a sufficiently long period.

Moreover, no data whatever exist regarding the regime of the movements of the mass of sea water at the most characteristic moments of great tempests, as the strong eddy currents and the inevitable damage which would result, make a study under such conditions physically impossible. It would, therefore, appear necessary that for the methodical and rational study of the regime of the movements of the aqueous mass of the seas and oceans, recourse should be had to a method which would enable the regime of the water movements to be recorded without interruption at all times and in all seasons, *i.e.*, by automatic hydrological recording devices.

The system of recording hydrological observations, at hydrometeorologic stations, should be the same as that which is used for meteorological observations, except that at the latter automatic recorders are used.

The following is an example of a fixed installation for hydrologic observations:—

A position is chosen on the seashore which comes within the radius of activity of the hydrometeorologic station; a heavy hydrological tripod, made of wood or metal and of sufficient height to prevent the highest waves from reaching the top, is set at a depth of 3.5 to 6 metres.

Various recording instruments are attached to this tripod, namely:—

- 1) a current meter or vane for recording the horizontal and vertical speeds of the currents (Fig. 1).
- 2) an automatic bathometer which takes samples of water according to the different directions of the current, and pours them into separate receptacles.
- 3) a bottom bathometer which takes samples of the sediments which move about over the bottom, according to the different directions of the currents.
- 4) an apparatus which automatically records the height of the highest waves, together with an indication of the time.
- 5) Paris' apparatus for measuring waves.
- 6) an anemograph
- 7) a tide-gauge
- 8) a vaporometer

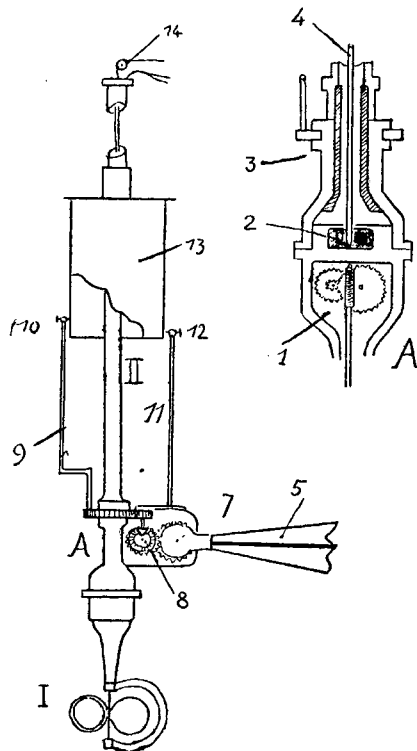


Fig. 1

The recording apparatus is put into a hermetically closed box, which is placed on the top of the tripod. A clock-work mechanism, which requires winding every one to three days, imparts a rotary movement to a recording drum of large diameter, or a ribbon. A row of pens, attached to electromagnets, inscribe on the drum, or ribbon, at the passage of the electrical currents caused by the functioning of the electric recorders, a series of vertical lines or dashes. A pen is provided for each instrument. By this method it is possible to collect together all the data required for so complicated a study as that of the regime of water movements at a fixed point, and with respect to a given vertical line. With a group of these vertical lines, judiciously distributed in the zone to be studied, it is possible to obtain detailed information of the whole area under examination; observations made by harbour and roadstead research stations, should such observations be made, might also be useful.

In the U. S. S. R., as well as in foreign countries, there already exists a large number of instruments which are indispensable for carrying out this work according to station methods. Other instruments may be constructed by organisations or persons interested (it might be advi.

sable to encourage such construction by means of prize competitions, etc.). I have myself constructed and tested several of these instruments, principally in the Azof Sea, and others, of which at present I have the designs only, will be examined in detail.

(1) I can recommend the marine recording vane (Fig. 1) for measuring the speed and recording the direction of the currents. It is a device which I made on the principle of the vane, which later was constructed by Mr P. F. MOROZ, Assistant Master at the Professional School of Temriouk under my supervision, and tried in the Azof Sea. The construction of this vane was described in detail by Engineer D. G. SCHAPOSHNIKOFF in the *Bulletin of the Polytechnical Institute of the Don*, No 2, 1926. Its greatest defects, of which mention is not made in this description, lie in its lack of a contrivance for measuring the vertical angle of inclination of the current and the fouling — which is inevitable in cases of troubled waters — to which the ball bearings of the vane are subject. The result is an incorrect measurement of the speed of the current.

In the new model marine vane (fig. 1) these disadvantages have been overcome by modifying the tail and replacing the ball bearings by ordinary bearings. The apparatus comprises a device for measuring the currents (11) with a Harley type of vane (1), in which the contact box, as well as the transmission organ (A) of the contacts, from the movable part to the fixed rod, have been slightly modified. The conduits from the air box (1) pass through an insulated tube into the mercury receptacle (2) from whence, through the medium of the central rotating rod (4), they transmit the movement to the organs contained in the recording apparatus. This vane and the tail (5) turn freely on the vertical axis (3). The tail itself is formed of two perpendicular fans; it can move freely in a vertical sector of 120° , on the axis (7). On the tail is a small fixed pinion which, during the rotation of the tail, communicates, through the system of cog-wheels (8), a rotary movement to the rod (9) which carries an electric needle (10). The tail also carries a rod (11) with a needle (12). The recording drum, which acts as a weight (13) does not rotate, but it can be lowered by means of clock-work mechanism and a silk cable (14) which is rolled on a special pulley. The drum is first immersed in a bath of melted wax, in order to cover it with a thin layer of that substance, on which the needles 12 and 10 can inscribe the curves of direction of the currents, the former, that of the currents acting in the horizontal plane, the latter that of the currents acting in the vertical plane. The layer of wax may be replaced by a paper coated with wax or by tracing paper. The height of the drum is $120 \frac{m}{m}$; from a clock wound up for a day, readings can be obtained every 6 to

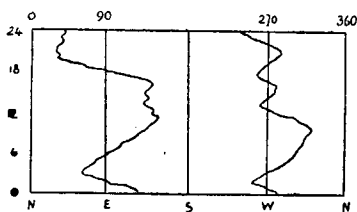


fig 2.

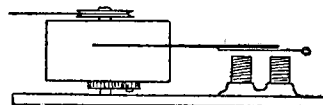


fig 3

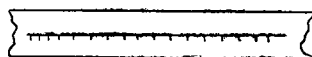
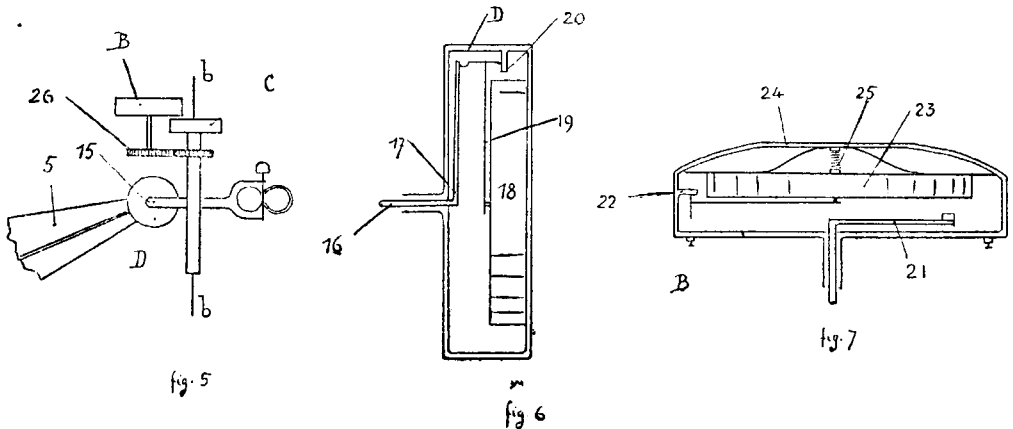


fig 4

12 minutes. The development of the circumference of the drum is $240 \frac{m}{m}$ for 360° , which enables the measurement of the angles of the horizontal inclination of the currents to be read with an approximate accuracy of 0.5° to 1° . The ratio of the gear wheels for recording vertical directions is calculated in such a way that for an upward tail movement of 60° , the needle (10) turns 90° in the opposite direction and for a downward tail movement, clock-wise; thus, the direction of the vertical angles can be read with an approximation of $20'$ to $40'$ (120° for $120 \frac{m}{m}$). When the position of the tail corresponds to a horizontal direction of the current, the needle (10) is 180° from the needle (12). The size of the vertical angles is determined by the difference of the abscissae of the points of the curves inscribed on the diagram by needles 10 and 12. Fig. 2 gives an example of curves of direction of currents. Fig. 3 shows the apparatus for recording the speed of the currents and Fig. 4 the ribbon for the speeds of the current.

(2) As regards the current measuring device itself, reference should be made to diagram (fig. 5). This device comprises a Price (Preis) type of vane, with a special measuring organ which turns freely on the axis (*b*). The whole is mounted in a strictly vertical position. The box (*D*) serves to measure the vertical inclination of the current; it is permanently fixed on the tail (5) which is formed of two surfaces, perpendicular to each other, and can be moved in a vertical plane around the axis (15). The fixed rod (16) (fig. 6) serves as an axis for the tail and, by the bend (17), penetrates the box (*D*). This box contains the clock (18) with the index (19); the latter has, at its extremity, little contact-makers which, during the circular movement it makes, alternately touch the rod (17) or the pin (20) fixed in the box, closing the circuit and causing the inscription of a mark by the pen of the automatic recorder on a ribbon of Morse type. The interval of time between two contacts gives the size of the angle of inclination of the current with regard to the horizontal plane. The crosslines of the ribbon being appropriate, the size of the angle is obtained by simple subtraction. The air contained in the box prevents the entrance of water, and the clock-work mechanism, as well as the contacts, can work correctly. The round air box (*B*) (fig. 7) measures the horizontal inclination of the current. Its construction and functioning are similar to that of the box (*D*); but the rod in the horizontal box moves, and the box and the pin (22) are fixed. The clock work mechanism (23) is fixed to a special plate, which is kept in position against the upper side, under pressure of springs (25). The rod (21) is moved by the pinion (26), (fig. 5). The air now serves to insulate the organs of transmission running from the movable parts to those which are fixed.



If the indexes of the clock-work mechanism of the air boxes make a complete revolution in 30 minutes, and the length recorded on the ribbon in 24 hours be equal to $600 \frac{\%}{m}$ the angles can be read every 30 minutes with an approximation of 1° to 2° .

The speed air box (*C*) (fig. 5) establishes contact every 250 to 500 revolutions; the pen inscribes the contacts on the same ribbon.

Thus the automatic recorder of the current measuring apparatus has 3 electric pens: one for the vertical angle measuring box, one for the horizontal angle measuring box, and one for the speed box. The device is rather complicated and requires to be minutely studied and tested.

The advantage which it possesses over the marine recording vane lies in the possibility of obtaining records from it above water in any position, the convenience of its handling, the permanent control of its working and the power of being able to move it vertically up and down by means of the supporting rod, which also enables it to be installed in deeper waters than the above apparatus; several appliances may be installed simultaneously at different depths.

(3) For determining the quantity of sediment in suspension, the bathometer, constructed by the author in collaboration with Engineer M. N. MARKINE, may be used.

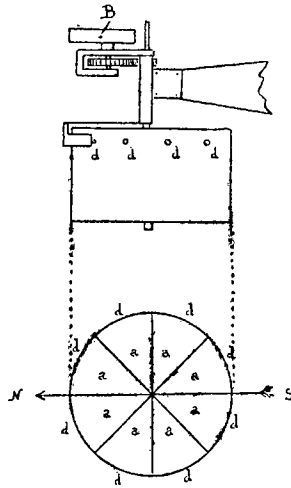


Fig. 8

The Bathometer for taking samples of water, as shown in fig. 8 comprises eight compartments (*a-a*) provided with lateral openings (*d-d*), to which are fitted special valves opening at the moment the tail is in the zone of the opposite sector, that is to say, as the bathometer is oriented in a fixed direction, in the direction of the current of a known point of the compass. An air box (*B*), similar to that described in the current measuring apparatus for the determination of horizontal angles, can be fixed to the bathometer to ascertain the hour of change of direction of the current. At the closing of the valves, an electric current passes through the electro-magnet actuating the pen of the automatic recorder, and thus a mark is made on the recording drum or ribbon.

The device described is simple, and its construction should not be costly; before use it should be carefully tested. As wind plays a predominant rôle in conditions at sea, an anemograph is indispensable; the ordinary model, mounted on a tripod, suffices, and this is generally easy to realise. This apparatus might be a large vane, with electrical contact, producing the inscription of the number of revolutions effected in a given time; the inscription is made on a drum of the automatic recorder. The direction of the wind may be recorded by means of the drum with downward movement, upon the ribbon of which the pencil of the tail inscribes the curve of the directions for a given time — in the main, the device is similar to the apparatus for measuring currents described for the marine recording vane.

Any scheme for the study of the regime of coastal waters, as well as the proposed appliances, should naturally be examined by specialists; a beginning is generally made with a preliminary installation, which is afterwards improved.

In 1925, I was requested by the TSUMOR to take up the study of the regime of coastal waters in collaboration with the Chief of the Research Service of the Department of Ports of the Sea of Azof, Engineer A. A. TOCHEBYKINE. It was necessary to draw up a reconstruction plan of the port of Temriouk. While making the preliminary researches, I considered it was absolutely necessary to study in detail the regime of the waters in the areas of the moles, above all from the point of view of speed and direction of the currents, in order to determine the cause of the obstruction of the port, and so set up rational protective works. The Eckmann device, which we used to observe the currents, does not seem appropriate for this work: it is difficult to handle, it gives inaccurate indications in bad weather because of the swinging which is produced, the construction is too weak, it gives incorrect information on the horizontal angles and entirely lacks a device for measuring the vertical angles. Observations in strong wind were

of particular interest, that is to say, at those times when the entrance to the port was most obstructed; the trials undertaken with the Eckmann vane in launches and even in large steamships failed, because even under the command of experienced captains, the vessels were thrown against the moles or thrown up on the coast by the waves. Occasional and discontinuous observations were not sufficient to establish the correlation between the currents and the winds, although the knowledge of this correlation was indispensable for the following reasons: the observations had to be of short duration, but as indications of the anemograph for the last 25 years were available, it is clear that, knowing the relation between the current and the direction of the wind, the system of the currents of the port could be deduced for these 25 years and, in consequence, the movements pertaining to its obstruction could be followed. For these reasons, I decided to try using fixed observations devices for the study of the regime of the waters with regard to speed and direction of the currents, as well as for measuring the height of waves in the area of the moles protecting the entrance to the channel of the port of Temriouk. In consequence of insufficient material means, the conduct of the experiments was excessively difficult, and that in spite of the effective help in their organisation which was given me by M. N. MARKINE and F. G. TOULINE.

A hydrological wooden tripod was installed at a distance of 700 metres from the shore, and at a depth of 3 metres. The following devices were fixed on this tripod:

1. A pole to measure the maximum height of waves.
2. An automatic marine recording vane for horizontal measurement of currents.
3. A recording apparatus — drum with clock-work mechanism and pen.

The pole for measuring the maximum height of waves was made of wood, total length 2.5 metres and breadth between the teeth 0.10 m.; the pitch of the latter was 0.05 m. and depth 0.01 m. and they were covered throughout with galvanised iron. The float was of thick galvanised iron, its diameter was 0.30 m. and height 0.10 m. Two strong springs held it to the pole, on which it could slide freely. The pole was fixed to two parallel supports of the tripod; zero was at 0.75 m. above the ordinary level of the sea. The pole acted perfectly, and showed that the height of the waves in heavy weather was considerably above the height, based on visual observations, which it had been customary to reckon up to then. The cost of the pole for measuring the maximum height of waves, including the float, was 15 roubles. The use of these poles is recommended, not only for fixed observations carried out by harbour authorities, but also at all hydrometeorological stations, on account of the accuracy of the indications and the cheapness of construction; their installation and management present no difficulty, more especially when these stations are situated near moles or other hydrotechnical works. It should be noted that the pole was first tried at the head of the East Mole of the port of Temriouk and it gave the height of the waves, in all kinds of weather, perfectly.

Mention has been made, above, of the construction of the automatic marine recording vane. The cost of this vane, including various accessories, was 125 roubles. It was fixed to the middle of the tripod and the supporting rod was kept in place by two nuts.

This device, owing to its simple construction and its satisfactory working, appears most suitable for this kind of work; it provides data of indubitable accuracy. The clock-work mechanism can be wound up to run for 1 to 3 days, it saves much labour, it does not take more than one hour every 1 to 3 days to change the drum or to take a copy of the curve as well as to change the ribbon.

The construction of this apparatus is clearly shown in Fig. 3. If the drum were replaced by a ribbon, even more accurate results, and speed contacts every 25 to 100 revolutions would be obtained.

Fig. 4 represents the ribbon, on which the small vertical dashes of the line of speeds indicate the time and the number of contacts of the vane (in this case about 320 revolutions).

These appliances were installed at the end of 1925. The tripod was made of wood, formed of three beams 5.5 m. in length and 0.15 m. thick. The upper parts of these beams were joined together, clear of the water, by stay-bolts and clamps. At the base of each foot, anchors of 160 kgs. each were securely fixed, to keep the tripod in position. In spite of this precaution, during the exceptional storm of the 10th September, it was shifted and the apparatus had to be removed. The movement of the tripod was apparently caused by a change in the configu-

ration of the bottom, owing to the movement of sediment; the open construction which was adopted did not hold sufficiently against the assault of either waves or wind.

The fixing of the tripod should not be difficult in constant bottoms, but for changing bottoms the beams should be driven in, as for piles.

In deep water, the method described is not practicable because of the difficulty of installing the tripod; it is evident that, in harbour construction, observations at great depths are not so necessary as at small depths, and at great depths the movement of the sediments is of no practical interest.

The experiment carried out at the port of Temriouk showed the possibility and the utility of the appliances described above for the study of the regime of the waters by fixed contrivances.

Their application should be generalised in order to collect useful and instructive data relative to this question; they could also be applied to rivers, the study of which leaves much to be desired, because of the absence of rational methods of work and appropriate apparatus.

