DIFFERENTIAL TIDE-GAUGE FOR RECORDING SEICHES.

by MARCIANO A. BALAY, Technical Adviser of Department of Navigation and Hydrography, Buenos Aires.

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The short-period oscillations in sea-level known as « seiches » have long caused oceanographers concern the world over, as except for those of seismic origin it has not so far been possible to ascertain with strict scientific precision either the force that generates or the laws that govern this curious phenomenon.

It is a well-known fact that a « seiche » can occur both in inland seas and lakes or the open sea, and that it reaches maximum proportions in gulfs, bays, and ports with deep, narrow entrance channels.

Its amplitude is considerable in certain parts of the world, as in San Francisco, Mar del Plata, etc., and its effects along the coasts of Japan and the Philippines, where the natives termed it « mar loco » (mad sea), may be disastrous.

It occurs in the shape of small oscillations varying in period, ranging from a few minutes to one or two hours, and amplitudes from a few millimetres to two metres may be attained.

It is interesting to note that the period of oscillation of « seiches » for a given area remains fairly constant, and that variations occur only in amplitude and duration.

The period of « seiches » is more irregular in the open sea, owing to the variation in the limits of oscillating areas affected by the phenomenon.

When recorded it has the appearance of a micrometric tide, in which the apparent manifestation of its wave components may be observed.

As it accompanies all phases of the astronomical tide, it cannot easily be identified on diagrams obtained by using ordinary tide-gauges, which record total variations in sea-level.

Recording of « seiches » seem to be best defined at times of high and low water, when the rate of variation in the tide is at its lowest.

This fact led to the devising by the author of this paper of a machine that would enable « seiches » to be recorded separately and at the actual time of occurrence.

The mechanism in combination with an ordinary « Standard » tide-gauge makes it possible to plot a curve representing the difference between the tide and the tide plus the « seiche », that is, supplying an isolated record of the « seiche ».

The equipment is based on the delay in the passage of water through an opening of given cross-section and communicating with the open sea through a pipe whose cross-section has likewise been determined.

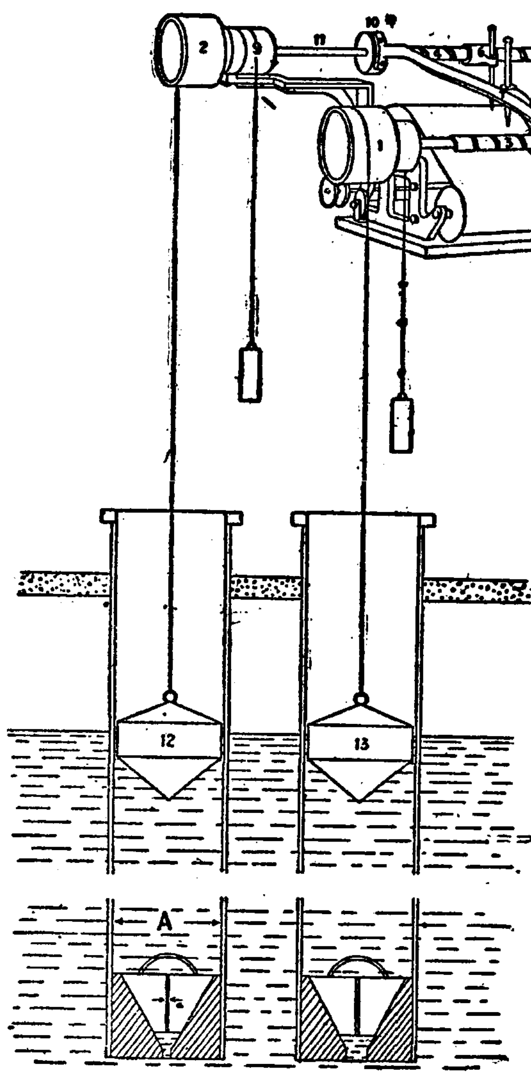
Inside the tube is an appropriately counter-balanced float connected with the counterweight by a special wire wound in the grooves of a pulley. The pulley is joined to a worm-screw operating a carriage equipped with a stylus, which records the variations in sea-level.

The apparatus as a whole consists of a pipe (A), pulley (2), worm (4), stylus arm (6), adapted to the « Standard » tide-gauge (1), (3), and (5).

The worm (4) of the differential apparatus is hollow and shifts on the grooved rod (11), following the action of the pulley (1), which transmits motion through the agency of the worm (4), carriage with stylus (5) and arm (7).

The worm (4) of the « Differential » gauge therefore follows all the movements of the worm (3) of the « Standard » gauge.

MAREÓGRAFO DIFERENCIAL



The stylus-bearing arm (6) of the « Differential » moves by means of the corresponding worm-screw (4), following the rotating action transmitted by the pulley (2) to the rod (11).

The rod (11) is grooved and its ends are connected to the pulley (2) and bearing at (8).

The pulley (2) motion is transmitted to the worm (4) through the medium of a head fitting into the rod-groove (11), causing it to revolve on the bearings (10).

The arm bearing the stylus is thus actuated by its own pulley (2) as well as by the « Standard » pulley (1), but in the opposite direction (owing to the direction of winding of the wire on the pulleys), so that its motion with reference to a fixed point only represents the difference in the distance travelled by the two floats (12) and (13).

The tube connected to the « Differential » systems has an opening for the admission of water of such cross-section as to cause a delay sufficing to prevent the « seiche » from making itself evident within the tube. If acting independently, the system would therefore record an attenuated tidal curve.

The « Standard » system tube operates normally, that is in the sense that it allows a tidal curve to be plotted showing all variations in sea-level, except those of very short period due to the direct action of ordinary waves.

As the « Differential » stylus only records the difference between the movements in both systems, the remaining curve will be the one that corresponds to the « seiche », and will also reveal the existence of « tsunami » waves.

Tsunami waves are short-period (2-minute) irregular oscillations in sea-level, of small amplitude (half a foot), and related to trains of waves near the coast (1).

The diagrams show a manifestation of the latter in conjunction with « seiches » and varying in intensity in accordance with the wave conditions on that particular day.

DETERMINING DIAMETER OF TUBE-OPENING OF « DIFFERENTIAL » TIDE-GAUGE SET UP AT MAR DEL PLATA

Rate of speed of water particles passing through opening:

$$V_1 = \sqrt{2g\,\Delta}$$

where:

Δ = height of water (difference between levels of water inside and outside the tube) ;

g = usual gravity co-efficient.

Taking friction and other forces into account, we can write:

$$V_1 = \mu \sqrt{2g\,\Delta}$$

where:

μ = coefficient of efflux, with an approximate value of 0.6;

Let:

a = cross-section of opening;

A = section of tube of float;

$V_2 = \frac{dH}{dt}$ velocity of variation in open sea-level.

Equalizing the variation per second in the volume of water inside the tube with the flow through the opening during the same length of time, we get :

$$\frac{dH}{dt} A = a\,\mu \sqrt{2g\,\Delta} \qquad (1)$$

The average period of « seiches » recorded at Mar del Plata (in open water) is 8 minutes and maximum amplitude does not ordinarily exceed 30 cm.

In order that the level of the water inside the tube may remain unaffected by the short-period variations due to « seiches » in the sea outside, it will be sufficient to bring about a delay inside the tube equal to one-half of the « seiche » semiperiod.

This can be done, by causing during this time-interval the variation in water-level in the tube to reach a pre-determined minimum value capable of being recorded.

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(1) W. H. Munk : « Transactions American Geophysical Union », Vol. 30, No. 6.

The apparatus in operation at Mar del Plata works at a height-scale of 1 : 16; under normal conditions, a variation of 0.1 cm. on the tide-gauge will be evident, which corresponds to a 1.6 cm. change in actual sea-level.

As the rate of change in water-level inside the tube is not constant, but decreases as the difference in heights (inside and out) diminishes, we can consider approximately one minute more, or 3 minutes, as the necessary time interval for a 1.6 cm. variation in water-level inside the tube.

The average rate of change in level inside the tube will then be:

$$V_2 = \frac{1.6 \text{ cm./sec.}}{180} = 0.0088 \text{ cm./sec.}$$

The velocity of the water as it passes through the opening at the time of maximum change in level due to the « seiche » will therefore be (Δ = 15 cm., semi-amplitude of the « seiche »):

$$V_1 = 0.6 \sqrt{2 \times 980 \times 15} = 103 \text{ cm./sec.}$$

substituting in (1):

$$103\, a = 0.0088\, A.$$

Designating as d and D respectively the diameters of opening and tube, we get:

$$d = \sqrt{\frac{0.0088\, D^2}{103}}$$

D being equal to 40 cm. (Mar del Plata tube), we therefore get:

$$d = 0.37 \text{ cm.}$$

This value for the diameter of the opening admitting sea-water into the « Differential » float causes the water to penetrate gradually and creates a delay sufficing to prevent the « seiche » from making itself felt inside the tube.

The ratio between tube and opening cross-sections supplies the damping coefficient, through which the delay to be produced can be ascertained.

Whenever avoidance of the effects of short-period (semidiurnal, diurnal, etc.) waves becomes necessary, a filter having a definite porosity coefficient should be used instead of the opening.

These filters enable the obtaining of 3 to 6 hour delays which are essential in nullifying the effects of such waves inside the tube.

The equipment now in operation at Mar del Plata was set up in accordance with foregoing specifications, and records obtained fully meet set requirements.

Following the experience acquired with this initial model, a new one is to be installed at the new Geodetic Tidal Station now being built at Mar del Plata, with certain changes in design that will enable variations in sea-level to be recorded with greater accuracy.