

AN OFFSHORE TIDE GAUGE

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1. INTRODUCTION

Between October and December 1970 the Hydrographic Department of Japan carried out jointly with the Governments of the Republic of Indonesia, Malaysia and the Republic of Singapore a hydrographic survey of the Straits of Malacca and Singapore lasting about 80 days.

The present paper reports on an offshore tide gauge which was specially manufactured for the occasion and worked very successfully during the field operations.

Since these Straits form the longest channel in the world and tides there vary not only lengthwise but also crosswise between the two shores, at the time the survey was being planned it was thought that tidal observations ashore would not suffice for providing proper tidal corrections for the soundings taken in the mid-channel passages. After some discussion it was decided to place a tide gauge on the seabed in the survey area.

2. PARTICULARS OF TIDE GAUGE

1. Maximum depth of installation : 50 metres.
2. Scale of record : 3/100.
3. Range of record : 5 metres.
4. Paper feed speed : 12 millimetres per hour.
5. Recording paper : Roll type, length 10 metres.
6. Recording pen : Sapphire stylus.
7. Duration of continuous observations : Approximately a month (34 days).
8. Clock system : Self-winding.
9. Power source : 4 dry cell, 1.5 volt, batteries.
10. Weight : the instrument itself — 70 kilogrammes in air and 30 kilogrammes in water; the base : 100 kilogrammes.

3. DESCRIPTION OF THE MECHANISM

The gauge consists of a recorder, a sensor and a base. The recorder is housed in a water-proof case. An automobile tyre tube lining was used as sensor. Water pressures on the sensor are transmitted to metal bellows and their expansion and contraction are registered on the recording paper.

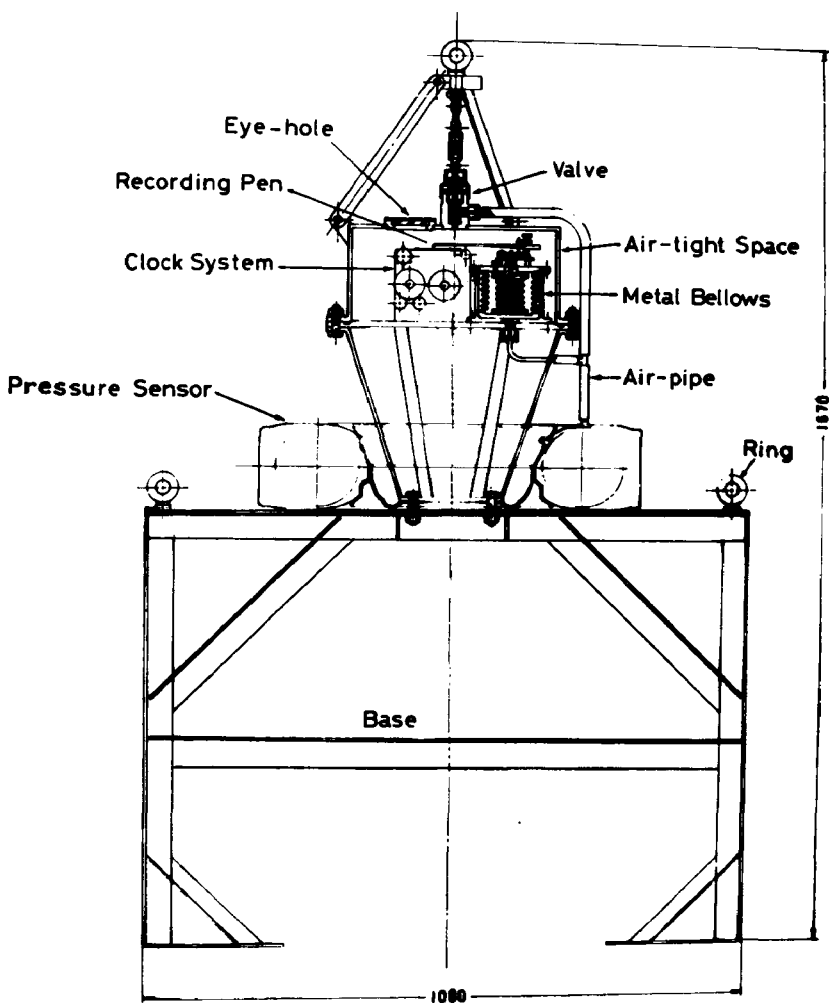


FIG. 1. — Offshore tide gauge. Type DT-II.

In order to eliminate any overpressure on the sensor while the gauge is being lowered to the bottom, a branch air-pipe fitted with a valve connects the sensor and the metal bellows to the case of the recorder. While the gauge is being lowered the valve is kept open and the water pressure

increases equally inside both the metal bellows and the recorder, and thus the recording pen does not move. Then when the gauge is in position the valve is closed by hand and thus pressure changes caused by the rise and fall of sea level affect only the bellows and are registered on the recording paper.

Before lowering the gauge, air is pumped into the tyre tube sensor at a pressure consistent with the depth at which the gauge is to be installed (see the table given below). At such pressures the tyre tube can be hand-pumped.

Since the recording pen can be set for any given tidal height, it is desirable to set it to take into account the expected height of the tide at the time the gauge will be lowered in order that, so far as possible, the curves may appear on the middle portion of the recording paper.

Let P_1 be the air pressure pumped into the sensor before lowering the gauge and V_1 its volume inside the sensor, V_2 the volume of air contained in the recorder case, P_2 the water pressure for the expected depth and α the coefficient of diminishing volume in the tyre tube sensor. We then have :

$$P_1 = \frac{P_2 (V_1 \alpha + V_2)}{V_1 + V_2}$$

If α has as value 1/3, the values of P_1 are as follows :

Air pressure at time of installation

5 metres	0.3 kg/cm ²
10 "	0.5 "
20 "	1.1 "
30 "	1.6 "
40 "	2.1 "
50 "	2.7 "

One of the problems with this gauge is "back pressure". As the metal bellows expand or contract after the valve is closed the volume of air inside the recorder case varies, and this results in recording errors. As this error differs according to the pressure originally existing inside the case it is not possible to obtain records based strictly on a fixed scale factor.

Let ΔP be the change in pressure caused by the tide, ζ the expansion or contraction of the bellows, P the pressure inside the bellows just before the gauge was lowered, A the surface area of the bellows (69.4 cm²), k the reactive force of the bellows including the interior spring (18.4 kg/cm²), V the volume of air in the recorder case (10.0 litres), l the reciprocal of the record scale factor (20) and $\Delta P'$ is the 'back pressure' caused by the expansion or contraction of the bellows. The variation in pressure is then given by the formula : $\Delta PA = k\zeta + \Delta P'A$. The relation between the air inside the recorder case (which was pressurized for the depth at which the gauge is placed) and its small change in pressure can be expressed by the equation :

$PV = (P - \Delta P')(V - \zeta A)$. The 'back pressure' ($\Delta P'$) can accordingly be expressed by :

$$\Delta P' = \frac{PA\zeta}{V - \zeta A}$$

and changes in water pressure due to the tide (ΔP) can be expressed by :

$$\Delta P \doteq \frac{(KV + PA^2)\zeta - KA\zeta^2}{AV - A^2\zeta}$$

Neglecting the terms whose effect is minor, the last equation becomes :

$$\Delta P \doteq \frac{(KV + PA^2)\zeta}{AV}$$

The recording error (E) can be expressed by :

$$E = \frac{\Delta PAI}{K}$$

The recording error (E) caused by the 'back pressure' (computed with the above equation) for depths of 20 metres and 50 metres, with a tidal amplitude of 150 centimetres, is respectively 1.2 centimetres and 2.4 centimetres.

Leaving aside any discussion as to whether or not these values are within an allowable error for a water pressure type tide gauge, it is desirable that corrections should be made to the readings prior to the actual operations on the basis of results from a test carried out with the gauge installed at the depth expected to be encountered during the survey.

4. PRELIMINARY TEST

When the prototype gauge was ready, it was set on the seabed at a depth of 20 metres, and its observations were compared with those of the tide gauge at the marine observation tower of the National Research Centre for Disaster Prevention, Science and Technology Agency. The results were good, and correction values for the readings have been obtained in this way.

5. CONDITIONS FOR INSTALLING THE GAUGE IN THE STRAIT OF SINGAPORE

The gauge was lowered about 20 metres onto the seabed on a 10 mm wire from the forward derrick of *R. I. Burudjulasad*, a survey vessel belonging to the Indonesian Naval Hydrographic Office. When the gauge reached the bottom a marker buoy was attached to it, as shown in figure 2, and a skin-diver closed the valve. The time required for the whole installation

operation was about 20 minutes. About an hour later a diver inspected the recording through a special eye-hole in the upper part of the recorder case and confirmed that the gauge had started normal operation. Taking advantage of the occasions when every two or three days divers had to change the recording paper of the automatic current meter attached to the surface marker buoy, the recording conditions of the gauge were inspected and time-checks were made. The diver effected the verification, making the recording stylus register by pressing the sensor with this thumb and confirming the time with his special watch.

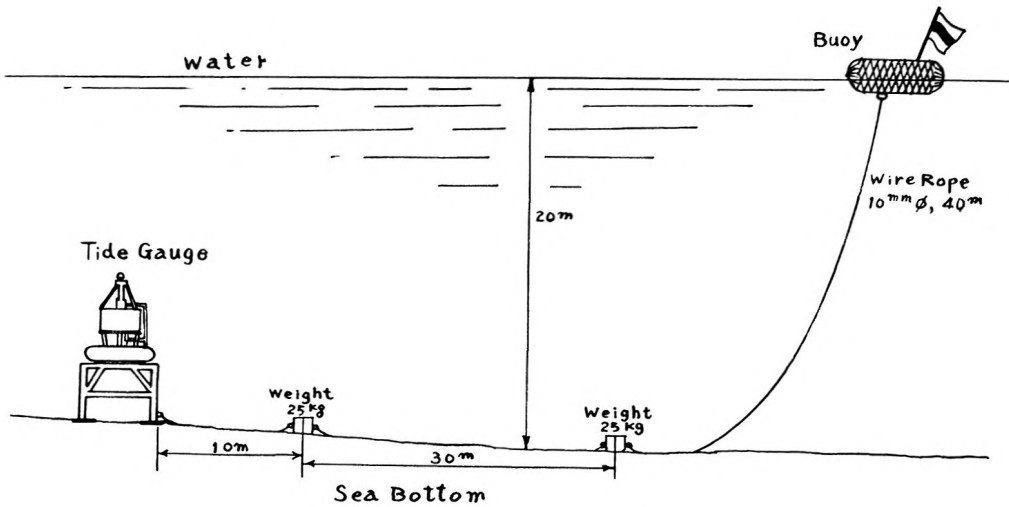


FIG. 2. — Tide gauge on the seabed, with its marker buoy.

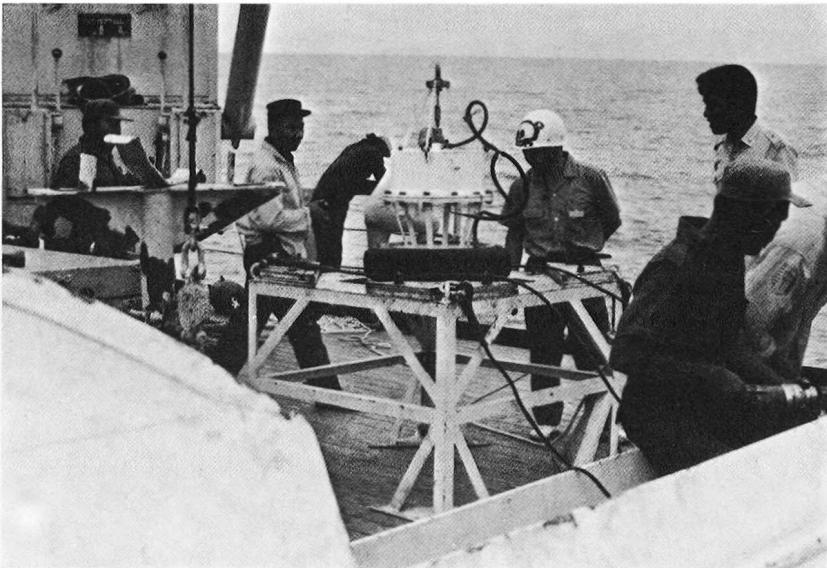


FIG. 3. — Adjustment of the recorder.

On the thirty-first day after it had been installed, a diving unit using a 3-ton boat recovered both recorder and sensor after detaching them from the base. The base itself was taken aboard the *R.I. Burudjulasad* at a later date. The composition of the bottom at the point where the gauge was installed was part mud part sand, and it was found that the base had become covered with a layer of mud about 15 centimetres thick during the 55 days it was in position.

The tidal corrections obtained were good enough for practical use. The error of the paper feed was about 10 minutes.



FIG. 4. — Handling the tide gauge aboard *R.I. Burudjulasad*.

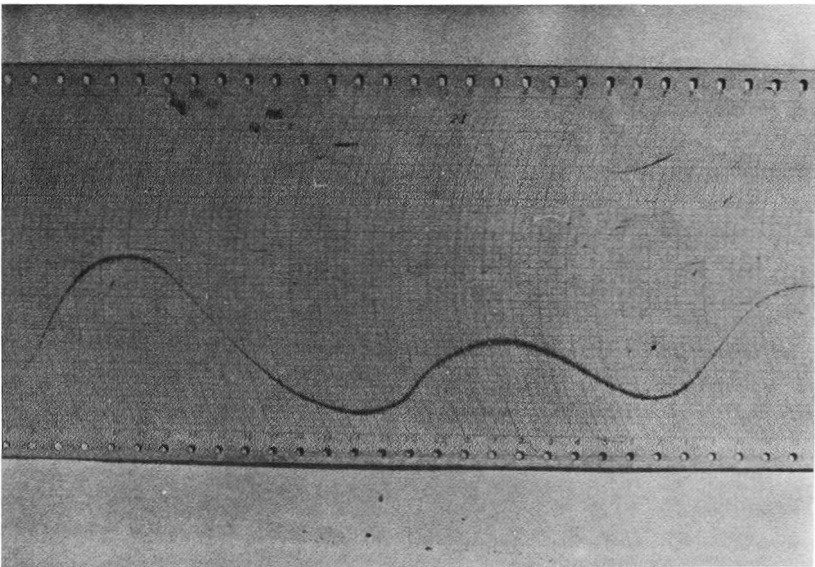


FIG. 5. — Tidal record.

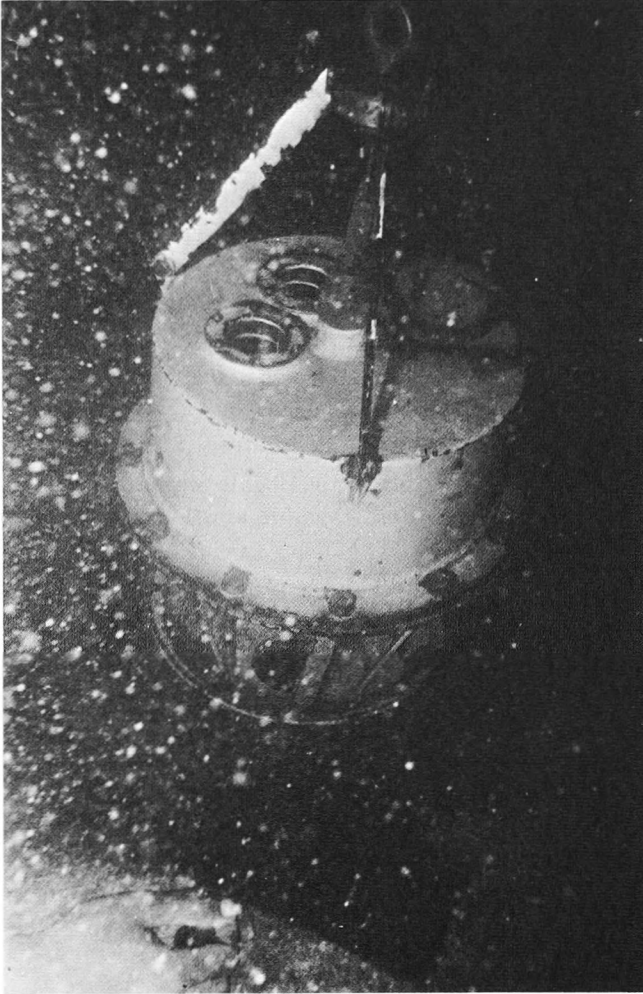


FIG. 6. — Tide gauge on the seabed.

6. IMPROVEMENTS REQUIRED

1. Incorporation of a time switch on the valve, to enable the valve to be opened and closed without recourse to the use of divers.
2. Incorporation of an automatic clock system using a clock capable of functioning accurately over long periods of time, a tuning fork clock for example.
3. The addition of interior lighting in order to facilitate inspection of the recording conditions.
4. A weight of about 100 kg for the instrument's base was originally decided upon, in order to take into account the possibility of being able

to use *R. I. Burudjulasad's* 2-ton derrick, and also the strength of the tidal currents in the Straits of Malacca and Singapore (about 3 knots). It ought, however, to be possible to reduce this weight according to the quality of the seabed, the tidal currents, and other environmental factors at the selected position, and as a result the gauge could be placed in position by hand from a launch two or three tons in weight.

In addition there are several other problems with the present type of offshore tide gauge. These should be discussed and solutions found for the future.

1. Each time the gauge is installed on the seabed there is a change in the observation datum level.
2. Comparative observations between the gauge and a tide pole are impracticable.
3. The help of a diving unit is required.
4. There is a risk of failing to re-locate and recover the gauge from the seabed if the marker buoy and its cable and anchor do not prove strong enough.
5. The gauge may sink out of view if the bottom sediments are too soft.