ON A METHOD OF OBSERVING TIDES IN THE OPEN SEA WHERE IT IS POSSIBLE TO ANCHOR

by

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As a method of observing the periodic rise and fall of the sea level or tides, direct reading of the height of sea levels by means of a scale on a plank or by means of a self-recording automatic tide gauge has hitherto been used. This method, however, is applicable only near shore, and there have been no means by which the object was successfully attained on the sea far from land. Our Navy in 1929 assigned H.J.M.S. *Yodo* to try such observation work in the Yellow Sea without getting satisfactory results.

In 1931, the *Yodo* was again instructed to carry out mid-sea tidal observations at three stations in the Yellow Sea, viz. off Chefoo, off Shantung Promontory, and in the middle part of the Yellow Sea; the method to be adopted was left entirely to the ship's discretion. Thus the *Yodo*, after repeated studies on the field in the Li Chan-Shan Islands (Elliot Group), an assigned surveying area for that year, evolved a method by the use of certain apparatus which, though primitive in principle, is easy and simple to handle and which gives good results. A brief description of the methods and experimental records are given in the following chapters.

I. — *BRIEF DESCRIPTION OF THE APPARATUS.*

1. CONSTRUCTION (Fig. 1).

a) A SIGSBEE sounding machine, with the sounding wire and sinker replaced by special ones, is used.

The sinker, of a weight corresponding to about 1/6 of the breaking strength of the suspending rope (in place of sounding wire of the sounding machine proper), is lowered almost to the bottom of the sea. By appropriate use of the SIGSBEE machine the sinker is kept about 1 to 2 metres from the bottom, and made to touch the bottom only at the moment of observation so as to keep the suspending wire vertical even when the ship swings at anchor.

b) Another wire rope (called the indicator rope), which passes through two leading sheaves fitted near the outboard end of a boom, is fixed to the sinker at one end and has a weight (index weight) on the other. The indicator wire is always kept taut. The index weight, which has a pointer for reading its position, is fitted in a graduated wooden frame so as to slide up and down along the length of the frame with the rise and fall of the sea level. The height of sea level is read on the scale by the position of the pointer of

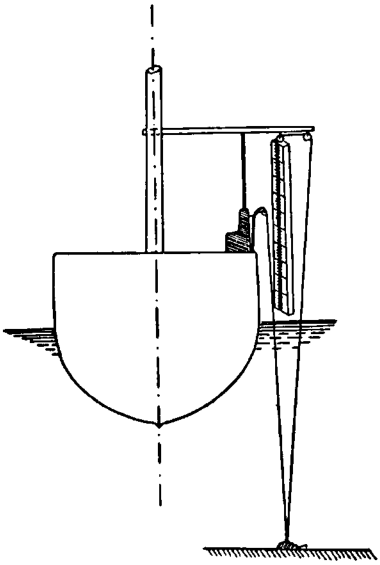

Fig. 1

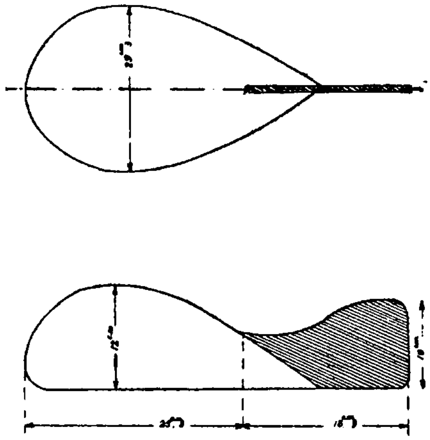

Fig. 2

the index weight. The observations are made at intervals of 10 minutes, except near the time of high and low water, when the interval is shortened to 5 minutes.

As can be seen from the above, the object of the observation is to find the difference in heights of sea levels measured, no to obtain the depth itself at a given time.

To make the observed value accurate, the following must be taken into account :

i) Correction for heeling of the ship.

ii) Correction for inclination of the indicator wire.

iii) Correction for change in ship's draught. (This may be neglected for observation for one day or two).

iv) Where the bottom of the sea is not even, correction for change in position caused by the ship's swing. This correction is almost impracticable. However, such a small area as lies within the swinging radius of a ship at anchor may be considered to have an even bottom, if the bottom deposits are mud or sand and mud.

2. Brief Description of the various Parts of the Apparatus.

a) *Suspending wire :*

A steel rope 2 $^{m}/_{m}$ (0.08 in.) in diameter, consisting of a strand of 7 wires, is used.

b) *Sinker :*

Experiments show that a fish-shape sinker, as shown in Fig. 2, is suitable, and has the following advantages :

i) Since the fish-shape sinker keeps head on in the current, the angle of inclination of the indicator rope is reduced.

ii) For the same reason the suspending wire and indicator ropes rarely get fouled.

The heavier the sinker the better it will be, the weight corresponding to about 1/6 of the breaking strength is preferable, taking into account the shocks received by the wire in a rough sea.

To keep the wire ropes clear it is necessary to attach them to the centre by means of a swivel; but it will not be effective unless it works very smoothly with friction balls.

c) *Index weight :*

Good results were obtained by the use of a lead of an electric sounding machine as the index weight. The lead is about 1 metre in length and 14.3 kgs (31 lbs) in weight. A square piece of timber was attached to the upper part of the lead so as to make it slide up and down easily in a graduated wooden frame.

d) *Indicator wire-rope :*

A steel rope consisting of a strand of seven wires, 1.3 m/m (0.05 in.) in diameter, is attached to the index weight.

e) *Index :*

A pointer is fixed on the wooden part of the index weight for reading the scale.

f) *Graduated frame :*

This is a long wooden rectangular frame of about 11 c/m (4.3 ins) inside width (graduated on one outer side which faces the ship) and has along the central line a narrow opening which acts as a guide, in which the index slides up and down. The top of the frame is fitted to the boom, through a hole letting indicator rope go into the frame.

g) *Sheaves :*

Two sheaves are fitted on the boom projecting over the water as leads for the indicator rope.

h) *Devices for determining corrections :*

A) *Clinometers for measuring Ship's Heel.*

a) A pendulum-clinometer which consists of a sector-plate of a radius of about 1.5 metres (5 ft) with the arc graduated up to 20 degrees on both sides of 0° and a pendulum pointer which is made sensitive by adding a lead weight toward the lower end.

b) A U-shape clinometer which consists of two glass tubes, with both ends open, erected one on each side of the ship, and a long rubber tube connecting the lower ends of the glass tubes. This is filled with an adequate quantity of fresh water, and the list of the ship is read on the scale graduated on the glass tubes in units of length.

B) *Clinometer for measuring the inclination of the indicator rope.*

A kind of pendulum-indicator consisting of a plate containing a sector, about 0.5 metres (20 ins) in radius, with an arc of 30 degrees, which is graduated from 0° at one end to 30° at the other, is fixed, point up, to the indicator rope so as to make the rope come nearly in line with (i.e. parallel to) the 0° line of the sector in a vertical plane perpendicular to the ship's side. A pendulum pointer suspended from the centre of the sector indicates the degree of inclination of the indicator rope. This is quite simple but fairly reliable.

II. — *OBSERVATION.*

(1) Every 10 minutes (5 minutes near high and low water times) the sinker is lowered and made to touch the sea bottom, when the following data are observed :

a) Reading of the index weight.

b) Heel of the ship (Pitching and change in draught within 24 hours or so may be neglected).

c) Inclination of index rope.

Remarks :

1. It is preferable to lower the sinker by working the machine by hand. Electric control should be limited to cases where the operators are skilled and the sea is calm.

2. The velocity at which the sinker is lowered should be uniform, to avoid plunging the sinker into the bottom in different ways which introduces errors in the observed values.

3. On calm days, when the rolling of the ship is negligible, the observation should be made at the moment the sinker touches bottom, but experience shows that when the ship rolls considerably, such moments being often not clearly known, other moments must be chosen. In any case, in any one series of observations a single method must be followed.

4. When reading the scale the observer's eye and the index must be on the same level.

5. Ten minutes is sufficient for the intervals between observations, but when the change in water level is very small, as for instance near high or low water, intervals of five minutes will be preferable.

6. The time of each observation must be recorded accurately. This will assist in accurate recording and lessen the chances of error by other recorders which are possible since the printed recording form is only divided into columns for every 10 minutes.

7. Observation near high and low water requires considerable skill. This must be taken into consideration in assigning the stations of the observers.

8. Corrections for heel of the ship and inclination of indicator rope must be made as accurately as possible. (It is assumed that the indicator rope is in a straight line and its length is equal to that of the suspending wire, which

is represented by the indicator of the sounding machine. The corrections are calculated from the data thus assumed and the angles measured).

9. Watches should be accurately set.

(2) Observed values are entered on the printed form. Curves are drawn to represent the results of observations. From the curve incorrect observations may also be detected.

NOTES.

1. The foregoing is a brief description of what is considered the best method at present.

2. This method of observation, if conducted by a skilled observing party, will be serviceable during weather conditions that obtain when the velocity of the wind is up to 15 m/sec. (50 ft/s), the height of waves up to 2 metres (6 ft), and the rolling of the ship up to 5° each way.

3. Since the change in draught of the ship is very small (6 m/m (0.25 in.) in 24 hours) the correction therefor was omitted.

III. — *EXPERIMENTS.*

All the foregoing is based on the following experiments :

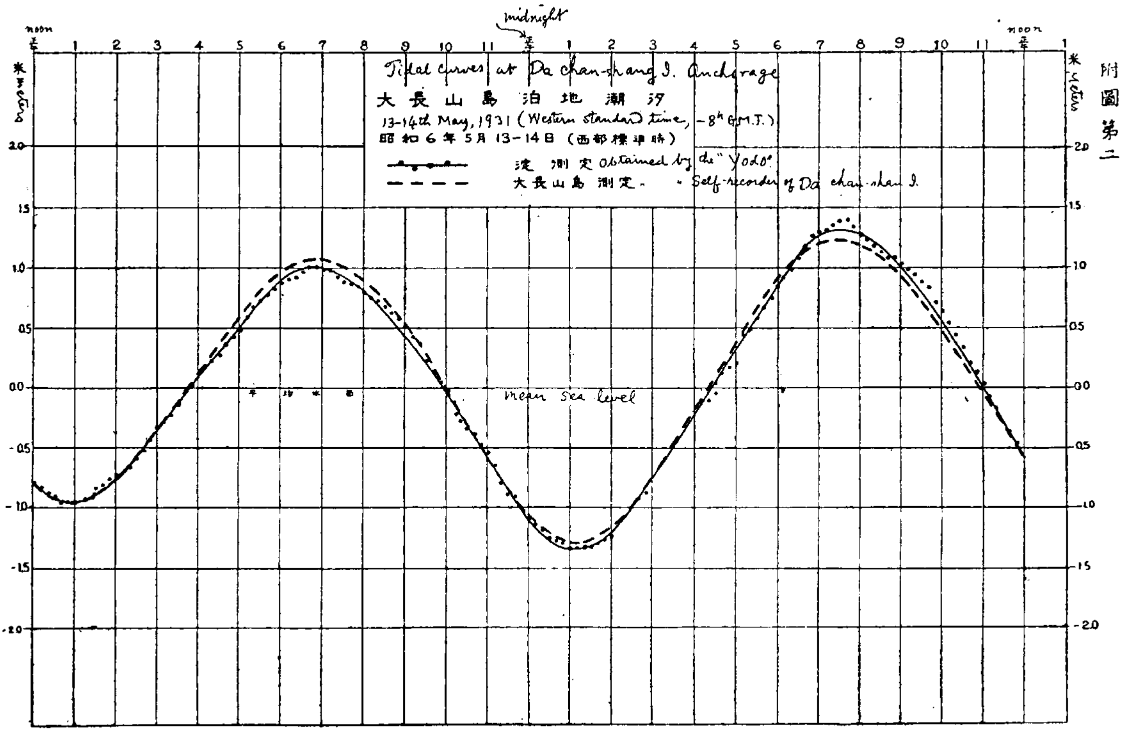

Fig. 3

1. THE FIRST EXPERIMENT.

a) Observations were made in order to test the first plan for 24 hours from noon on 13th May, 1931, at Da Chan-shan Island anchorage. The result obtained is shown in Fig. 3. The state of the weather, etc. were as follows:

Weather: cloudy to overcast sky; height of waves: 0 — 1; wind force: 0 — 1 (Beaufort).

Pitching of the ship: 0; rolling: 1° (at the maximum).

Depth of water: 10 metres (6 ½ fms). The ship rode at single anchor. Cable out: 5 shackles. Distance the ship swung at anchor: about 40 m.

b) *The results of the observations.*

From the values measured at intervals of 10 minutes a curve was drawn on a recording chart for the self-registering tide-gauge. The curve thus obtained was compared with that obtained by the self-registering tide-gauge at the tidal station on shore. The two curves coincided fairly well, and it was confirmed that the apparatus was reliable.

In this test the following corrections were omitted (Had these corrections been made, the two curves would have been more nearly identical): —

(*i*) Correction for heel of the ship (this correction for a list of 1° was 9.3 c/m (3.66 ins)).

(*ii*) The watch used in the test was not compared with that in use at the self-registering station. The difference in time between the two was some 3 minutes.

c) *Things learned and points to be improved.*

(1) Corrections for heel of the ship should be accurately made. Since the error for a list of only 1° amounted to 9.3 c/m (3.66 ins), a pendulum-clinometer with a sector of a long radius must be used. (The ordinary clinometers furnished to our Naval vessels are not sensitive enough). Without this correction, no matter how accurately the scale is read, the final results will prove worthless.

(2) When the ship does not roll at all or rolls very slightly, it is advisable to read the scale at the moment the sinker touches the bottom.

(3) A graduated plank, instead of the graduated frame, was used, but it made the reading difficult on account of the swinging of the index weight when the ship rolled.

(4) When reading the scale, the eye must lie on the same level as the index, otherwise an error of 5 c/m (2 ins) at the maximum may be introduced.

(5) Observations near high and low water, where change in sea level is very slight, must be made with special care, and it is better to shorten the intervals to 5 minutes.

(6) It is advisable to draw a curve, from the data, without delay in order to study the tendency of the curve and detect any errors.

(7) Each party should consist of three men, and skilled parties should be assigned for the observations near high and low water.

2. THE SECOND EXPERIMENT.

a) Taking into account the lessons learned from the first experiment the second one was carried out for 24 hours from noon, 17th May, 1931, at Da Chan-shan I. anchorage, while training for offshore current survey.

Weather: blue sky to partly cloudy.

Wind force: 1 — 2 (Beaufort).

Age of the moon: 29.1.

Pitching: 0; rolling: $1^{\circ}.5$ (at the maximum).

Depth of water: 10 m.

The ship was moored with 2 anchors forward and a kedge aft.

Cables out: starboard bower, 2 shackles, port bower, 3 shackles.

Thus swinging distance was restricted to a maximum of about 40 metres.

b) *The result of the experiment.*

As can be seen in Fig. 4, the curve obtained from the data, which were corrected for heel of the ship, almost coincides with that of the self-register. From this result it may be assumed that, by the use of this apparatus, good results can be expected in fairly rough open sea if the work were performed by skilled observers.

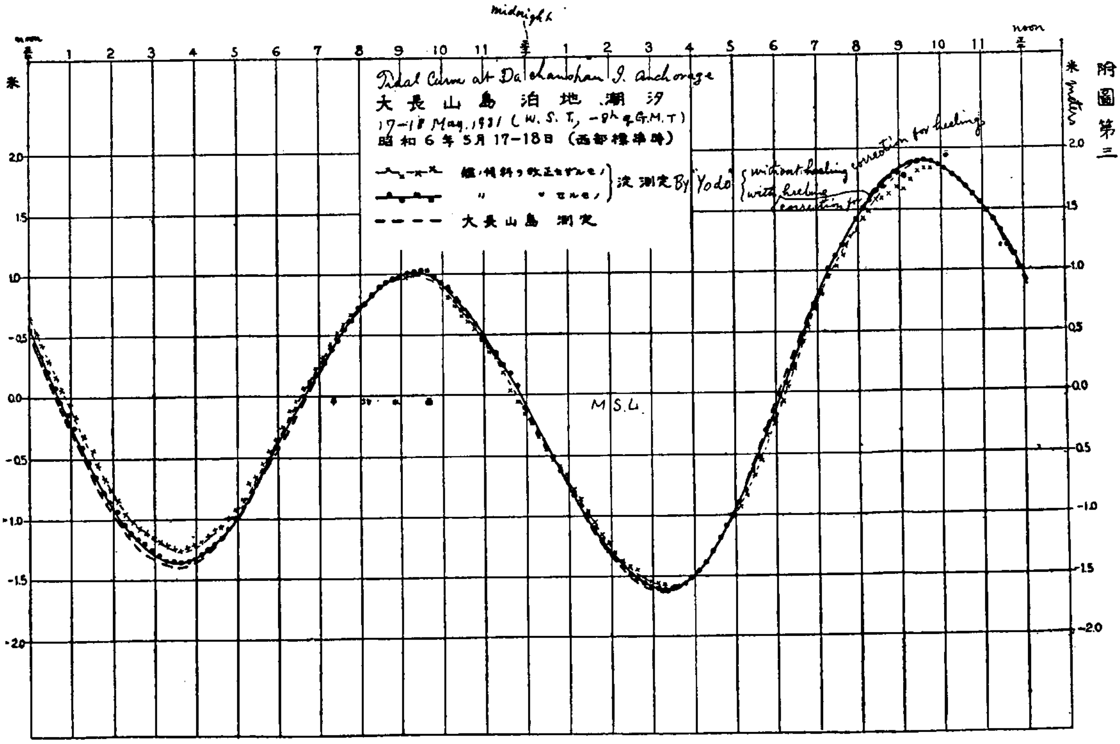

Fig. 4

c) *Things learned.*

(1) The efficiency of the graduated frame was good and it furnished better results than in the preceding experiment. As an ideal plan, however,

the graduated frame should be made of metal, consisting of a number of equal parts, each being 2 metres (6 ½ ft) in length and 10 centimetres (4 ins) in width; and so constructed that an adequate number of such parts can be joined together according to the range of tides. However, this was beyond the capacity of the *Yodo's* machine-shop.

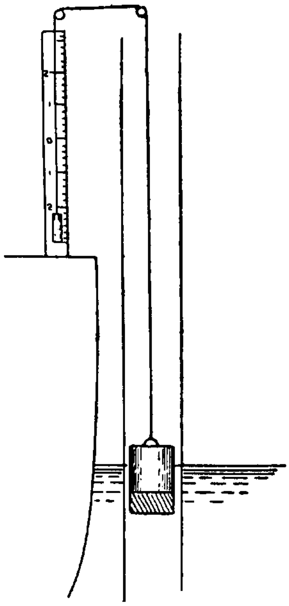

Fig. 5

(2) For the measurement of the correction for heel of the ship the use of a device such as is shown in Fig. 5 may be more effective than ordinary types of clinometer, though the latter may be used supplementarily. If the scale (Fig. 5) be graduated in units of length and 0° represents the position of the index when the ship is on an even keel, the readings will be such that they can be directly added to or subtracted from the observed height of the sea level.

(3) Mooring with anchors forward and aft may cause the ship to list when the current flows in an athwartship direction, thus making the work difficult. If a currentmeter is in use at the same time it may be carried along the keel or swept away.

3. THE THIRD EXPERIMENT (For 24 hours from noon on 2nd June, 1931).

a) Good results having been obtained in the preceding two preparatory experiments at Da Chan-shan anchorage, the third experiment was made as a first step to mid-sea tidal observation at station D (Fig. 6) (Lat. 39°-5' N., Long. 122°-30' E.), well to the south off Kasu-yan Tao, while carrying out a current survey there. The general conditions were as follows:

The depth of water: 38 metres (124 3/4 ft.). The ship rode at single anchor; cable out: 3 shackles. The observations were started at noon on 2nd June, 1931, when the weather was clear and the state of sea 2 (DOUGLAS Scale). The barometer gradually went down, the number of clouds increased adding nimbus to stratus, the wind became stronger and the sea rougher until 5 p.m. when the wind velocity was 12 m/sec. (39 ft/s) and the state of the sea 4. From about 8 p.m. the velocity of the wind increased to 14 m/sec. (46 ft/s.) and the height of waves reached 2 metres (6 ½ ft) causing the ship to roll about 5° and pitch about 1°,5.

In addition, a long swell set in and it began to thunder. At 10 p.m., for fear of dragging the anchor, the cable was veered 6 shackles. After about 10 h. 30 m. p.m., when it began to rain, the wind gradually lessened to a velocity of 7 to 8 m/sec. (23 to 26 ft/s.), but the rolling of the ship remained as before, on account of the swell. At about 5 a.m. next day the wind died down to 1 m/sec. (3 ft/s.). At 8 h. 25 a.m. as the weather cleared the cable was hove in again to 3 shackles.

After about 8 p.m. on the first day, the observations became difficult as the rolling increased. The ropes fouled and the inclination of the indicator rope was measured as much as 9°.

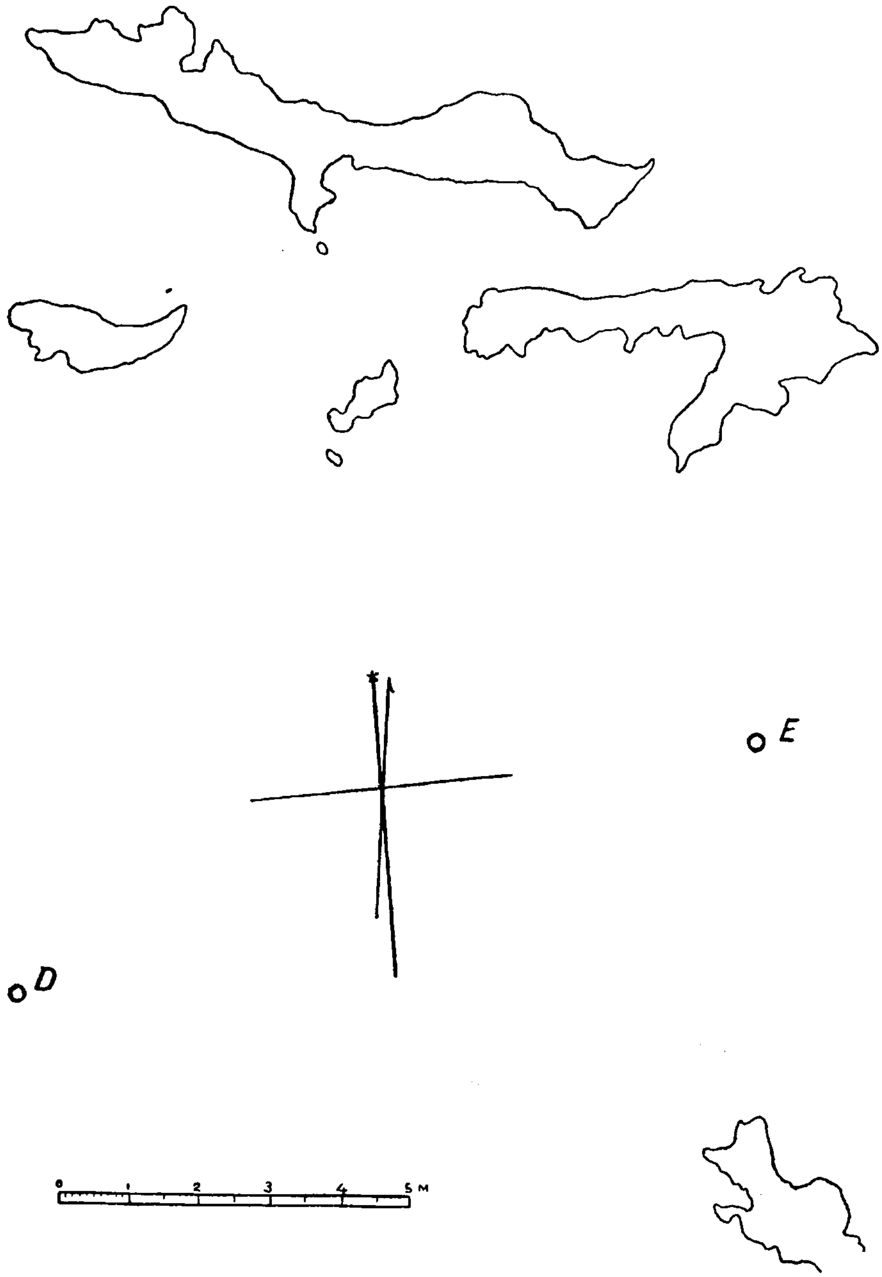

Fig. 6

Observations near the time of high water in the afternoon of the first day and near the time of low water on the next morning were almost impossible. We were compelled to draw these parts of the curve by assumption, basing them on the trend of the other parts of the curve. It was fortunate, however, in that a maximum limit at which the use of this apparatus is possible was found.

The range of tide at the station seems a little smaller than that at Da Chan-shan I., as shown on Fig. 7, judging by the observed data at every station in the region.

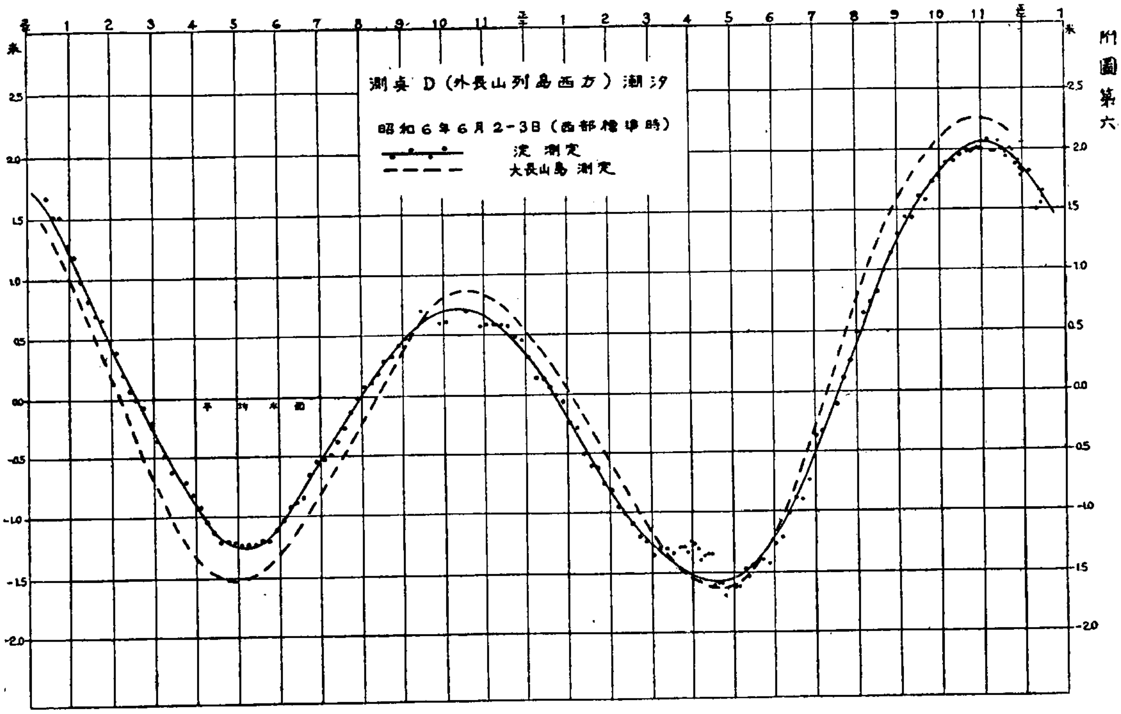

Fig. 7

b) *Things learned.*

(1) Modification in shape of the sinker was found to be necessary. The sinker used this time was not suitable, as it was one that had, at its base, a cross of iron bars which was attached to prevent it sinking into the bottom. This caused the sinker to make kite-like movements, and the wire to be twisted and have large inclinations. The sinker must be so shaped as to keep head on to the current with a minimum resistance. Fig. 2 shows an example of such sinker.

(2) The device for measuring the ship's heel, which was hit upon from the preceding experiment, was found to be suitable only for observations when the sea is very calm; in other cases it is of no practical value.

(3) For measuring the heel of the ship the use of a U pipe as described earlier is preferable. A range in the height of the water of 7.33 centimetres (2.886 ins) accounting for a heeling angle of 1 degree (in the case of the *Yodo*), far more accurate and direct corrections are obtainable than by ordinary types of clinometer.

(4) Where the ship rolls appreciably the suspending wire rope is subjected to jerks, and it is advisable to fix the weight of the sinker at 1/6 of the breaking strength of the rope. In the *Yodo* the breaking strength of the rope, 2 m/m (0.79 in.) in diameter, of a strand of seven steel wires was calculated as 200 kgs (440 lbs), hence the weight of the sinker was fixed at 33 kgs (73 lbs).

(5) When the ship rolls the observation requires high technique, especially near the apices of the tidal curve. This must be borne in mind when allotting parties.

(6) If the height of the waves is more than 2 metres (6 ½ ft), the use of the present appliances is not practicable, since it results in inaccurate observations.

(7) When the ship is rolling and pitching, it is better to read the scale shortly after the touch of the sinker on the bottom, rather than to read at the moment of such touches. Moreover, even when the ship rolls, there occur periodical instances when the ship is upright for a moment, offering chances for observation of which advantage should be taken.

c) The results of the observations in this experiment are shown in Fig. 7. The curve is drawn partly by assumption as mentioned above.

4. The Fourth Experiment.

a) The fourth experiment was made for 24 hours from 6 p.m., 16th June, 1931, at station E (Fig. 6) (Lat. 39°-8' N., Long 122°-43' E.) in Outer Chan-shan Passage.

Weather : blue sky.

State of the sea : calm and smooth (1 — 2) with no swell.

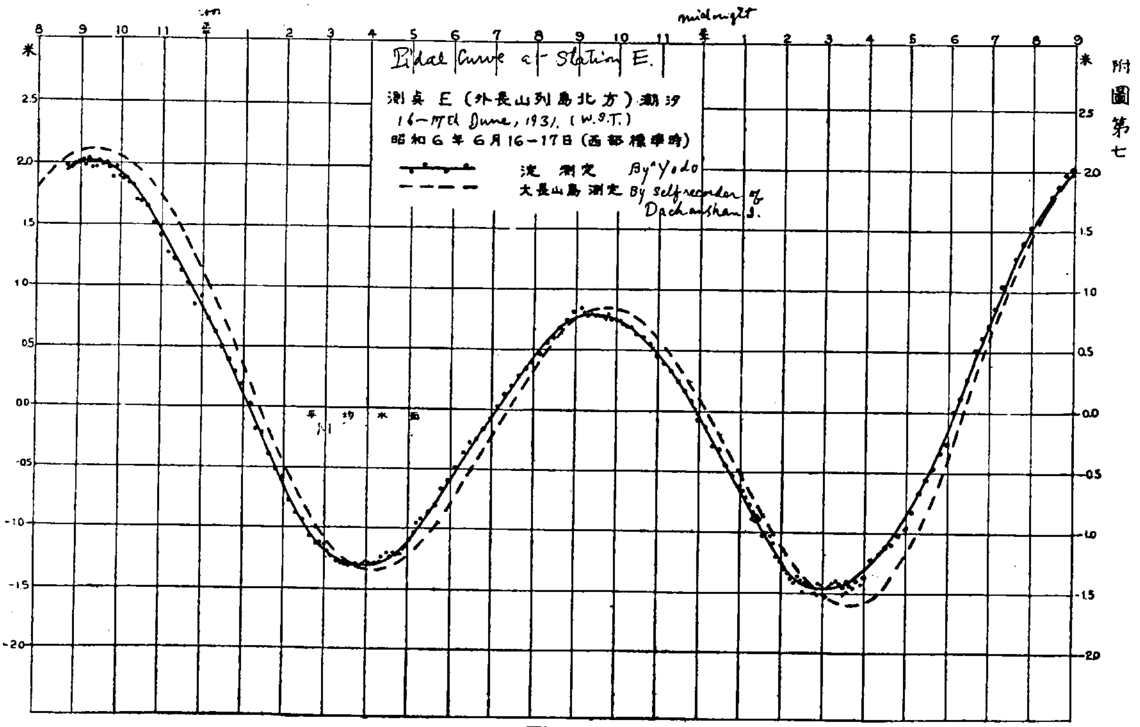

Fig. 8

Wind velocity : 0 to 3 m/sec. (0 to 10 ft/s.).

Pitching : 0 ; rolling : 1°.5 at the maximum.

Depth of water : 37 m. (121 ½ ft).

Ship rode at single anchor, cable 3 shackles.

b) *Things learned.*

(1) For the suspending rope a rope (about 2.5 m/m (0.1 in.) in diameter) consisting of a strand of 12 steel wires was used with successful results.

(2) A fish-shape sinker of 38 kg. (84 lbs) in weight gave good results, In deeper water, however, a sinker of about 50 kg. (110 lbs) would be better.

(3) The U pipe gave very good results. However, as fresh water decreases in quantity by evaporation, it is better to fill the pipe with some other suitable liquid. The device may be used effectively in such cases where the velocity of wind is less then 15 m/sec. (50 ft/s.), the height of the waves less than 2 metres, and the rolling of the ship less than 5°.

(4) Fig. 8 shows the result which is represented by a fairly complete curve.

IV. — *CONCLUSION.*

As stated above, the curves derived from the data obtained by means of this apparatus coincided fairly well with those obtained by the self-registering tide gauges.

Since in such a small area as lies within the swinging radius of a ship at anchor the bottom of the sea may be assumed to be even, the present apparatus, if constructed by mechanical experts so as to afford easy handling and accurate operation, can be used to make tidal observations in the open sea and thus marks a step towards making such observations under all possible conditions.