CONTRIBUTION TO THE HISTORY OF THE HIGH SEA TIDE RECORDER

by

Dr. H. RAUSCHELBACH, OF THE DEUTSCHE SEEWARTE, HAMBURG.

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For recording variations of the sea level on the coast caused both by the attractive forces of the moon and the sun on the liquid masses on the earth. and by the atmospheric pressure and the wind on the surface of the sea, very varied types of tide-gauges have been independently devised during the last 80 or 90 years in Germany, Great Britain, France, the Netherlands and the United States of America.

The registration of tides being of considerable importance, not only to science, but also to harbour and coastal works, to coastal hydrography and, above all, to navigation, as it must be the basis for tidal predictions, instruments for this purpose have been installed in gradually increasing numbers, at many points along the coast and in those parts of rivers where the tide is felt.

The installation of a tide-gauge generally entails considerable expense, which does not appear justifiable unless the apparatus is likely to operate during a sufficiently long period at the same place. The use of such tide-recorders is naturally very limited on account of the fact that they are fixtures. It is only when situated on the coast or on constructions jutting out to seaward that these fixed tide-gauges can record the height of the water.

For recording the variations in sea level, such as those occurring at greater distances from the coast and in the open sea, separate efforts have been made since about 1880 in Germany and France, and during the last ten years in Holland and Russia, to construct a practical tide-gauge lying on the sea bottom. If these efforts have been partially unsuccessful for an extended period, it is probably owing principally to the fact that the technique is not as yet sufficiently advanced to solve the difficult problems presented. As an example, an idea of the difficulty of the problem may be gathered from the fact that, up to now, tidal records from the high seas are very rarely mentioned in bibliographies.

Free tide-gauges are submerged from a vessel and moored on the bottom of the sea at suitable points; therefore, they do not register the height of the water directly (as do most fixed tide-gauges), but the pressure to which the instrument, lying on the bottom, is subjected, thus constituting a kind of automatic tide-recorder enclosed in a watertight case, of which the interior or the exterior communicates directly with the water.

Although such tide-gauges can be placed almost anywhere where fixed tide-gauges already exist, they are in no way intended to replace them; their principal function is rather to obtain observations at such places where, for some reason or other, fixed tide-gauges cannot be set up, and to complete the observations obtained by these on the coast, by providing observations near the coast, some distance offshore or in the open sea.

The first instrument which could be moved on the bottom of the sea — which, however, did not give satisfactory results — was constructed in 1879 by BESSON (1) for the Hydrographic Service of the French Navy.

In Germany, C. BÖRGEN, Director of the former Imperial Observatory at Wilhelmshaven, according to unpublished papers found after his death, had been perseveringly engaged since 1880 in the construction of an instrument for recording tides in the open sea, a "tide recording manometer". During thirteen years he had made a whole series of investigations and tests with an instrument to be lowered to and moored at a definite depth below mean sea level. The first instrument which was really able to give records, though yet not quite satisfactory ones, was the FAVÉ "marégraphe plongeur" (2) constructed by DÉMICHEL in 1887 for the French Navy. The organ for measuring pressure was originally composed of elastic boxes similar to aneroid boxes; later, they were replaced by BOURDON tubes. It was not until 1908, when J. RICHARD, of Paris, had

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(1) L. FAVÉ, *Marégraphe plongeur. Appareil enregistrant les marées sur les côtes et au large.* Annales Hydrographiques, 2e *série, Tome* 30, *Paris*, 1910, p. 383 (*Foot Note*)

(2) L. FAVÉ, *loc. cit.*, p. 413.

improved the FAVÉ tide-gauge (1), that the Hydrographic Service of the French Navy used it on various occasions for coastal surveys and in the colonies. The serious disadvantage of the FAVÉ tide-gauge was the extremely small scale of the record. For a range of tide of one metre the free ends of the BOURDON tubes only moved 0.6 $\frac{m}{m}$ with reference to each other. These movements were inscribed by means of two pins which pressed against a slowly rotating smoked glass plate, and the record had to be carefully measured afterwards with a micrometer.

That none of BÖRGEN'S schemes were ever carried out must be attributed to the fact that Captain A. MENSING (Retd.) developed a type of "pneumatic tide-gauge" in 1893 which was approved by the Nautische Abteilung of the Reichs-Marine-Amt; the Wilhelmshaven Observatory, of which Captain MENSING was the Director, was directed to test the instrument.

In its primitive form the instrument was a mercurial pressure gauge intended for use in a boat; it was connected by an air-pipe to an air-bell on the bottom to which the sea-water had access.

As a result of unsuccessful tests at Wilhelmshaven and of further suggestions from BÖRGEN, MENSING subsequently constructed a submarine tide-recorder to which he was the first to give the name of "high sea tide-recorder". This instrument was tested in the Jade in 1897, by a committee appointed by the Reichs-Marine-Amt. After various alterations suggested by this committee had been made, the pressure-gauge, since 1899, consisted of three BOURDON tubes, the movements of which were transmitted to an inscribing stylus (2).

As the loyal friend of MENSING, BÖRGEN had carried out experiments for fifteen years, at the expense of the Reichs-Marine-Amt, in the hope of final triumph by means of the new device invented by MENSING, after each unsuccessful test of the gauge, to eliminate existing causes of failure or such as might arise. But, after the introduction of each additional device, the construction of the high sea tide-recorder became more and more complicated.

After obtaining the necessary funds, the Reichs-Marine-Amt received a new and improved model of the MENSING tide-recorder in 1907. Although isolated tests in the Jade gave utilisable results, the device was too delicate for use at sea.

BÖRGEN'S successor, Commander CAPELLE (Retd.), who later on became President of the Deutsche Seewarte, gave up testing the MENSING tide-recorder in 1913. In collaboration with Torpedo-Oberstabsingenieur KREPLIN, he invented a far simpler high sea tide recorder which was constructed by the Imperial Dockyard at Wilhelmshaven. The CAPELLE-KREPLIN high sea tide-recorder incorporated an idea of BÖRGEN, conceived in 1890. This was to use, as the pressure-gauge, a rubber membrane or a rubber funnel together with a spring-balance. But this tide-recorder, although relatively easy to lay out, did not fulfil requirements, as the friction of the stylus on the paper was too great.

The same idea is found as the basis of the DE VRIES free tide-gauge (3); in an improved form, it constitutes the Photographically registering Water-level Recorder of the firm of H. M. SMITT of Bilthoven. This tide-recorder, which can only be used in shallow water, and which in consequence can hardly be classed as a high-sea tide-gauge, also has a rubber membrane or a rubber plate; by means of two spiral springs, the membrane or plate tends to counteract the pressure of the water. The movements of the membrane or plate, due to variations of water pressure, are transmitted to a wheel the translucent periphery of which is graduated; every half-hour a part of this and an index are photographically recorded.

From 1916, in his private capacity, and from 1920, as President of the Naval Observatory at Wilhelmshaven, K. HESSEN undertook tests with the KUHLMANN tide-recorder(4) at the instance of the Marineleitung.

This high sea tide-gauge was constructed by the firm of Franz KUHLMANN, of Rüstringen-Wilhelmshaven. This firm, when preparing the MENSING tide-gauge, had become

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(1) L. FAVÉ, *loc. cit.*, pp. 383-415. L. FAVÉ, *Marégraphe plongeur. Appareil enregistrant les marées sur les côtes et au large.* Annales Hydrographiques, 3e *série, Tome* 4, *Paris* 1921, pp. 193-237.

(2) A. MENSING. *Der Hochseepegel. Zeitschrift für Instrumentenkunde. Jahrgang* 23, *Berlin* 1903, pp. 334-342.

(3) J. J. DE VRIES. *Verplaatsbare zelfregistreerende peilchaal. Marineblad,* 32e *Jaargang, Helder* 1918, pp. 380-386.

(4) *The* KULHMANN *Submarine or High-sea Tide-gauge.* Hydrographic Review, *Vol. IV* N° 2, *Monaco,* pp. 169-177.

familiar with questions relating to the construction of high-sea tide-gauges ever since 1909.

In order to avoid the friction of the stylus on the paper, this instrument also registers the difference of pressure phographically by means of a small rotating mirror moved by a set of six BOURDON tubes. Although half a dozen such instruments have passed through the hands of the Marineleitung, except for several tests made at Wilhelmshaven and Heligoland, I do not know whether they have given any long-period tidal-curves.

MENSING himself, in spite of his advanced age, recommenced after the war to make tests and plans for a new instrument, which he caused to be constructed at the expense of the Marineleitung by SCHAFFER & BUDENBERG of Magdeburg-Buckau. As a result of personal researches, on this occasion he used in his recording pressure-gauge two strong spiral BOURDON tubes mounted in parallel, the arc of which covered 450°.

As this tide-gauge, the construction of which was scarcely less complicated than that of previous ones, did not work satisfactorily, A. WERNER (1), after the death of MENSING which took place in 1929, essayed for the Nautische Abteilung of the Marineleitung to bring MENSING'S work to fruition by constructing a new high sea tide-gauge embodying the ideas and the essential parts or MENSING'S device. Trials with this instrument are not yet concluded.

Several years ago SHOULEJKIN (2), in Moscow, succeeded in constructing a relatively small instrument, by using a slightly modified RICHARD pocket barograph. Nothing is known as yet regarding the results of the tests of this instrument.

As metal manometers, whatever their construction may be, cannot record the total hydrostatic pressure at great depths with sufficient accuracy, high sea tide-gauges are provided with special devices for measuring not the absolute pressure but the differences of pressure engendered by the tide. Pressure equilibrium in the CAPELLE-KREPLIN high sea tide-gauge was obtained by applying a tension to a spiral spring corresponding to the depth of water, before laying the instrument out, whereas, in the older tide-gauges of MENSING and KUHLMANN, it was necessary to fill tanks with air before submersion, either by means of a pump or by admitting compressed air, until the interior pressure corresponded approximately to the pressure on the sea bottom. In order not to overload the BOURDON tubes or risk damaging them by bad handling or valve failure, in the FAVÉ and SHOULEJKIN high sea tide-gauges the filling of the tanks with compressed air was done automatically by the gradual compression of the air contained in an appropriately constructed antichamber, as the hydrostatic pressure increased during submersion. In the MENSING-WERNER high sea tide-gauge, the air tank is gradually filled during submersion by connecting several compressed air bottles to the tank and providing it with the necessary pressure compensation valves.

As metallic membrane and BOURDON tube manometers are very sensitive to jarring and, also, as they are not free of elastic reaction, which reaction is greater the lower the temperature, in 1928 I tried using an air-gauge as a pressure recording device. The first instrument (which was constructed by the ASKANIA-WERKE A. G. of Berlin-Friedenau, using the tank of the CAPELLE-KREPLIN tide-gauge, lent by the Marineleitung as a test apparatus) worked satisfactorily from the very first time it was laid out in the Outer Ems, and thus we can without apprehension work on the final model. This new instrument has already produced several tidal-curves at points off Norderney and in the southern Kattegat.

(1) A. WERNER. *Ein neuer Hochseepegel. Marine-Rundschau. Jahrgang* 34. *Berlin* 1929, pp. 509-516.

(2) W W. SHOULEJKIN. *A Maregraph for the open sea.* Journal du Conseil, *Vol. IV, Copenhague* 1929, pp. 194-199.