entrance of the Bristol Channel the range of spring tides is about 18 ft., and at Chepstow about 50 ft. This augmentation of the height of the tide-wave is due to the concen­tration of the energy of motion of a large mass of water into a narrow space. At oceanic ports the tidal phenomena are much less marked, the range of tide being usually only 2 or 3 ft., and the interval from high to low-water sensibly equal to that from low to high-water. The changes from spring to neap tide and the relation of the time of high-water to the moon's transit are, however, the same both on the open coast and in rivers.

In long and narrow seas, such as the English Channel, the tide in mid-channel follows the same law as at a station near the mouth of a river, rising and falling in equal times; the current runs in the direction analogous to up stream for three hours before and after high-water, and down stream for the same period before and after low-water. But near the sides of channels and near the mouths of bays the changes of the currents are very complex; and near the headlands separating two bays there is usually at certain times a very swift current, termed a “ race.”

In inland seas, such as the Mediterranean, the tides are nearly insensible except at the ends of long inlets. Thus at Malta the tides are not noticed by the ordinary observer, whilst at Venice they are conspicuous.

The effect of a strong wind on the height of tide is generally supposed to be strongly marked, especially in estuaries. In the case of an exceptional gale, when the wind veered round appropriately, Airy states@@1 that the water has been known to depart from its predicted height at London by as much as 5 ft. The effect of wind will certainly be different at each port. The discrepancy of opinion on this subject appears to be great—so much so that we hear of some observers concluding that the effect of the wind is insensible. Variations in barometric pressure also cause departures from the predicted height of water, high barometer corresponding to decrease of height of water. Roughly speaking, an inch of the mercury column will corre­spond to about a foot of water, but the effect seems to vary much at different ports.@@2

Mariners and hydrographers make use of certain technical terms which we shall now define and explain.

The "establishment of the port,” already referred to above, is the average interval which elapses between the moon’s transit across the meridian, at full moon and at change of moon, and the occurrence of high-water. Since at these times the moon crosses the meridian at twelve o’clock either of day or night, the “ establishment ” is the hour of the clock of high-water at full and change.

It has already been remarked that spring tide occurs at most places a day or a day and a half after full and change of m∞n. Now it is more important in the theory of the tides to know what occurs at spring tide than what occurs at full and change of moon. Thus the term ” the corrected establishment of the port ” is used to denote the interval in hours elapsing at spring tide between moon’s transit and high-water. The difference between the ordinary and the corrected establishments is of small amount. At any other state of the moon, except full and change, the “ interval ” or “ lunitidal interval ” means the interval between the moon’s upper or lower transit and high-water.

The average interval elapsing between full or change of moon and spring tide is called the "age of the tide ” ; as already remarked this interval is commonly about a day or a day and a half, but it may be twice as great in some places. The use of this term arises from the idea that spring tides are generated at some undefined place exactly at full or change of moon, and take an interval of time denoted the “ age ” to reach the place of observation. The term is not altogether satisfactory, since it implies a theory, but it must be referred to as in general use.

The average height at spring tide between high and low-water marks is called “ the spring rise the similar height at neap tides is, however, called "the neap range.” "Neap rise ” is used to mean the average height between high-water of neap tides and low-water of spring tides.. Thus both at springs and neaps the term “ rise ” refers to the rise above the level of low-water at spring tide. French hydrographers call half the spring rise "the unit of height.”

The “ diurnal inequality ” of the tide denotes the fact that successive high-waters and successive low-waters are unequal to one another. In England the diurnal inequality scarcely exists.

The practice of the British admiralty is to refer their soundings and tide tables to ” mean low-water mark of ordinary spring tides.” This datum is found by taking the mean of all the available observa­tions of spring tides, excluding, however, from the mean any spring tides which may be considered abnormal. The admiralty datum is not, then, susceptible of exact scientific definition; but when it has once been fixed with reference to a bench-mark ashore it is expedient to adhere to it, by whatever process it was first fixed.@@3

When new tidal stations are established in India the datum of reference has, since about 1885, been "Indian low-water mark,” which is defined as being below mean sea-level by the sum of the semi-ranges of the tides M2, S2, K1, O (see §§ 24, 25 on Harmonic Analysis below).

In ordinary parlance sailors very commonly use the term "tide ” when they mean what may be more accurately described as a tidal current.

§ 3. *Tidal Observation: the Tide-gauge.*—Tidal prediction is only possible when accurate observations have been made of the phenomena to be predicted; and the like is true of verification after prediction. It was formerly thought sufficient to note the heights of the water at high and low-water, together with the times of those events, and the larger part of the observations which exist are still of this character, but complete investigation of the law of tidal oscillations demands that the height of the water should be measured at other times than at high and low-water.

With whatever degree of thoroughness it is proposed to observe the tides the procedure is much the same. The simplest sort of observation is to note the height of the water on a graduated staff fixed in the sea, with such allowance as may be possible for wave motion. It is, however, far preferable to sink a tube into the sea into which the water penetrates through small holes; and the wave motion is thus annulled. In the calm water inside the tube there lies a float, to which is attached a cord passing over a pulley and counterpoised at the end. The motion of the counterpoise against a scale is observed. In either case the observations may be made every hour, or the times and heights of high and low-water may be noted.

In more careful observations than those referred to above the tidal record is automatic and continuous and is derived by means of an instrument called a tide-gauge.

This gauge should be placed in a place where we may obtain a fair representation of the oscillation of the surrounding sea. In such a site a well or tank is built on the shore communi­cating by a channel with the sea at about 10 ft. below lowest low-water mark. In some cases an artificially constructed well may be dispensed with, where some lagoon or pool exists so near to the sea as to permit junction with the sea by means of a channel below low-water mark. At any rate we suppose that water is provided rising and falling with the tide, without much wave-motion. A cylindrical float, usually a hollow metallic box or a block of. greenheart wood, hangs and floats in the well, and is of such density as just to sink without .support. The float hangs under very light tension by a platinum wire, or by a metallic ribbon, or by a chain. The suspension wire is wrapped round a wheel, and imparts to it rotation proportional to the rise and fall of tide. By a simple gearing this wheel drives another, by which the range is reduced to any convenient extent. A fine wire wound on the final wheel of the train drags a pencil or pen up and down or to and fro proportionately to the tidal oscillations. The pencil is lightly pressed against a drum, which is driven by clockwork so as to make one revolution per day. The pen leaves its trace or tide-curve on paper wrapped round the drum. The paper is. fixed to the drum with the edges of the paper at the XII o’clock line, and the record of a fortnight may be taken without change of paper. An example of a tide-curve for Apollo Bunder, Bombay, from the 1st to the 15th of January 1884, is shown in fig. I.

The curves are to be read from right to left, and when we reach the left-hand edge of the paper, we re-enter again at the same height on the right-hand edge. The numbers on the successive curves denote the days of the month.

We have chosen an example from a sub-tropical region because it illustrates the remarkable regularity of the tides in a region where the weather is equable. Further, if the reader will note the succes­sive high-waters or low-waters which follow one another on any one day, he will see a strongly marked "diurnal inequality,” which would have been barely perceptible in a European tide-curve.

@@@1 Airy, ” Tides and Waves.”

@@@2 Ibid. §§ 572-573.

@@@3 See J. N. Shoolbred on datum levels, *Brit. Assoc. Reports* (1879).