CO-ORDINATION OF CHART DATUMS

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I. — Definition of Chart Datum.

Chart datum is the level to which depths shown on the chart are referred and which should be used as the zero of the tidal predictions, or other tidal information, for the place. Were each place separately considered, the level of chart datum in relation to tide levels would not be of great importance, provided it were known locally, but as ports are used by strangers and vessels may visit many in the course of a single voyage, the level becomes of more than local importance and lack of co-ordination must necessarily cause difficulties, and may even be dangerous to navigation.

II. — Co-ordination defined.

Datums of different places cannot be at the same level, relatively to mean sea level, owing to differences in the range and type of the tide ; they can however be co-ordinated, that is to say, at all places having the same type of tide, the astronomical conditions which cause a fall to, or below, datum at one place should cause a corresponding fall to, or below, datum at all other places ; the fall to, or below, datum will not necessarily occur on the same day at all places owing to differences in the so-called " Age " of the tide. When the type of tide changes the problem becomes more complicated, for the same astronomical conditions then have different effects, and what is required is that the vertical distance between mean sea level and the average lowest low water as ascertained from observations covering a long period of time shall bear the same relation to the vertical distance between mean sea level and datum at all places ; as there are few, if any, places on the earth's surface at which the type or tide is really identical, it is this latter requirement which should govern the level of chart datum everywhere.

III. — Effects of lack of Co-ordination.

Lack of co-ordination may be either intentional, accidental, or due to the use of a faulty datum. Intentional differences, which are avoidable, occur when different datums are deliberately adopted, as for instance " lowest possible low water " and " mean low water "; accidental differences are unavoidable and are generally due to the insufficiency of the observations from which the datums have been computed ; differences due to the use of a faulty datum are considered at VI, VII and VIII below. The intentional differences may be large and important, the accidental are usually small but may reach considerable magnitude where the tide is of " mixed " type and observations are few. The importance of large intentional differences is perhaps best illustrated by an imaginary example of their effect, as follows :— A vessel, draft 20ft. left Le Havre at 6 hours on 1st September 1924, bound for Flushing ; she carried the French tide tables, which give predictions for Le Havre but not for Flushing. Steaming about 13 knots she arrived off the Schelde at 21 hours on the same day ; it was low water when she left Le Havre, but in accordance with the tide tables, she found about 3 ft. more water in the entrance channel than shown on the chart ; it was also low water when she arrived off the Schelde and, assuming that there would be the same additional depth, she steered to cross a 20 ft. shoal and grounded, for datum (*) is some 5 ft. lower at Le Havre than at Flushing and the depth on the 20 ft. shoal at the time was 18 1/2 ft. only. Though information from which such differences in datums may be ascertained is usually given on the charts and in tide tables, it frequently escapes notice and there have been cases of vessels grounding in consequence ; the safe course is therefore co-ordination.

IV. — Recommendations of the International Hydrographic Conference, 1919.

The danger of the differences referred to above was recognised at the International Hydrographic Conference, 1919, where the following Resolutions were passed :—

" Tidal datum should be the same as chart datum and should be a plane so low that the tide will not frequently fall below it. "

(*) *Note by the Bureau.* — The chart datum of the Schelde is the mean of the lowest tides in each calendar month.

"It is greatly to be desired that a uniform datum plane should be adopted by all nations, and the following rule is suggested for the further consideration of Hydrographers for a universal datum plane, which should be called " International low water ".

" That the plane of reference below mean sea level shall be determined as follows :— " Take 1/2 the range between mean lower low water and mean higher high water and multiply this 1/2 range by 1.5. "

The wording of these Resolutions is somewhat unfortunate for " not frequently " has a very wide meaning and might cover almost any datum, and a " uniform datum plane " is not possible ; datum must necessarily vary with the range of the tide and can therefore only be a plane over a very small area and cannot be uniform ; their meaning is however clear and is (*a*) that negative heights of tide should seldom occur, and (*b*) that, by means of a uniform rule for deciding on the datum to be used, co-ordination should be established.

V. — Datums now used.

The question of co-ordination is one that has exercised the minds of surveyors almost from the commencement of exact hydrographic work and each nation, though adopting a different datum, has accordingly endeavoured to obtain co-ordination in its own waters by means of a national standard. Nations have, however, only very exceptionally adopted the standards of others, and consequently large changes occur in comparatively short distances. On the north coast of Europe, for instance, we have " lowest possible low water " in France " 1/2 ft. above mean low water springs at Ostend " in Belgium, " mean low water " in Holland (*) and " mean low water springs " in Germany and Denmark. With a single possible exception all the datums now in use are suitable for particular types of tide only ; the exception, " Indian spring low water ", however, requires detailed examination.

(*) *Note by the Bureau.* — The soundings on Dutch charts are now reduced to the mean of the lowest tides in each calendar month, but this level is called " low water springs ", because this denomination is familiar to the seaman and the difference is not very considerable. The charts of the Schelde and its estuary show soundings reduced to this level. Those of the other estuaries will be revised as soon as possible according to this principle.

VI. — Indian spring low water.

This datum, in the harmonic notation H of $(M_2 + S_2 + K_1 + O_1)$ below mean sea level, is not easily expressed non-harmonically but is probably intended to be approximately the level of the lower low water at springs $(M_2 + S_2)$ with the moon in maximum declination $(K_1 + O_1)$ and average parallax (N_2 omitted) and the sun in average declination and parallax (P_1 and T_2 omitted). It is however not this level exactly, for the quarter diurnal constituents, which may have considerable effect on the low water levels at ports situated on estuaries and shallow seas, are omitted and the solar portion of K_1 is included but K_2 is omitted, *etc.* Further the datum rests on the assumption that, at springs, low water of the four constituents included occurs at the same moment, and this is only exceptionally true. The datum is therefore not suitable for general adoption and co-ordination could not result from its use because (*a*) the quarter diurnal constituents are omitted, (*b*) the principal part of the effect of the sun's declination is omitted, (*c*) the effect of changes in the moon's parallax is omitted (there are a number of places at which the range of the lunar anomalistic constituent exceeds that of the principal solar semidiurnal constituent) and (*d*) the level found is based on the incorrect assumption that, at springs, low water of the four constituents included occurs at the same time ; the lack of co-ordination resulting from these omissions and incorrect assumption is illustrated by the table at VIII below.

VII. — International low water.

This suggested datum certainly overcomes the defects due to the omission of the shallow water and other constituents and to the assumption regarding the simultaneous occurrence of low water of the four constituents included in Indian spring low water, for it depends on observation, but a constant factor is substituted for the effect of the sun on the tide. As the ratio of the solar tide to the lunar varies, at different places, between about 1 : 1 and 1 : 4 it is evident that the use of this datum cannot result in co-ordination. Examples of the lack of co-ordination which would result from the use of either Indian spring low water or International low water are given in the table at VIII below.

VIII. — Table showing lack of co-ordination in chart datums resulting from the use of Indian spring low water and International low water.

The ports included in the table have been chosen to represent the more usual types of tide. At Heligoland the tide is mainly semidiurnal, the importance of the diurnal constituents increases progressively at Elephant Point (Rangoon River) and Penang and at Victoria B. C. the tide is mainly diurnal ; at Puerto Belgrano the tide is of anomalistic type and at Adelaide the ranges of the principal lunar and solar semi-diurnal constituents are about equal. Indian spring low water has been obtained from the harmonic constants ; International low water and the average lowest low water computed from the predictions in the Admiralty Tide Tables 1925, the months of January, April, July and October only being used for the former level but the whole year for the latter ; the level of lowest low water has also been obtained from the 1925 predictions. In the table, (*A*) gives the level of Indian spring low water, (*B*) of International low water, (*C*) of average lowest low water and (*D*) of lowest low water, all referred to mean sea level ; (*E*) gives the ratio (*A*) : (*C*) and (*F*) the ratio (*B*) : (*C*). It is evident that, if the datum is co-ordinated, the ratio will be constant for all ports ; as neither ratio is constant, co-ordination by means of either Indian spring low water or International low water is impossible. It is further evident that co-ordination is only possible if " average lowest low water ", or a level obtained by multiplying the difference between mean sea level and average lowest low water by a constant factor, is accepted as datum ; a constant factor is permissible in this case because all tidal constituents are included in average lowest low water, but this level itself accords with the International Hydrographic Conference resolution regarding the level of datum and appears to form a satisfactorily datum.

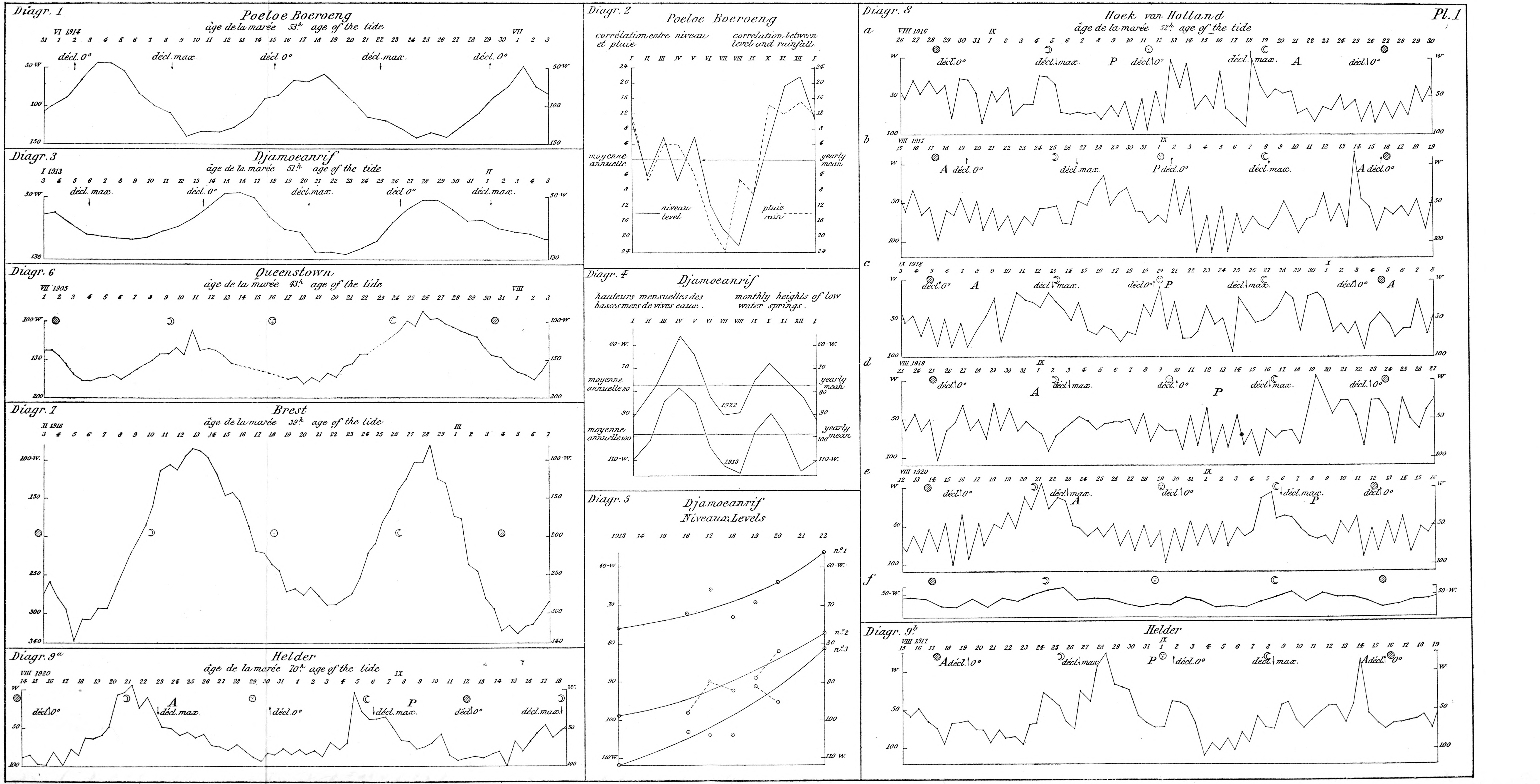
PLACE	(A) ft.	(B) ft.	(C) ft.	(D) ft.	(E)	(F)
Heligoland	— 4.5	— 6.1	— 4.7	— 4.9	0.96	1.30
Puerto Belgrano	— 6.7	— 8.2	— 7.1	— 7.8	0.94	1.15
Elephant point	— 9.3	— 11.4	— 10.8	— 12.0	0.86	1.06
Penang	— 3.8	— 3.8	— 4.3	— 4.8	0.88	0.88
Adelaide	— 4.7	— 4.2	— 3.9	— 4.6	1.21	1.08
Victoria	— 4.8	— 4.1	— 5.2	— 6.3	0.92	0.79

IX. — Computing a datum.

To compute any datum exactly requires tidal observations extending over an almost infinite period in order that seasonal changes in level, and changes of longer period in both level and range, may be eliminated ; a good approximation can however usually be obtained from one year's tides, for the important seasonal variation, which may amount to as much as about + 3 ft., is then eliminated and longer period changes are small and may be neglected. Datums must, however, frequently be decided upon when only one month's tides are available and in such cases, or in fact whenever less than one year's tides have been used, a statement of the months covered by the observations should always accompany the datum statement. As a standard method of obtaining average lowest low water the averaging of the lowest tide in each calendar month for a solar year is suggested ; another method would be to average the lowest tide occurring in each of twelve lunar periods, using synodic, tropical or anomalistic months according to the type of tide ; differences resulting from the method employed would be small but all values so obtained would, strictly speaking, be approximate. The level of average lowest low water could be computed from the harmonic constants but the formula would necessarily include all constituents with periods of a month or less and it would further be necessary to multiply the H of each constituent by a factor depending, according to the type of tide, on the difference at new or full moon or at some other definite astronomical circumstance, between the time of low water of the greatest constituent and each other constituent. A formula would therefore be extremely complicated and datum is best ascertained directly from the observations.

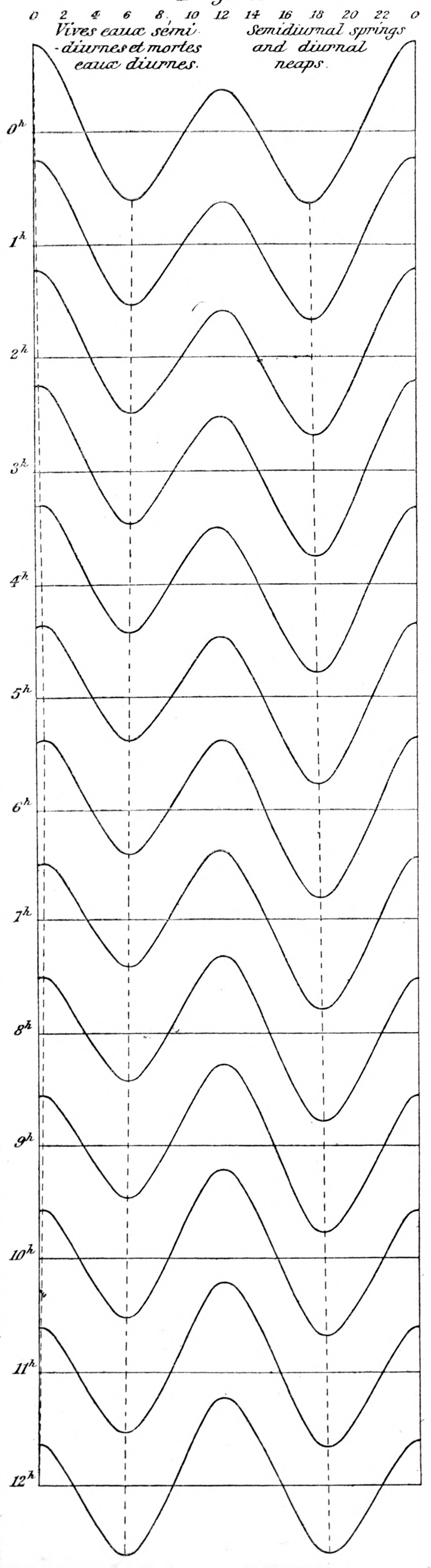
Note. — The above paper was completed prior to the receipt, in the Hydrographic Department of the British Admiralty, of information regarding the late change in the Netherlands chart datum ; as the level of datum in the Schelde entrance has now been lowered, the Example given in Part. III is no longer possible.

Information regarding the new datum is not yet (January 1925) complete but it appears to be exactly that recommended ; this datum is also largely used in Canadian waters and the conclusions reached in the paper have thus already received double, though still partial, confirmation. H. D. W.

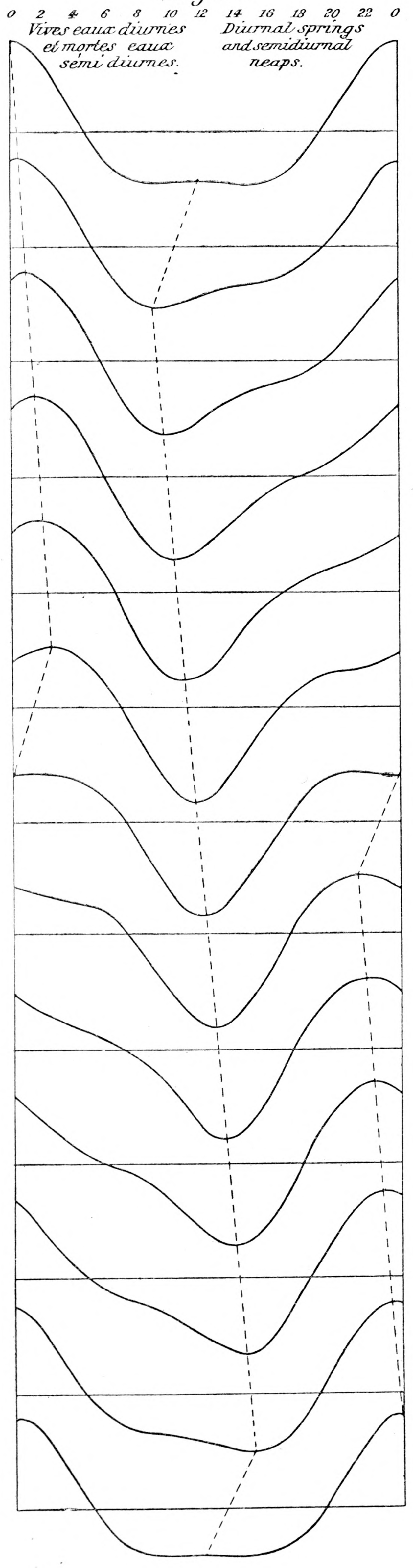

Pl. I
Diagr. 1
Poeloe Boeroeng
âge de la marée 53h. age of the tide
décl. 0°
décl. max.
Diagr. 3
Djamoeanrif
âge de la marée 51h. age of the tide
décl. max.
décl. 0°
Diagr. 6
Queenstown
âge de la marée 43h. age of the tide
Diagr. 7
Brest
âge de la marée 39h. age of the tide
Diagr. 9a
Helder
âge de la marée 70h. age of the tide
A
P
Diagr. 2
Poeloe Boeroeng
corrélation entre niveau et pluie
correlation between level and rainfall.
moyenne annuelle
yearly mean
niveau
level
pluie
rain
Diagr. 4
Djamoeanrif
hauteurs mensuelles des basses mers de vives eaux.
monthly heights of low water springs.
moyenne annuelle
yearly mean
1922
1913
Diagr. 5
Djamoeanrif
Niveaux. Levels
n°1
n°2
n°3
Diagr. 8
Hoek van Holland
âge de la marée 52h. age of the tide
a
b
c
d
e
f
Diagr. 9b
Helder


Pl. 2.
Diagr. 10 a
St. John. N.B.
âge de la marée 38h. age of the tide
Périgée ou apogée coïncidant avec la nouvelle et pleine lune.
Coïncidence of perigee or apogee with new and full moon.
P décl. 0°
décl. max.
A décl. 0°
décl. max.
P décl. 0°
décl. max.
A décl. 0°
décl. max.
décl. 0° P
250 - W.
300
350
400 - W.
xéro du marégraphe 4.27 M.-W.
xero of selfregistering tide gauge 4.27 M.-W.
Diagr. 10 b
Périgée ou apogée intercalé entre les phases de la lune
Perigee or apogee occurring between the moons phases
P décl. 0°
décl. max.
A décl. 0°
décl. max.
P décl. 0°
décl. max.
décl. 0°
xéro
Diagr. 10 c
Apogée coïncidant avec les quartiers.
Coïncidence of apogee and the quarters.
I 1919
II
décl. 0°
P
décl. max.
décl. 0°
A
décl. max.
décl. 0°
P
décl. max.
200 - W.
400 - W.
xéro
Diagr. 10 d
Périgée coïncidant avec les quartiers
Coïncidence of perigee and the quarters
VIII 1919
IX
A
décl. max.
décl. 0°
P
décl. max.
décl. 0°
A
décl. max.
xéro

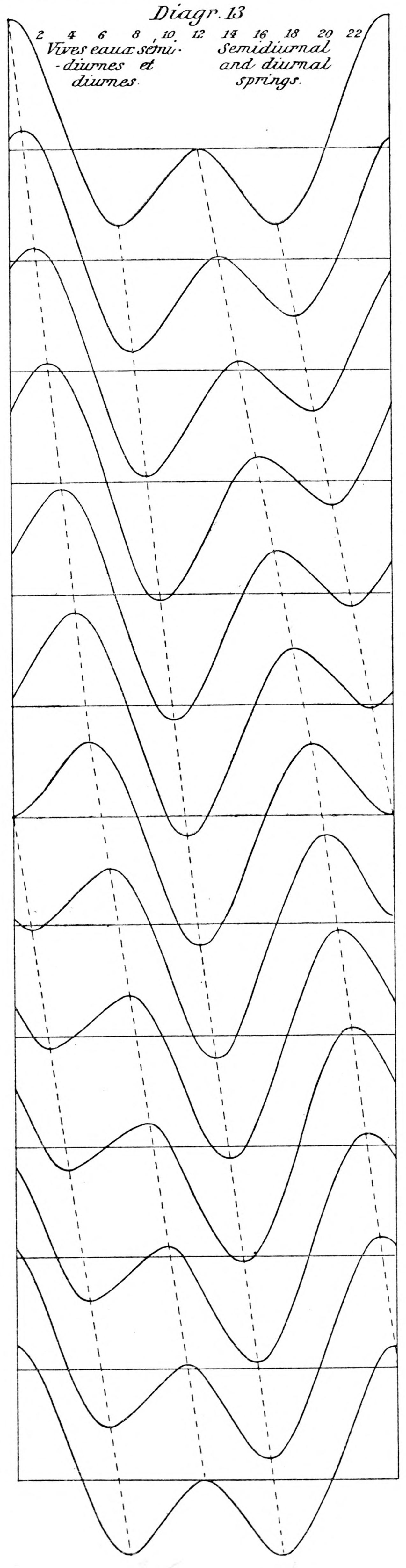
Diagr. 11



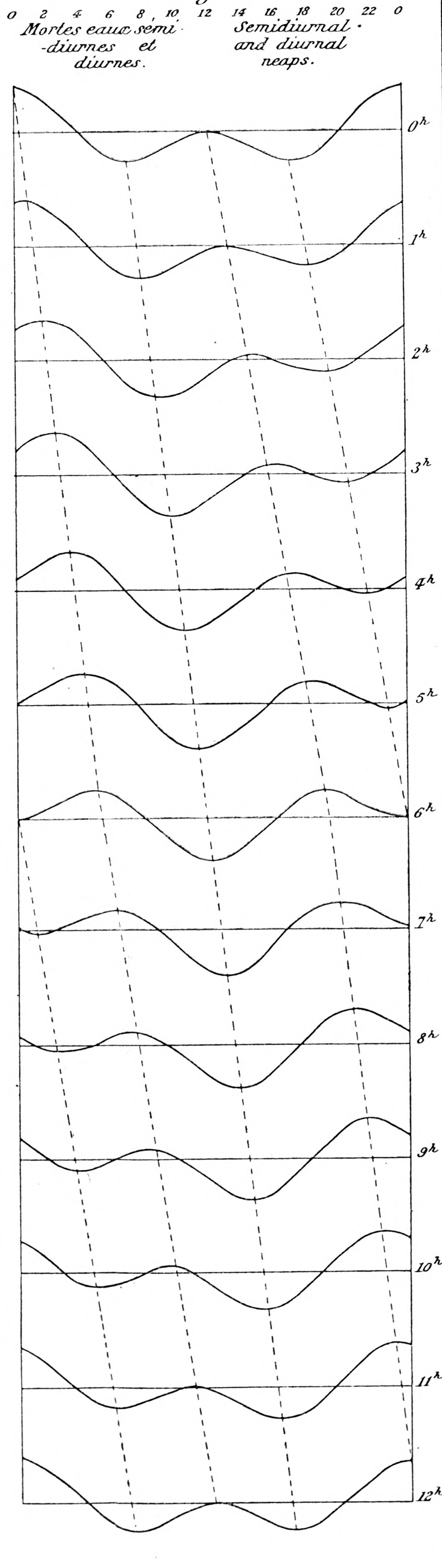
Diagr. 12



Diagr. 13



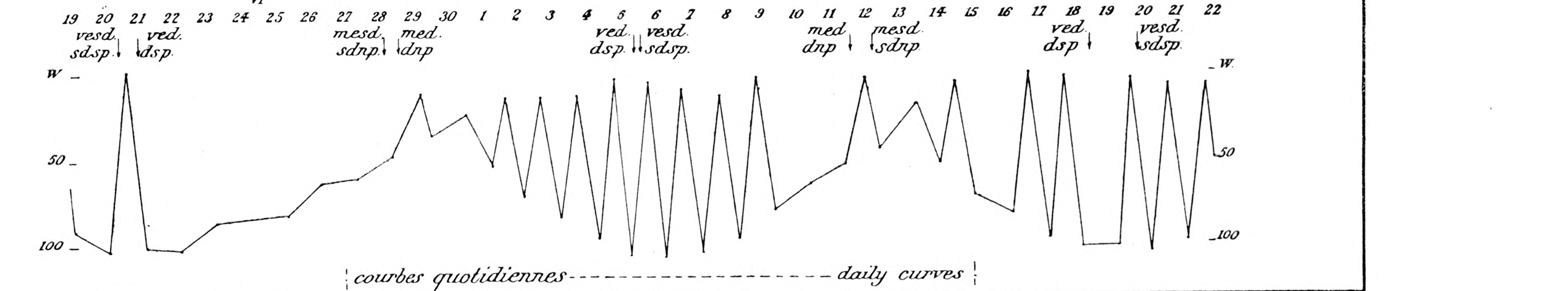
Diagr. 14



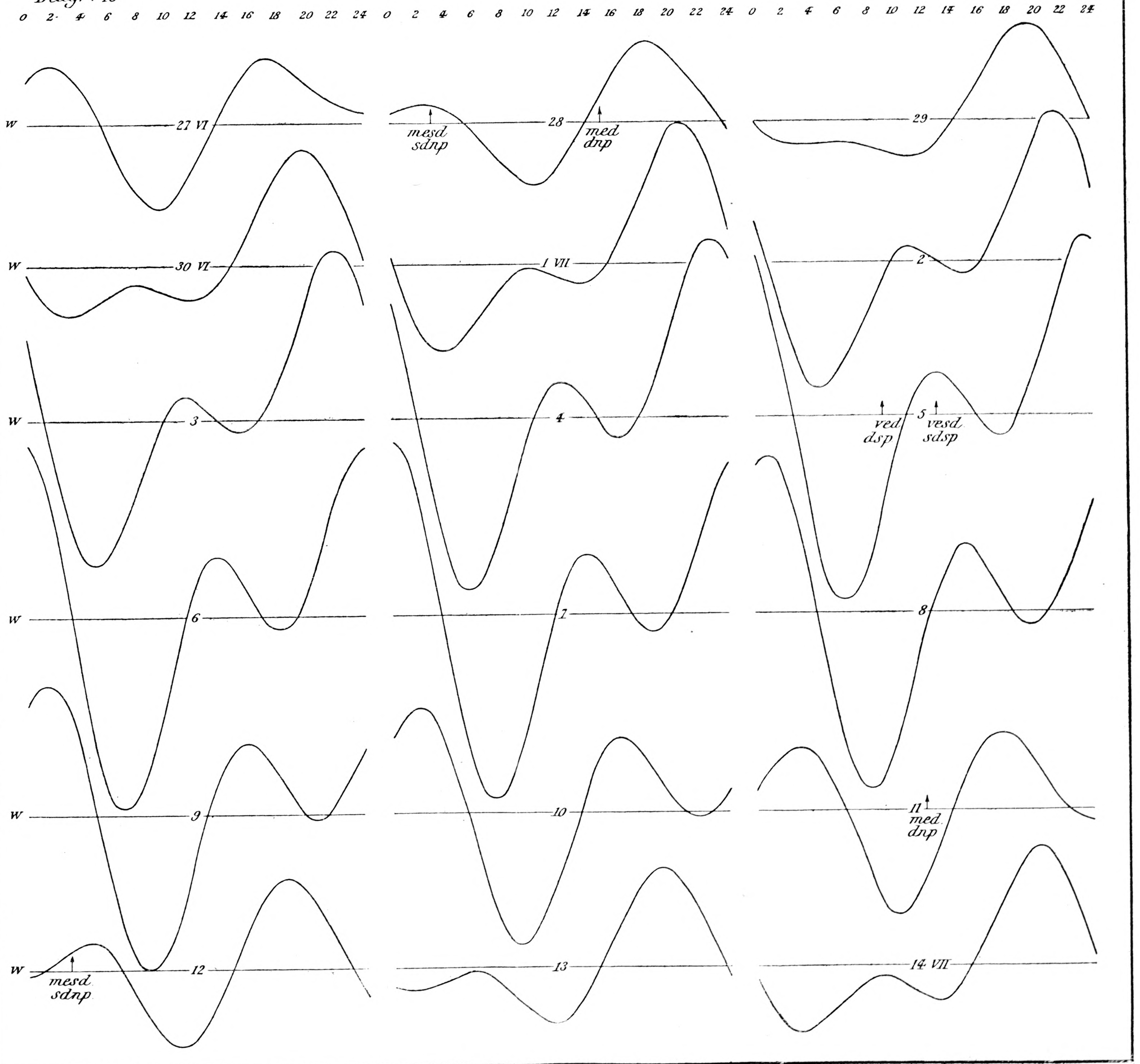
Diagr. 15 Soerabaja 1921

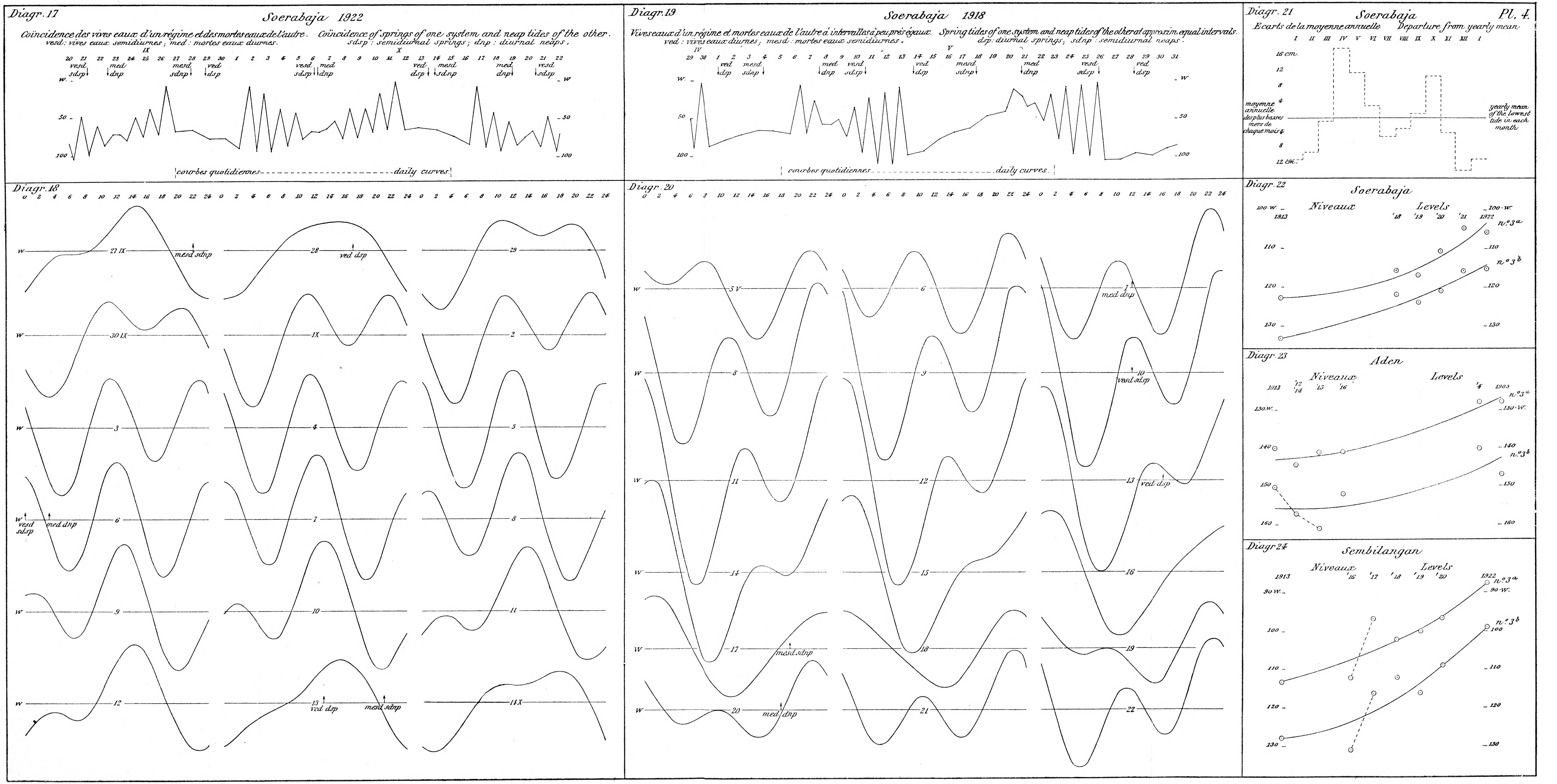
Coïncidence des vives eaux et des mortes eaux des deux régimes. vesd. vives eaux semidiurnes; med: mortes eaux diurnes.

Coïncidence of springs and of neap tides of both systems. sdsp: semidiurnal springs; dnp: diurnal neaps.



Diagr. 16




Pl. 4.
Diagr. 17
Soerabaja 1922
Coïncidence des vives eaux d'un régime et des mortes eaux de l'autre. Coïncidence of springs of one system and neap tides of the other.
vesd: vives eaux semidiurnes; med: mortes eaux diurnes. sdsp: semidiurnal springs; dnp: diurnal neaps.
courbes quotidiennes daily curves
Diagr. 18
Diagr. 19
Soerabaja 1918
Vives eaux d'un régime et mortes eaux de l'autre à intervalles à peu près égaux. Spring tides of one system and neap tides of the other at approxim. equal intervals.
ved: vives eaux diurnes; mesd: mortes eaux semidiurnes. dsp: diurnal springs; sdnp: semidiurnal neaps.
courbes quotidiennes daily curves
Diagr. 20
Diagr. 21
Soerabaja
Ecarts de la moyenne annuelle Departure from yearly mean
moyenne annuelle des plus basses mers de chaque mois
yearly mean of the lowest tide in each month
Diagr. 22
Soerabaja
Niveaux Levels
Diagr. 23
Aden
Niveaux Levels
Diagr. 24
Sembilangan
Niveaux Levels