



HARMONIC ANALYSIS OF TIDES

THE following is a summary of replies received by the Bureau to Circular-Letter No. 30 of 5th. September 1922, in which the following questions were asked : —

I. — Is harmonic analysis applied to tides in your country :

(a) in the Hydrographic Service — for surveying, description of tides in sailing directions and for tide tables, and by what system, machine or calculation, are the predictions made ?

(b) by the seamen for calculating the height of the tide at ports which are not to be found in tide tables ?

II. — What are the principal manuals on the subject and what are the tables published in your country to facilitate the calculations ?

III. — What data for tides are given on the charts ?

IV. — Is harmonic analysis included in the courses of instruction on tides given in schools where officers of the Navy and Merchant Marine are educated ? What are the programmes of this course of instruction and which manuals and tables are used ?

Argentine.

I. (a) The Argentine Republic employs harmonic analysis for the study of tides, and it is used by both the Navy and Public Works Departments. The tides published in the Navy Department Tide Tables are calculated by a Kelvin Machine with constants resulting from analysis of periods from a fortnight to three years. Analysis for a longer period than three years are not in existence, as the necessary material for simultaneous observations could not be obtained.

(b) Seamen generally use the methods recommended in the above Tide Tables for ports for which no predictions have been calculated ; these methods are similar to those in use by the British Admiralty.

II. The only manual on the subject is "Mareas" by Lt. RICARDO A. VAGO. The manuals in general use by the Hydrographic Service are those published in English and French on the subject.

III. Tidal data given on the charts are similar to those of the French Hydrographic Service.

IV. The subject of Harmonic Analysis was introduced into the course of Hydrography in the Naval School in 1922, but is only superficially discussed.

Australia.

I. (a) Harmonic Analysis is not utilised in the Hydrographic Service.

Various States of the Australian Commonwealth issue local Tide Tables; and the following are the methods of prediction used:

NEW SOUTH WALES: — Analysis provided by the Coast and Geodetic Survey of the United States of America.

VICTORIA: — A modified form of analysis by the State Observatory.

SOUTH AUSTRALIA: — By the special machine invented by the late Captain INGLIS, Harbour Master, and by the British Admiralty.

QUEENSLAND: — By the British Admiralty.

WESTERN AUSTRALIA: — By the State Observatory; the data are supplied by the Coast and Geodetic Survey of the United States of America.

(b) In the Australian Navy a method laid down in the British Admiralty Tide Tables is used.

II. The Admiralty Tide Tables and Manual of Navigation. No local tables are published to facilitate calculations.

III. The British Admiralty Charts are always in use.

IV. At the Australian Naval College a general outline of the subject only is given. No instruction is given for the Mercantile Marine.

Belgium.

I. (a and b). No reply received.

II. "L'Annuaire de l'Observatoire Royal de Belgique" published annually.

III. No reply received.

IV. No course of instruction for Naval Officers is given on this subject. The Manuals in general use are Dutch, British and French.

Brazil.

No reply received.

Canada.

I (a) The tides of the six ports on the Atlantic coast and six ports on the Pacific coast are predicted by harmonic analysis. Observations and reductions being made by the Tidal and Current Survey ; the Tide Predicting Machine by Edward Roberts and Son, England, is used. Additional Tide Tables and Tables of Slack Water by means of differences of time are based on the above predictions, nearly all the differences being obtained from simultaneous observations.

In Hudson Bay and Hudson Strait, and on the Labrador coast, the tides are referred, by differences of time, to ports of reference in the Tide Tables.

(b) The data given to seamen for calculating the height of the tide at ports, not given in the Tide Tables, are as follows : —

In Eastern Canada the height of the tide is indicated by the rise above the Low-water datum at Spring and Neap tides.

For the Bay of Fundy, the rise at Perigee Springs and Apogee Springs is distinguished.

On the Pacific Coast, throughout the straits and interior waters, around Vancouver Island, the ratio of the rise is given with reference to the predicted ports in the Tide Tables.

II. No manuals are published in Canada regarding tidal calculations nor tables of data.

III. Tidal information on Canadian charts usually consists of the Establishment, and the rise at Springs and Neaps unless the tides are declinational. References are given on charts to the Tide Tables for the region.

IV. Courses of instruction in Naval Schools do not include Harmonic Analysis. A publication has been issued by the Tidal Survey entitled " The Tides and Tidal Streams ", which gives a general account of the tides, their characteristics, and explanations regarding the behaviour of tidal streams.

Naval cadets and candidates for Mercantile certificates are required to make themselves familiar with the use of Tide Tables and Tidal Reports.

Chile.

No reply received.

China.

I. (a) Harmonic Analysis is used in surveying and for the compilation of Tide Tables for the Side Saddles at the entrance of the River Yangtze.

(b) No.

II. No publications on the subject.

III. H. W. F. and C., Rises, Ranges and brief notes of local tidal peculiarities.

IV. No.

Denmark.

I. (a) For the Harbour of Esbjerg (the only Danish Harbour where tides must be considered) the Meteorological Institute has made tidal observations with a self-registering tide-gauge during one year. From these observations, by means of harmonic analysis, the establishment of the port has been computed.

(b) No.

II. No Tide Tables are published in Denmark.

III. The establishments are given on Danish, Faerö and Iceland charts, as also the difference between High and Low Water (as a rule at Springs and Neaps) at places considered necessary.

IV. Harmonic Analysis is not taught in any of the Naval Schools.

France.

I. (a) Harmonic Analysis is employed in the Naval Hydrographic Service for : —

(1) drawing up tables of the heights of the tide from hour to hour at Brest and St. Malo, which tables are published in the " Annuals of the tides on the Coasts of France ".

(2) drawing up Tide Tables in French Colonies, for which there are three annual publications, Atlantic, Indian Ocean and China Seas.

The calculations of Harmonic Constants have been made by using the method of Darwin's Slide Rules for the Brest and St. Malo tides, and by method of observations over short periods as regards colonial ports.

The prediction of tides by means of the Harmonic Constants is done by means of a Kelvin's Tide Predictor, which can deal with a total of 16 components.

(b) French seamen are not accustomed to the use of harmonic analysis for calculating the height of the tide.

II. The principal works on Harmonic Analysis published in France are : —

HATT : On the Harmonic Analysis of observations on tides, from English sources (*Annales Hydrographiques*, 1893).

HATT : On Tides (An Encyclopedia of Memoranda, Gauthier-Villars et Masson, 1895).

ROLLET DE L'ISLE : Harmonic Analysis of short period Observations (*Annales Hydrographiques*, 1896).

ROLLET DE L'ISLE : The calculations of the height of the tide at any given moment (*Annales Hydrographiques*, 1899).

ROLLET DE L'ISLE : The calculations of the time and height of high water by means of harmonic Constants (*Annales Hydrographiques*, 1903).

ROLLET DE L'ISLE : Observation, examination and prediction of Tides (Service Hydrographique, No. 870, 1905).

COURTIER : Notes on the prediction of tides by means of harmonic formulæ (*Annales Hydrographiques*, 1908).

MAURICE LÉVY : Lessons on the theory of Tides (Gauthier-Villars, 1898).

H. POINCARÉ : The Theory of Tides (edited by E. FICHOT, Gauthier-Villars, 1910).

E. FICHOT : Tides and their use for industrial purposes (Gauthier-Villars, 1922).

III. (a) When a semi-diurnal tide preponderates, charts show : — the establishment of the port, the unit of height, and the heights of high and low water at average Spring and Neap tides. Occasionally some information on the amplitude of the diurnal wave is added.

(b) When the diurnal wave attains an amplitude equal or superior to that of the semi-diurnal wave, the information is generally limited to the maximum amplitude of the total tide, with an indication of the proportion of the two waves.

(c) When producing American charts, the equivalents generally used are : —

High water interval or Higher High water interval.	} Etablissement ;
High water height.	: Hauteur de la pleine mer.
Higher High water height.	} Hauteur de la pleine mer en vive- eau.

The level of the lowest low water with reference to the zero of the Soundings is given also.

IV. Harmonic Analysis is taught at the Naval School and in the College Course for Officers ; instruction is also given in both these establishments on the calculation of the height of the tide at a given hour by means of harmonic constants, using VAN DER STOK'S tables. It is not taught in the Navigation Schools for candidates for the Mercantile Marine.

Great Britain.

No reply received.

Greece.

No reply received.

Italy.

I. (a) Harmonic Analysis is not generally applied by the Italian Hydrographic Office ; it is used by the Italian Tidal Commission and by Students.

(b) As a rule seamen do not make use of harmonic analysis to calculate the height of the tide in ports for which tidal predictions are not given in the tide tables.

II. On the coasts of Italy, as well as on those of its colonies, the data for the tide are always deduced from direct observations. Tide tables, the computation of which requires machines for calculation or prediction, are not issued.

III. As a rule no data of tides are given on charts.

IV. Harmonic Analysis is taught to the Officers of the Royal Navy and has been inserted in the programme of study for the Officers of the Mercantile Marine for the past few years.

The Tide Tables in use are those published by the Hydrographic Offices of Great Britain and the United States of America.

Manuals treating of the application of harmonic analysis to tides are not used and the teachers make use of their annotations to give their lessons.

Japan.

I. (a) Harmonic Analysis is applied whenever Surveying Parties have at their disposal more than a fortnight's tidal observations, and

non-harmonic constants for insertion on charts are calculated. In Sailing Directions, although no terms concerning harmonic analysis are used, tides are described as far as possible by harmonic constants. In Tide Tables, tides are predicted by Kelvin's Tide-Predicting Machine with 15 components (Messrs. Kelvin, Bottomley and Baird, Ltd., 1914).

(b) No.

II. The "Suiro-Sokuryosho" (Manual of Hydrographic Surveying) published by the Hydrographic Dept., Tokyo, shows how to apply harmonic analysis to tides. This method is that which is explained in Darwin's "Tides", Admiralty Scientific Manual (1886) and is good for tides observed during a fortnight or four weeks. No tables have been issued excepting those contained in our Suiro-Sokuryoyo-shohyo (Various Tables used for Hydrographic Surveying). Where harmonic analysis is to be applied to the tides observed during more than one year, the method of tidal abacus, described in DARWIN'S "On an apparatus for facilitating the reduction of tidal observations" (Proceedings of the Royal Society, III, 1892) is used.

III. The following data for tides are generally given on charts : —

H. W. F. and C., Springs rise, Neaps rise, Neap range. On charts published in and after 1921, the following are given : — Mean high water interval, Springs rise, Neaps rise, Mean sea level, Height above datum. For districts where remarkable inequalities of tides exist, which are liable to cause frequent high and low waters in a day, the following data is given as to tropic tides, in addition to those for equinoctial tides : — Mean high water interval, Mean low water interval, Height of mean high water above the datum, Height of mean low water above the datum.

IV. The courses of instruction on tides given in schools where Officers of the Navy and Mercantile Marine are educated include rudimentary notions of harmonic analysis.

Netherlands.

I. (a) Harmonic Analysis is applied to the study of tides and for the deduction of their constants, fixing by means of these the datum for reduction of soundings. The description of tides in the Sailing Directions is also based on this theory.

Tide Tables calculated upon the harmonic constants by the Royal Magnetical and Meteorological Observatory at Batavia are issued for the following places, giving hourly the actual depths for the most shallow part of the bar ; Belawan (Deli) ; Palembang ; Little Kapoeas (Pontia-

nak) ; Barito (Bandjer masing) ; Koetel (Samarinda) and Soerabaja (E. and W. entrance).

Although for the Netherlands the constants of a great number of places are calculated, harmonic analysis is not used here for fixing the chart datum and for the description of tides ; these records being known exactly by the minute observations made for more than a century by the " Algemeenen Dienst van den Waterstaat " (General Service of Public Works). The Tide Tables are calculated by this Service according to the empirical method of DE BRUYN, a modification of that of LUBBOCK. The tides of the Netherlands coast being of a nearly pure semi-diurnal character, this is not only permissible, but the method of DE BRUYN gives even slightly better results than harmonic analysis. This fact is not yet sufficiently explained and is believed to be the result of imperfect knowledge of the shoal water tides, and the use of Harmonic Analysis is, therefore, applied in the Netherlands chiefly to theoretical questions.

(b) Harmonic analysis is applied by seamen to calculate the heights of the tide. Tide Tables being available for the principal ports for which knowledge of the height is required, this necessity is not often felt except in the E. I. Archipelago.

II. The principal Manuals and Tables on the subject are : —

Dr. J. P. VAN DER STOK, " Wind and Weather, Currents, Tides and Tidal Streams in the East Indian Archipelago ", 1897.

Dr. J. P. VAN DER STOK, " Elementaire theorie der getijden " (Elementary Theory of Tides), 1910.

P. J. SMITS, " Harmonische analyse der watergetijden " (Harmonic Analysis of Tides), 1910.

J. M. PHAFF, " Tafelen benooidigd bij het Hydrographisch opnemen " (Tables for hydrographical surveying) 2nd edition, 1913.

J. L. H. LUYMES, " Overzicht der getijleer ten dienste der hydrographische opneming " (Summary of the theory of tides and its application to hydrographical surveying), 1919.

W. NOORDUYN, " Leerboek der zeevaartkunde " (Handbook of the Art of Navigation) 9th edition, 1922.

P. HAVERKAMP, J. VAN ROON, L. M. J. GREGORY, " Zeevaartkunde " (The Art of Navigation), 1921.

P. VAN DER ZEE, " Watergetijden " (Tides), 1920.

III. On the existing charts of the Netherlands the datum for reduction of soundings is " mean low water ". A re-survey has been commenced for which the datum is " low low water springs ", being the mean of the lowest low water springs occurring each month ; new editions of charts 203 and 214 in which the soundings have been reduced to this datum have

already been issued. On these charts the following information is given for a number of places : —

Mean high water lunitidal interval,

Mean height of high water springs and neaps above chart datum,

Height of mean sea level above chart datum,

Height of N. A. P. (general land survey datum of the Netherlands) being also the datum of the Tide Tables above chart datum, and at the Light-vessels roses showing the tidal currents for every hour before and after high water.

In the East Indian Archipelago the datum for reduction of soundings is “ the lowest possible height, according to harmonic constants ”. On the charts “ low water springs ” is mentioned, although this expression is theoretically only correct for tides of a pure or nearly pure character and not for those of a mixed type, as prevail there. The term is retained, however, on account of its shortness and popularity. On the large scale charts the height of mean sea level above chart datum is given.

IV. Harmonic Analysis is included in the course of instruction on tides given in schools where Officers of the Royal Naval and Mercantile Marine are educated. The Manuals and Tide Tables are mostly the three last named books mentioned in II.

Norway.

I. and II. Harmonic Analysis is not used and accordingly no manuals on the subject are published.

III. All depths on the charts are reduced to mean Low Water Springs.

IV. Harmonic Analysis is not included in the course of instruction on tides given in schools where Officers of the Navy and Mercantile Marine are educated.

Peru.

No reply received.

Portugal.

No reply received.

Siam.

No reply received.

Spain.

No reply received.

Sweden.

I. (a and b). The tides on the Swedish coast are entirely negligible in comparison with the variations of the water-level produced by meteorological and other causes ; the tidal range in the Baltic being only a few centimetres and in the Kattegat one or two decimetres. Consequently there are no tidal corrections applied either in surveying or in coastal navigation.

II. There is a Manual on Tides (with tidal charts of the Channel, North and Irish Seas) published by Capt. O. GLYDEN, R. S. N., which is used at the schools for Officers of the Navy and Mercantile Marine. No Tide Tables are published in Sweden.

III. Neither on the charts of the Swedish coast nor on those of foreign waters are any data given for tides. On the latter charts the level of reduction used is that adopted by the country in question, or generally, mean low water springs.

IV. Harmonic Analysis is not included in any of the courses for Officers of the Navy or Mercantile Marine.

United States of America. Coast & Geodetic Survey.

I. (a) Harmonic Analysis is used for obtaining constants for the prediction of the tides which are published in the annual Tide Tables of the C. and G. S.

Predictions are made by means of a tide predicting machine which was designed and constructed by the U. S. C. and G. S.

Harmonic Analysis is not used in surveying nor in the description of tides in the sailing directions.

(b) Harmonic Analysis is not used by seamen for calculating the height of the tide at ports for which predictions are not contained in the Tide Tables, tidal differences only being used for this purpose.

II. The Manual of Tides by Dr. ROLLIN A. HARRIS, which was published in parts as appendices to annual reports of the Superintendent of the U. S. Coast and Geodetic Survey, and tables contained therein are used to facilitate the calculations for harmonic analysis.

III. The tidal data given on the charts of the U. S. Coast and Geodetic

Survey include the mean high water interval or corrected establishment, the height of mean high water for ports on the Atlantic coast and the height of mean higher high water for ports on the Pacific coast, and the lowest tide.

IV. Harmonic analysis is not included in the courses of instruction on tides given in schools where Officers of the Navy and Mercantile Marine are educated.

Hydrographic Office.

I. (a) Harmonic Analysis is employed by the Hydrographic Service. The machine employed is the Coast and Geodetic Survey Tide-predicter.

(b) Harmonic Analysis is not used by seamen for calculating the height of the tide at ports which are not to be found in Tide Tables.

II. Manual of the Tides by ROLLIN A. HARRIS, U. S. Coast and Geodetic Survey ; and the tables therein contained.

III. The corrected establishment of the Port, or, where data for this are lacking, the High Water at full and change of the Moon ; also the rise and fall of tide and sometimes the range.

IV. Harmonic Analysis is not included in the course of instruction on tides given in schools where Officers of the Navy and Mercantile Marine are educated.

The Bureau is of opinion that the above replies are of great interest and will be glad to receive similar information from other organisations interested in the study of tides.

