CALENDAR OF FUNDAMENTAL HARMONIC TIDES AND DIAGRAMS FOR THEIR GRAPHICAL PREDICTION

(Continuation)

by

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In a preceding note bearing on the same subject and published in Volume XIV N° 2 of the Hydrographic Review, Monaco, November 1937, p. 53, attention has been drawn to the practical utility offered, in the harmonic formula for the prediction of tides, by the evaluation of the initial arguments, not in degrees but in time. It is in fact customary to say that high tide occurs at a certain hour of the day and we do not seek to convert this time into degrees; high tide is expressed in time just like any other entry made in the ship's log.

Since the British authorities have introduced the term "g" to express the phase lags of the various component waves of the tides with respect to Greenwich, instead of the harmonic constant "kappa" referred to the local meridian, the preceding remark takes on increased importance. Professor L. M. Milne Thompson, of the Royal Naval College of Greenwich, whom we have consulted on this question, had already in 1928 recommended the idea of expressing such an element in hours, at least for the principal harmonic components of the tide, since such an expression would greatly facilitate the graphical prediction of the tides from the point of view both of the navigator and the hydrographer.

Much criticism has been directed against the harmonic method both on account of its excessive length and the tedious calculations it is necessary to perform when one wishes to add the diverse effects of the different component waves to obtain the total movement of the tide. We have sought to show in the preceding article in Hydrographic Review, Vol. XIV N° 2 of November 1937, that with some simple practical precautions, taken once for all, and with the aid of tables and diagrams which can be handled by anyone, it is possible to overcome these difficulties. Nevertheless, the practical application of the method which we have described depends essentially upon the use of an harmonic calendar giving the hours of the maximum potentials at Greenwich for the principal components and for each day of the year; this being a table of the kind Tm, of which a sample page was reproduced for the month of January 1940, page 54 of the above-mentioned volume of the Hydrographic Review.

To-day we invite especial attention to the simple manner in which a calendar of this kind may be prepared. This can be done in a few hours' time for any year whatever, by means of the method which we shall describe below.

The argument $\frac{360 - V_0}{n}$ is readily deduced from Table 15 in the *Manual for the Harmonic Analysis and Prediction of Tides* by Paul Schureman, Special Publication N° 98 of the U. S. Coast and Geodetic Survey. By employing the table of conversion called the *Table des Etablissements* of which we have given a sample on page 54 of the Hydrographic Review above cited, it is easy to convert into hours the argument in question for the lst of January of each year. Below we give, for instance, the table of time of maximum potentials at Greenwich expressed in hours and minutes for 1st January of each year of the decade 1940-1950 and for the various components M_2, S_2, N_2, K_2, K_1, O_1, P_1, Q_1, M_4, MS_4,

TABLE I.

Hours of Maximum Potentials at Greenwich

Ist January	M_2	S_2	N_2	K_2	K_1	O_1	P_1	Q_1	M_4	MS_4
1940	04.55	12.00	05.20	05.11	23.06	11.13	00.38	12.21	04.55	02.24
1941	02.19	12.00	06.15	05.20	23.18	05.27	00.41	13.57	02.19	01.08
1942	11.16	12.00	05.51	05.34	23.32	23.42	00.40	12.42	05.03	05.33
1943	07.49	12.00	05.27	05.45	23.44	16.14	00.39	11.32	01.36	03.51
1944	04.21	12.00	05.02	05.53	23.51	08.51	00.38	10.29	04.22	02.08
1945	01.43	12.00	05.57	05.53	23.50	03.24	00.41	12.25	01.44	00.51
1946	10.41	12.00	05.31	05.53	23.50	22.03	00.40	11.34	04.28	05.14
1947	07.12	12.00	05.06	05.49	23.46	14.55	00.39	10.47	00.59	03.32
1948	03.42	12.00	04.39	05.43	23.38	07.51	00.38	10.02	03.42	01.49
1949	01.02	12.00	05.31	05.30	23.26	02.37	00.41	12.12	01.02	00.31
1950	09.57	12.00	05.05	05.20	23.17	21.24	00.40	11.30	03.45	04.54

For the succeeding days of the month of January of any year whatever the hours of the maximum potentials at Greenwich for the various waves may be deduced from the respective figures given in the above table by adding to each the daily increment, expressed in time, in accordance with the monthly table given below:—

TABLE II.

Daily Increments, expressed in Time, for each Day of the Month.

Day	M_2	S_2	N_2	K_2	K_1	O_1	P_1	Q_1	M_4	MS_4
1	0.00	0	0.00	- 0.00	- 0.00	0.00	0.00	0.00	0.00	0.00
2	0.50	0	1.19	- 0.04	- 0.04	1.49	0.04	2.52	0.50	0.25
3	1.41	0	2.38	- 0.08	- 0.08	3.38	0.08	5.44	1.41	0.50
4	2.31	0	3.57	- 0.12	- 0.12	5.27	0.12	8.36	2.31	1.14
5	3.22	0	5.16	- 0.16	- 0.16	7.17	0.16	11.28	3.22	1.39
6	4.12	0	6.35	- 0.20	- 0.20	9.06	0.20	14.20	4.12	2.04
7	5.03	0	7.54	- 0.24	- 0.24	10.55	0.24	17.12	5.03	2.29
8	5.53	0	9.13	- 0.28	- 0.28	12.44	0.28	20.04	5.53	2.54
9	6.44	0	10.32	- 0.32	- 0.32	14.33	0.32	22.56	0.31	3.18
10	7.34	0	11.51	- 0.36	- 0.36	16.22	0.36	25.48	1.21	3.43

Day	M_2	S_2	N_2	K_2	K_1	O_1	P_1	Q_1	M_4	MS_4
11	8.25	0	0.31	- 0.39	- 0.39	18.12	0.39	1.49	2.12	4.08
12	9.15	0	1.50	- 0.43	- 0.43	20.01	0.43	4.41	3.02	4.33
13	10.06	0	3.09	- 0.47	- 0.47	21.50	0.47	7.33	3.53	4.58
14	10.56	0	4.28	- 0.51	- 0.51	23.39	0.51	10.25	4.43	5.22
15	11.47	0	5.47	- 0.55	- 0.55	25.28	0.55	13.17	5.34	5.47
16	0.12	0	7.06	- 0.59	- 0.59	1.28	0.59	16.09	0.11	0.06
17	1.03	0	8.25	- 1.03	- 1.03	3.17	1.03	19.01	1.01	0.31
18	1.53	0	9.44	- 1.07	- 1.07	5.06	1.07	21.53	1.52	0.56
19	2.44	0	11.03	- 1.11	- 1.11	6.55	1.11	24.45	2.42	1.20
20	3.34	0	12.22	- 1.15	- 1.15	8.45	1.15	0.45	3.33	1.45
21	4.24	0	1.02	- 1.19	- 1.19	10.34	1.19	3.37	4.23	2.10
22	5.15	0	2.21	- 1.23	- 1.23	12.23	1.23	6.29	5.14	2.35
23	6.05	0	3.40	- 1.27	- 1.27	14.12	1.27	9.21	6.04	3.00
24	6.56	0	4.59	- 1.31	- 1.31	16.01	1.31	12.13	0.42	3.24
25	7.46	0	6.18	- 1.34	- 1.34	17.50	1.34	15.05	1.32	3.49
26	8.37	0	7.37	- 1.38	- 1.38	19.40	1.38	17.57	2.23	4.14
27	9.27	0	8.56	- 1.42	- 1.42	21.29	1.42	20.49	3.14	4.39
28	10.18	0	10.15	- 1.46	- 1.46	23.18	1.46	23.41	4.04	5.04
29	11.08	0	11.34	- 1.50	- 1.50	25.07	1.50	26.33	4.54	5.28
30	11.59	0	0.13	- 1.54	1.54	1.07	1.54	2.33	5.45	5.53
31	00.24	0	1.32	- 1.58	- 1.58	2.56	1.58	5.25	0.23	0.12
32	1.14	0	2.50	- 2.02	- 2.02	4.46	2.02	8.18	1.14	0.36

The following table furnishes directly, from 1st January on, the increments for the first day of each month of the year, the increments being in each case expressed in time. The increments in question are calculated for the ordinary year; in the case of a leap year, the data in the table relating to 1st August, for instance, would then naturally be correct for 31st July of the leap year, etc.

TABLE III.

Increment at : —	M_2	S_2	N_2	K_2	K_1	O_1	P_1	Q_1	M_4	MS_4
1st Feb. .	01.14	0	02.50	- 02.02	- 02.02	04.46	02.02	08.18	01.14	00.36
1st Mar. .	12.22	0	01.44	- 03.52	- 03.52	04.04	03.53	08.02	06.10	06.05
1st Apr. .	01.11	0	04.34	- 05.54	- 05.54	08.49	05.56	16.20	01.12	00.34
1st May . .	01.35	0	06.07	- 07.52	- 07.52	11.46	07.54	21.47	01.36	00.47
1st June .	02.49	0	08.56	- 09.53	- 09.53	16.33	09.57	03.13	02.49	01.23
1st July . .	03.12	0	10.28	- 11.52	- 11.52	19.29	11.56	08.39	03.13	01.34
1st Aug. .	04.27	0	00.40	- 01.56	- 13.54	24.14	13.58	17.00	04.27	02.11
1st Sept. .	05.41	0	03.29	- 03.57	- 15.55	03.10	16.01	25.18	05.41	02.48
1st Oct. . .	06.04	0	05.01	- 05.55	- 17.53	06.06	17.59	03.53	06.06	02.59
1st Nov. .	07.19	0	07.52	- 07.57	- 19.55	10.53	20.01	12.12	01.06	03.35
1st Dec. .	07.42	0	09.23	- 09.55	- 21.53	13.49	22.01	17.38	01.30	03.47
1st Jan. . . (yearly increment)	08.56	0	12.14	- 0	- 0	18.34	0	25.58	02.44	04.23

When adding the successive increments care should be taken to deduct from the sum expressed in time the period or the cycle corresponding to a variation of 360° of the argument for each of the components. The respective periods for the various components are given in the following table :—

TABLE IV.

	M_2	S_2	N_2	K_2	K_1	O_1	P_1	Q_1	M_4	MS_4
Period :	12.25	12.00	12.39	11.58	23.56	25.49	24.04	26.52	06.13	06.06

The numerical quantities above, with the precautions indicated above, permit the rapid establishment of the calendar relating to the hours of maximum potentials at Greenwich for any period whatever comprised between the years 1940 and 1950.

Let us assume, for instance, that in the course of a hydrographic expedition one wishes to establish the calendar of hours of maximum potentials at Greenwich from 20th to 30th July 1940 ; we have :—

	M_2	S_2	N_2	K_2	K_1	O_1	P_1	Q_1	M_4	MS_4
Table (I) for 1940.	04.55	12.00	05.20	05.11	23.06	11.13	00.38	12.21	04.55	02.24
Table (III) for July.	03.12	0.00	10.28	-11.52	-11.52	19.29	11.56	08.39	03.13	01.34
Table (II) for the 20th or, for leap year, the 21st.	04.24	0.00	01.02	- 1.19	- 1.19	10.34	1.19	3.37	4.23	2.10
Total...	12.31	12.00	16.50	-13.11	-13.11	41.16	13.53	24.37	12.31	6.08
Deduction for the period (Table IV)	-12.25		-12.39	- 8.00 + 11.58	9.55	-25.49			-12.26	-6.06
Hours of maximum potentials at Greenwich on 20th July 1940...	0.06	12.00	4.11	3.58	9.55	15.27	13.53	24.37	0.05	0.02

For each succeeding day subsequent to 20th July 1940 we obtain in the same way the hours of maximum potentials at Greenwich by means of addition, employing the first lines of Table (II).

It should be noted that if one refers to the Harmonic Calendar, of which we have reproduced a specimen (Table Tm) on page 54 of the *Hydrographic Review*, Vol. XIV N° 2, November 1937, the first column of the table relating to the component M_2 is none other than the times of either the upper or lower transit of the moon at the Greenwich meridian for the various dates of the month, and when the time given in the column M_2 is $O.^h$ $o.^m$ it refers, evidently, to a new moon or a full moon.

NOTE :

In the above-cited article in the Hydrographic Review we have applied the graphical method by using the diagram B for evaluating the hourly ordinates relating to each component wave. We could have employed equally numerical tables, of the type given in the Manual *Maree e Correnti di Marea* published by Professor Tenani of the *Istituto Idrografico della Regia Marina,* Genoa, 1935, Table XVI, pages 194 to 208. The operations are then reduced to simple transcriptions before undertaking the summation in the form of the type given in Figure 8 facing p. 58 of Hydrographic Review, Volume XIV N° 2, November 1937.