Ivica Tijardović*
Vinko Marinković**

ISSN 0469 - 6255
(207-212)

A NEW TECHNIQUE FOR RESOLVING PRACTICAL TIDAL PROBLEMS

NOVA TEHNIKA ZA RJEŠAVANJE PRAKTIČNIH PLIMNIH PROBLEMA

UDK 525.6

Pregledni članak
Review

Introduction
Uvod

The officers in their practice have to resolve mainly three types of tidal problems:

1. Time of HW and LW on a particular day
2. Height of Tide at an Intermediate Time between HW and LW
3. Time at which a required Height of Tide is reached

For very practical purposes to resolve the first type of tidal problem they can use the Tide Tables from Brown's Nautical Almanac which give Time and HW only.
To resolve the second type of tidal problem they can use the Table of Constants from Brown's Nautical Almanac and to resolve the third or any type of tidal problem they can use Admiralty Tide Tables (or American version of Tide Tables).
This paper brings a new technique to resolve the mentioned types of tidal problems.

Analysis
Analiza

From the Brown's Nautical Almanac 1998 (p. 505) the officers can use "TABLE FOR DETERMINING HEIGHTS OF TIDE AT TIMES BETWEEN HIGH AND LOW WATER, AND WITH TIDAL DURATIONS FROM 5 HOURS TO 8 HOURS" compiled by S.T. Elliot, Extra Master, and the table is well known under the name "TABLE OF CONSTANTS".

Duration	Interval from H.W. or L.W.							
Hours	1/2	1	1 1/2	2	2 1/2	3	3 1/2	4
8 Hours	·01	·04	·08	·15	·22	·31	·4	·5
7 1/2 hours	·01	·04	·1	·17	·25	·35	·45	
7 hours	·01	·05	·11	·19	·28	·39	·5	
6 1/2 hours	·01	·06	·13	·22	·32	·44		
6 hours	·02	·07	·15	·25	·37	·5		
5 1/2 hours	·02	·08	·17	·29	·43			
5 hours	·02	·1	·21	·35	·5			

Fig. 1. Table of Constants, S.T. Elliot
Slika 1. Tablica konstanti

Below the table (p. 505) there is an example how to find the rise of tide at a given time (second type of tidal problem).

The following table is rewritten (accurately) version of Captain Elliot's table:

*Captain Dr. Ivica Tijardović, Master Mariner
**Captain Vinko Marinković, Master Mariner
Maritime Faculty Split, Split

INTERVAL FROM HW or LW		DURATION								
h	m	0500	0515	0530	0545	0600	0615	0630	0645	0700
0	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	30	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
	40	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02
	50	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.03
1	00	0.10	0.09	0.08	0.07	0.07	0.06	0.06	0.05	0.05
	10	0.13	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.07
	20	0.17	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.09
	30	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.11
	40	0.25	0.23	0.21	0.19	0.18	0.17	0.15	0.14	0.13
	50	0.30	0.27	0.25	0.23	0.21	0.20	0.18	0.17	0.16
2	00	0.35	0.32	0.29	0.27	0.25	0.23	0.22	0.20	0.19
	10	0.40	0.36	0.34	0.31	0.29	0.27	0.25	0.23	0.22
	20	0.45	0.41	0.38	0.35	0.33	0.31	0.29	0.27	0.25
	30	0.50	0.46	0.43	0.40	0.37	0.35	0.32	0.30	0.28
	40	0.55	0.51	0.48	0.44	0.41	0.39	0.36	0.34	0.32
	50	0.60	0.56	0.52	0.49	0.46	0.43	0.40	0.38	0.35
3	00	0.65	0.61	0.57	0.53	0.50	0.47	0.44	0.41	0.39
	10	0.70	0.66	0.62	0.58	0.54	0.51	0.48	0.45	0.43
	20	0.75	0.71	0.66	0.62	0.59	0.55	0.52	0.49	0.46
	30	0.79	0.75	0.71	0.67	0.63	0.59	0.56	0.53	0.50
	40	0.83	0.79	0.75	0.71	0.67	0.63	0.60	0.57	0.54
	50	0.87	0.83	0.79	0.75	0.71	0.67	0.64	0.61	0.57
4	00	0.90	0.87	0.83	0.79	0.75	0.71	0.68	0.64	0.61
	10	0.93	0.90	0.86	0.82	0.79	0.75	0.71	0.68	0.65
	20	0.96	0.93	0.89	0.86	0.82	0.79	0.75	0.72	0.68
	30	0.98	0.95	0.92	0.89	0.85	0.82	0.78	0.75	0.72
	40	0.99	0.97	0.94	0.91	0.88	0.85	0.82	0.78	0.75
	50	1.00	0.98	0.96	0.94	0.91	0.88	0.85	0.81	0.78
5	00	1.00	0.99	0.98	0.96	0.93	0.90	0.87	0.84	0.81

Fig. 2. New Table of Constants, I. Tijardović - V. Marinković
Slika 2. Nova tablica konstanti

The numbers (constants) from the Table are obtained by means of formula: Constant = $\sin^2$ (Interval · 90 /Duration), which was presented by Professor Ivo Sjekavica on one of his lectures.

The following two examples will show how to resolve the second and the third type of tidal problems by the means of the new "Table of Constants".

EXAMPLE I. : Find the height of tide at 12 13 on 9th October.

TIME	HEIGHT		
HW = 08 23	3.2	12 13	
LW = 14 40	1.4	- 08 23	
Duration = 06 17	Range = 1.8 m	03 50	= Interval between the given instant and time of high water (Interval from HW)

Enter Table with Duration (0617 ≈ 0615) and Interval (0350) and take out the tabulated Constant (0.67). Range (1.8 m) of tide multiplied by the Constant (0.67) will give the correction to be subtracted from height at high water to obtain the height of tide at given instant (1213):

HW = 3.2	or from LW	LW = 1.4
- (0.67 · 1.8) = - 1.2	(Interval from LW = 02 27;	+ (0.34 · 1.8) = 0.6
Height of tide at 1213 = 2.0 m	Constant = 0.34)	Height of tide at 1213 = 2.0

EXAMPLE II. : Find the time when a ship of draft 6.5 m will have 1.5 m clearance under the keel over a 6.0 m charted depth (HW = 0823 3.2 m; LW = 1440 1.4 m).

Draft	= 6.5	Duration = 0617	Range = 1.8m
+ Clearance	= + 1.5		
Required Depth	= 8.0	HW = 3.2	Fall of tide 1.2
- Charted Depth	= - 6.0	- Required Height = 2.0	Constant = $\frac{\text{Fall of tide}}{\text{Range}} = \frac{1.2}{1.8} = 0.67$
Required Height of tide	= 2.0 m	Fall of tide = 1.2 m	

From the vertical column of Duration (0617 ≈ 0615) find Constant (0.67) and in the same row on the left edge find out the interval from HW (0350).

HW = 08 23
± Interval from HW = + 03 50
At 12 13 a ship of draft 6.5 m has 1.5 m clearance under the keel over a 6.0 m charted depth.

To resolve the second type of tidal problem the officers don't need any more the Admiralty Tide Tables diagram "FOR FINDING THE HEIGHT OF THE TIDE AT TIMES BETWEEN HIGH AND LOW WATER" :

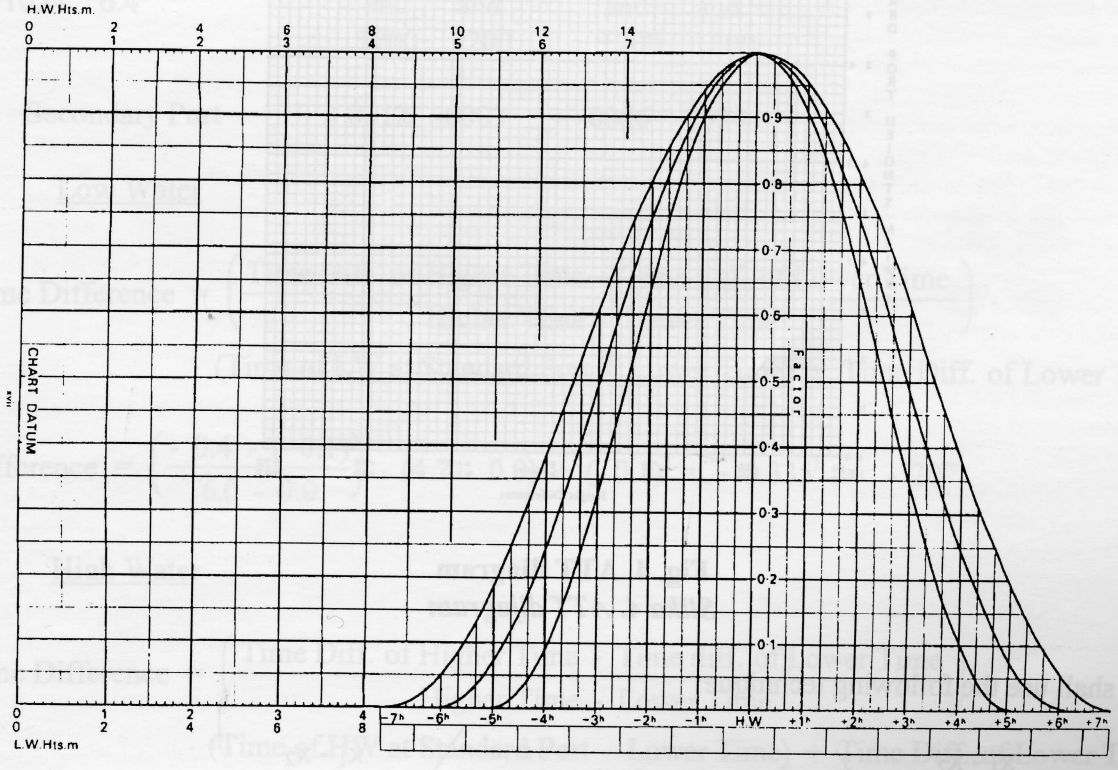


Fig. 3. ATT diagram

Slika 3. ATT dijagram

N.B. Since 1998 Admiralty Tide Tables are published in 4 volumes.

If the officers want to use the accurate technique then Admiralty Tide Tables are the most convenient publications.

In the third and fourth example we shall see how to use the new technique of tidal calculations when we need predictions for Secondary Port.

EXAMPLE III.: Find the time and height of high and low water at "Secondary Port" on 20th January from ATT.

Extract from Part I.

January	Time	M	
20	0324	0.9 = y (LW)	Standard Port
	1014	2.0 = y (HW)	Secondary Port

Extract from Part II.

Time Differences		Height Differences			
HHW	LLW	MHHW	MLHW	MHLW	MLLW
		$y_1 = 2.5$	$y_2 = 1.8$	$y_1 = 1.2$	$y_2 = 0.4$
-0015	-0025	$x_1 = -1.2$	$x_2 = -0.8$	$x_1 = +0.4$	$x_2 = -0.4$

Seasonal changes in mean level

	Jan.1	Feb.1
Standard Port	- 0.1	- 0.1 = y_3
Secondary Port	0.0	+ 0.1 = x_3

Instead of ATT diagram "SECONDARY PORT HEIGHT DIFFERENCE INTERPOLATION"

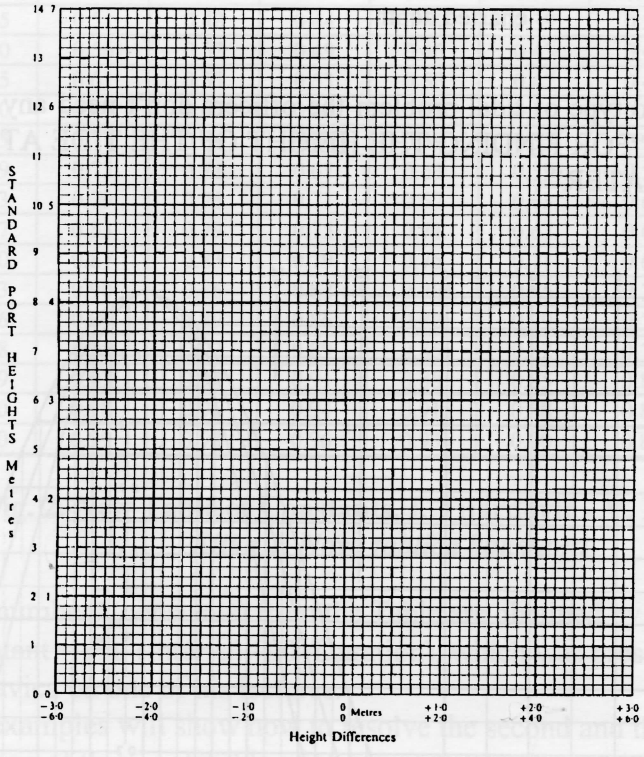
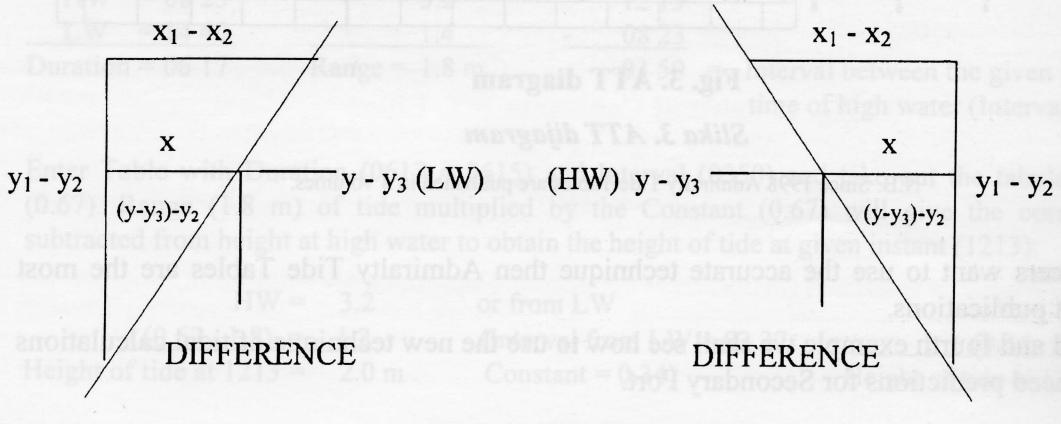


Fig. 4. ATT diagram
Slika 4. ATT dijagram

we shall use the following technique:



$$\text{Height Difference} = x + x_2 = \frac{x_1 - x_2}{y_1 - y_2} \cdot \left((y - y_3) - y_2\right) + x_2$$

LW Diff.

$$\frac{0.4 - (-0.4)}{1.2 - 0.4} \cdot ((0.9 + 0.1) - 0.4) + (-0.4) = +0.2\,\text{m}$$

HW Diff.

$$\frac{-1.2 - (-0.8)}{2.5 - 1.8} \cdot ((2.0 + 0.1) - 1.8) + (-0.8) = -1.0\,\text{m}$$

	Time (LW)	Height		Height	Time (HW)
Standard Port :	0324	0.9 + 0.1	$y - y_3$	2.0 + 0.1	10 14
Differences :	-0025	+0.2 + 0.1	+ Diff. + x_3	-1.0 + 0.1	- 00 15
Secondary Port	0259	1.1 + 0.2 = 1.3 m		1.0 + 0.2 = 1.2m	09 59

EXAMPLE IV.: Find the time of HW and LW at Secondary Port on 1st September from ATT.

Extract from Part I.

September	Time	M
1	0442	0.5
	1054	6.4

Extract form Part II.

Time Differences

	High Water		Low Water	
	0500	1000	0000	0600
	and	and	and	and
	1700	2200	1200	1800
Secondary Port	+0012	-0003	-0006	-0024

Low Water

$$\text{Time Difference} = \left(\frac{\text{Time Diff. of Higher Time - Time diff. of Lower Time}}{\text{Higher Time - Lower Time}}\right) \cdot (\text{Time of LW at Standard Port - Lower Time}) + \text{Time Diff. of Lower Time}$$

$$\text{Difference} = \left(\frac{-0.4 - (-0.1)}{6.0 - 0.0}\right) \cdot (4.7 - 0.0) + (-0.1) = -0.335^h \approx -20^m$$

High Water

$$\text{Time Difference} = \left(\frac{\text{Time Diff. of Higher Time - Time diff. of Lower Time}}{\text{Higher Time - Lower Time}}\right) \cdot (\text{Time of HW at Standard Port - Lower Time}) + \text{Time Diff. of Lower Time}$$

$$\text{Difference} = \left(\frac{0.2 - (-0.05)}{17.0 - 10.0}\right) \cdot (10.9 - 10.0) + (-0.05) = -0.0179^h \approx -1^m$$

	Time (LW)	Time (HW)
Standard Port	= 04 42	10 54
+ Difference	= - 20	- 01
Secondary Port	= 04 22	10 53

Conclusion
Zaključak

In this paper it is shown a new technique and the table with four examples for resolving practical Tidal problems. "Table of Constants" to find the intermediate times and heights between HW and LW is rewritten version of Captain Elliott's table (Brown's Nautical Almanac, 1998, page 505) with which is not only possible to find the heights (EXAMPLE I) but also the times of tides (EXAMPLE II). By using this table we don't need any more the Admiralty Tide Tables diagram FOR FINDING THE HEIGHT OF THE TIDE AT TIMES BETWEEN HIGH AND LOW WATER. By technique shown in EXAMPLES III and IV the ATT diagram SECONDARY PORT HEIGHT DIFFERENCE INTERPOLATION is needless.

References
Literatura

1. BROWN'S NAUTICAL ALMANAC 1998, Brown, Son & Ferguson, LTD., Glasgow, 1997.

2. ADMIRALTY TIDE TABLES 1989, Volume 3, The Hydrographer of the Navy, Taunton, Somerset, 1988.

Rukopis primljen: 9.6.1998.