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institute of coastal oceanography and tides
NATURAL ENVIRONMENT RESEARCH COUNCIL

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This Report was prepared before the Tidal Institute became the Institute of Coastal Oceanography and Tides.

Brief Description of Equipment

The N.I.O. Off-Shore Tide Gauge consists of a pressure transducer housed on a heavy tripod laid on the sea-bed. From this unit a heavily armoured cable rises to a buoy on the surface in which is housed an electronic circuit designed to translate pressure changes in the undersea unit into frequency changes. A radio signal, which is modulated in accordance with these frequency fluctuations, is transmitted from the buoy to a shore station whereupon the signal is again translated so as to be recorded graphically upon a potentiometer chart in a near-linear tidal scale.

In order to reduce the drain on the batteries in the buoy, a clock is incorporated in the circuit which switches on the units carried by the buoy for a period of 5 minutes per half-hour.

Programme

The equipment was assembled and tested by Messrs. Harris and Evans of the N.I.O. and with the ready co-operation of the Marine Surveyor's Department of the Mersey Docks and Harbour Board was laid in a position of 53° 28'35" N., 03°14'36"W. (HI-FIX DECCA CO-ORDS: Pattern 1 89.07, Pattern II 159.87) at a depth of 37 ft. below Chart Datum. The receiver was installed at the Tidal Institute approximately 8 miles distant. After calibration of the recorder and adjustments to the mean level position of the recorded trace, the first useful records were obtained on April 6th.

From the commencement, difficulty was occasioned by a high 'noise' level which affected day-time recording. This interference was discovered to be partly due to the effect upon the mains supply of calculating machinery housed in the Observatory, partly to radio emissions from such machinery and also from industrial and dock installations which are sited between the Observatory and the shore. By utilising maximum paper speed in the recorder and by carefully studying the quieter night-time records it was found possible in most cases to extract the true signal from the record. Unfortunately, however, the reception of the noise placed a considerable strain upon the recorder and after a few days, wear in the driving mechanism was sufficient to affect the record at times of

high water when the deflection of the recording pen was at its minimum. The result was to give an anomalous double high water on many tides. When this fault had been effectively diagnosed and new parts had been fitted to the recorder a more reliable record was given, dating from April 19th.

The reception was discontinued early in May when the buoy was cut adrift, presumably by the propeller of a vessel which passed over the armoured cable. The equipment was recovered by a Mersey Docks and Harbour Board vessel and the experiment concluded. The last tidal record was received on May 1st.

Interpretation of the record

In view of the history of the experiment outlined above, not all the aims of the investigation were achieved but every attempt has been made to derive the maximum amount of tidal information from the record available.

More weight has been placed upon observations made after April 19th than before, but the early record has not been ignored. After inspection, many of the early records have been accepted as valid and where the double high water feature has occurred, an estimate of the time and height of high water has been made, based upon the form of the erroneous record in each case. In the attached diagrams, plots which depend upon observations made prior to April 19th are shown by circles, those made after April 19th are plotted as crosses.

Results

A) Diagram I relates range of tide at the Off-Shore Station to the range of tide at the Alfred Dock Gauge. The latter is maintained by the Tidal Institute and is sited on the West Bank of the River immediately opposite to Princes Pier.

The disposition of the plotted values suggest a simple linear relationship between two variables. The fitted function shown on this diagram was derived by a least-squares solution in which a weight of unity was given to all observations prior to April 19th and a weight of 2 to all subsequent observations.

This solution indicates that

> The range of tide at the off-shore station = 0.835 times the range of tide at Alfred Dock, plus 0.52 ft.

B) Diagram II relates the high water time difference between the off-shore station and the Alfred Dock gauge to the range of tide at Alfred Dock. Here the range of tide is defined as the average of the differences in levels between the high water in question and those of the low waters on either side. The linear function has been fitted to the plotted values by eye. A tabular interpretation of this fit can be given as follows:

Range of Tide Alfred Dock (FT)	HWT difference (MINS) (Off-shore in advance of Alfred Dock given positive)
10	+ 8
15	+13
20	+17
25	+21
30	+26
35	+30

C) Diagram III shows low water time differences in a similar manner.

An appropriate tabular interpretation would be

Range of Tide Alfred Dock (FT)	LWT difference (MINS) (Off-shore in advance of Alfred Dock given positive)
10	+32
15	+16
20	+10
25	+19
30	+39
35	+59

D) An alternative method of treatment for high water time differences is given in Diagram IV where the differences are related to the time of high water at Alfred Dock. It should be noted that the procedure given earlier, which uses average tidal range, is

designed to take into account the diurnal tide is small at Liverpool, K_1 amplitude being 0.04 of M_2, so that this is unlikely to be of significance. Comparison of the relative degrees of scatter shown by diagrams IV and II confirm this view and it may therefore be that Diagram IV proves to be a more convenient technique, particularly since it conforms with procedure in Admiralty Tide Tables for secondary port differences.

A tabular representation of the data would be as follows:-

HWT Alfred Dock HRS	High Water Times at Off-Shore Station related to High Water Times at Alfred Dock MINS					
	0	10	20	30	40	50
00,12	2331	2342	2353	0004	0016	0027
01,13	0038	0050	0101	0113	0124	0136
02,14	0146	0157	0207	0218	0228	0239
03,15	0250	0300	0311	0321	0331	0342
04,16	0352	0402	0412	0422	0432	0442
05,17	0452	0502	0511	0521	0531	0540
06,18	0550	0600	0610	0619	0629	0638
07,19	0647	0656	0705	0715	0724	0733
08,20	0742	0751	0800	0809	0818	0827
09,21	0836	0846	0855	0904	0914	0923
10,22	0932	0942	0951	1001	1011	1020
11,23	1030	1040	1050	1100	1110	1121

e.g. When high water time at Alfred Dock is 1633 hrs.

Then high water time at Off-Shore Station is 1625 hrs.

E) In a similar manner Diagram V relates low water time differences to the time of low water at Alfred Dock.

A tabular interpretation of the data would be as follows:-

LWT Alfred Dock HRS	Low Water Times at Off-Shore Station related to Low Water Times at Alfred Dock MINS					
	0	10	20	30	40	50
00,12	2354	0005	0015	0026	0036	0047
01,13	0057	0107	0116	0126	0135	0145
02,14	0154	0204	0213	0222	0231	0240
03,15	0248	0257	0305	0314	0322	0330
04,16	0338	0346	0354	0401	0409	0417
05,17	0425	0433	0442	0451	0500	0510
06,18	0520	0530	0540	0550	0600	0611
07,19	0621	0631	0642	0653	0704	0715
08,20	0726	0737	0748	0759	0810	0821
09,21	0833	0845	0856	0907	0918	0929
10,22	0940	0951	1002	1014	1025	1037
11,23	1048	1059	1110	1121	1132	1143

e.g. When low water time at Alfred Dock is 1633 hrs.

Then low water time at Off-Shore Station is 1604 hrs.

F) The shortest convenient period for the application of harmonic analysis to tidal data is 15 days and, unfortunately, the observations from the off-shore recorder were discontinued before a 15 days period of completely reliable records had been received. However, with a short overlap into the period prior to April 19th an adequate span of data was made available for analysis, the central day being April 23rd. The harmonic constants from this analysis are listed below and for comparison purposes, the constants derived from a similar analysis of the same period of observations taken from the Alfred Dock tide gauge are included together with values for the same constants extracted from an analysis of 12 months records at the Princes Pier gauge, the central day of which was July 1st, 1930.

	OFF-SHORE TIDE GAUGE C.D. 23.4.63.		ALFRED DOCK TIDE GAUGE C.D. 23.4.63.		PRINCE'S PIER TIDE GAUGE C.D.1.7.30.	
	H	g	H	g	H	g
M_2	8.61.	315°	9.44	323°	10.14	325°
S_2	2.60	358°	3.11.	13°	3.29	10°
N_2	2.08	291°	2.53	308°	1.73	301°
K_1	0.47	200°	0.32	188°	0.40	193°
O_1	0.53	29°	0.38	54°	0.37	40°
M_4	0.69	196°	1.01.	206°	0.73	222°
MS_4	0.18	269°	0.39	267°	0.50	268°

Comparing the two 15 day analyses the amplitude reduction of the respective semi-diurnal harmonic constituents at the off-shore station is : 9%, 16%, and 18% giving an average of 14% which is in broad agreement with para. A above. Again the relationships between constituents are generally consistent : S_2/M_2 is .30 off-shore and .33 at Alfred Dock while N_2/M_2 is .24 and .27 respectively.

As one might expect, the reduction in the shallow water terms represented here by the 4th diurnals M_4 and MS_4 is much greater and approximates to 40%.

In contrast the diurnal constituents obtained from the off-shore observations show greater amplitudes than those given by the Alfred Dock records. It would be unwise to place much emphasis upon this feature in view of the 'noise' phenomenon described earlier. This might well have made some contribution of a diurnal character to the results.

The advance in phase of the constituents off-shore is 8°, 15° and 17° respectively for the 3 semidiurnal constituents representing an average advance of the time of tide of the order of 20 minutes. Again $S_2 - M_2$ is shown to be 43° off-shore, and so compares with a figure of 50° at Alfred Dock.

Comments upon the reliability of the results

It is difficult to make an assessment of the reliability of the results of the experiment other than to point out the possible sources of error. These can be arranged under the following headings:-

Instrumental Errors

The operation of the pressure head on the sea-bed is not in doubt so that the relationship between tidal level, pressure and transmitted frequency cannot be questioned. However, the potentiometer recorder was calibrated independently at the commencement of the experiment against frequencies generated by an oscillator. In view of the trouble experienced with the recorder during the experiment it would have been desirable to repeat this calibration at the close of the period of observation and, unfortunately, this was not possible. The designers of the equipment have, however, given the assurance that none of the adjustments made to the equipment are likely to have affected its calibration.

Reading Errors

The record was received in intermittent form covering a 5 minutes span in each half hour period. Reading procedure took the form of replotting the data at half hour intervals and of drawing a smooth curve between the plots. A record produced in this way is not as accurate as one which is produced continuously by the instrument since some uncertainty is inevitably introduced into the times and levels of turning points.

Furthermore, the 'noise' phenomenon is this case must have contributed an additional uncertainty.

Length of Record

It had originally been hoped that a period of 29 days of reliable records would be obtained during the experiment and unfortunately this was not achieved. The period of reliable record was in fact reduced to 12 days, but this was supported by a further 12 days of slightly questionable data. This short basis of the results must be remembered.

Summary

The fact that instrumental errors and reading errors are not unduly large is evidenced by the consistency of the plotted values on the attached diagrams. The degree of scatter is perhaps slightly greater than one would expect from a conventional shore-based gauge but not unduly so. The same can be said of the consistency of constituent relationships given by the analysis of the Off-Shore records when compared with those of the Alfred Dock analysis.

Finally, the value of a 15 day record can be assessed by comparing the analytical results from 15 days observations at Alfred Dock with those of one year's record at Prince's Pier. The latter record is now over 30 years old but since no evidence has been found of changes in tidal characteristics at Liverpool, the respective constants can be accepted as reasonably accurate.

The constants derived for the off-shore station can therefore be accepted as providing a useful contribution to tidal knowledge in an area where tidal information had previously been restricted to inference and rough estimates.

In view of the limitations of the experiment however, these should be accepted with caution.

Possible improvements to the equipment

The experience gained on these trials suggests that certain modifications to the equipment could be effected with advantage as follows:

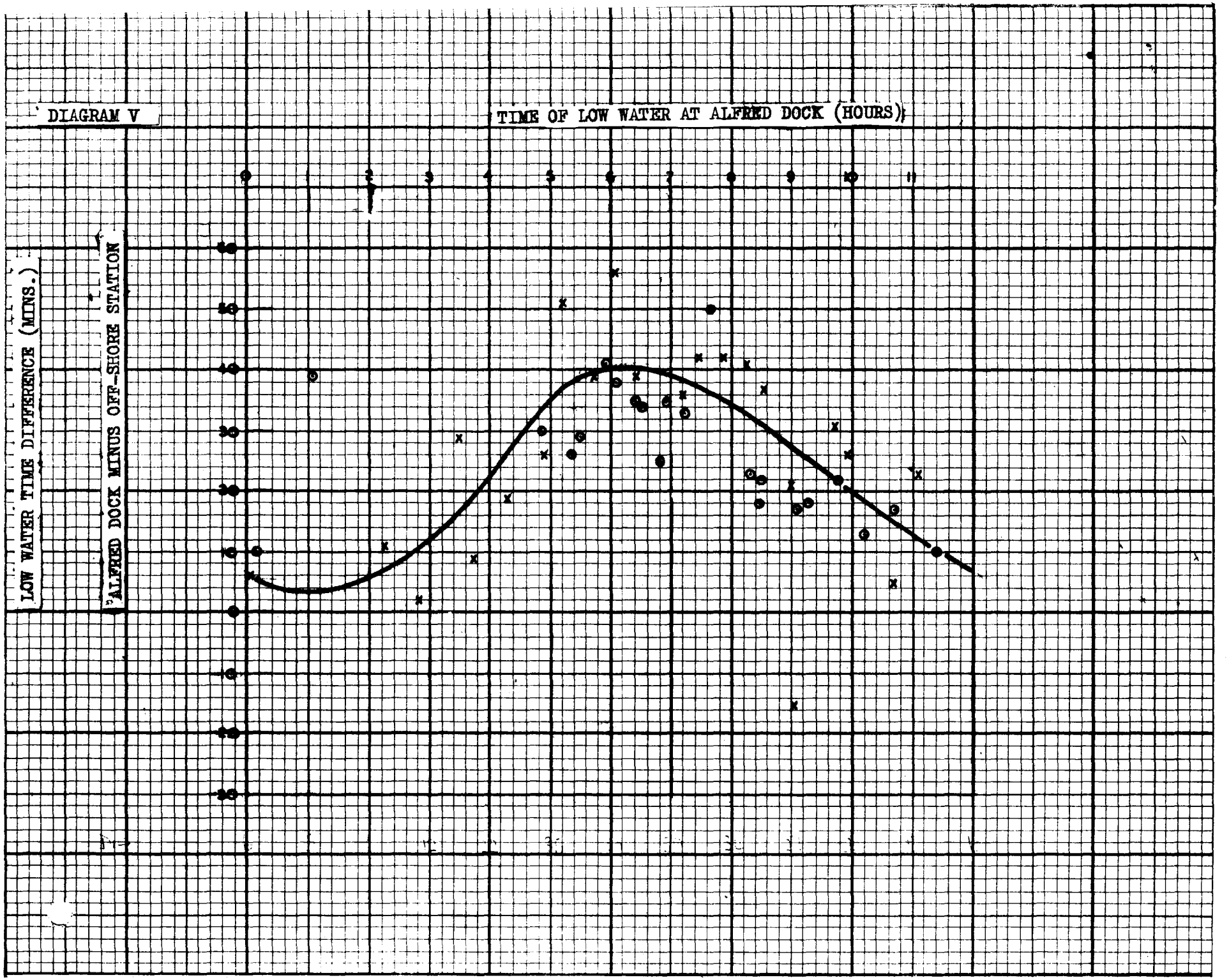
1) A high quality potentiometer recorder is required. Inadequacies in the existing recorder resulted in the virtual loss of the first half of the record and, at the close of the period, evidence existed to suggest that the recorder was again suffering from excessive wear.

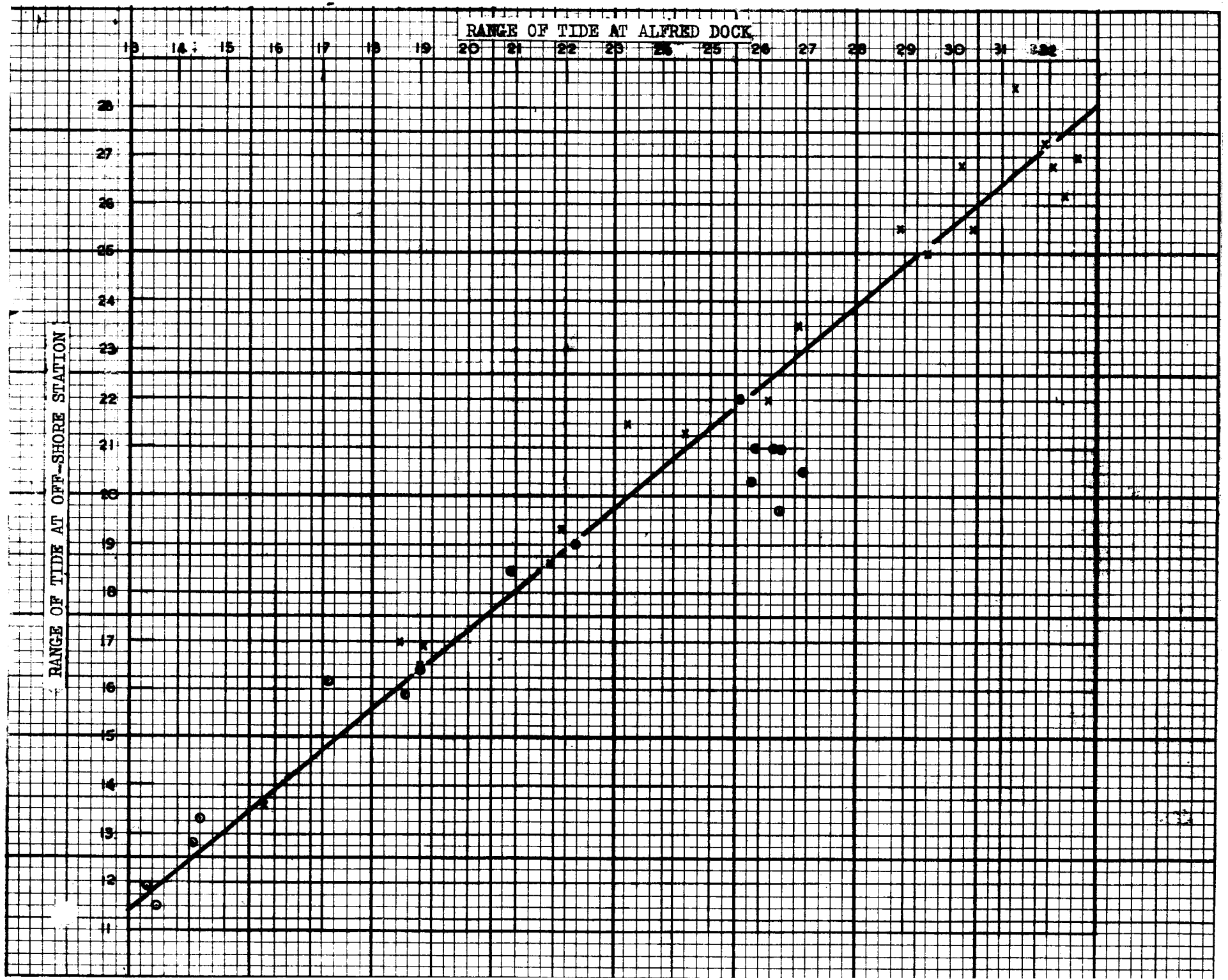
2) The transmitting and receiving electronics should be modified so as to improve the signal to noise ratio. If the equipment in the buoy could also be transistorised so that the buoy batteries could withstand continuous rather than intermittent transmission then this also would add to the validity of the record and eliminate many reading errors.

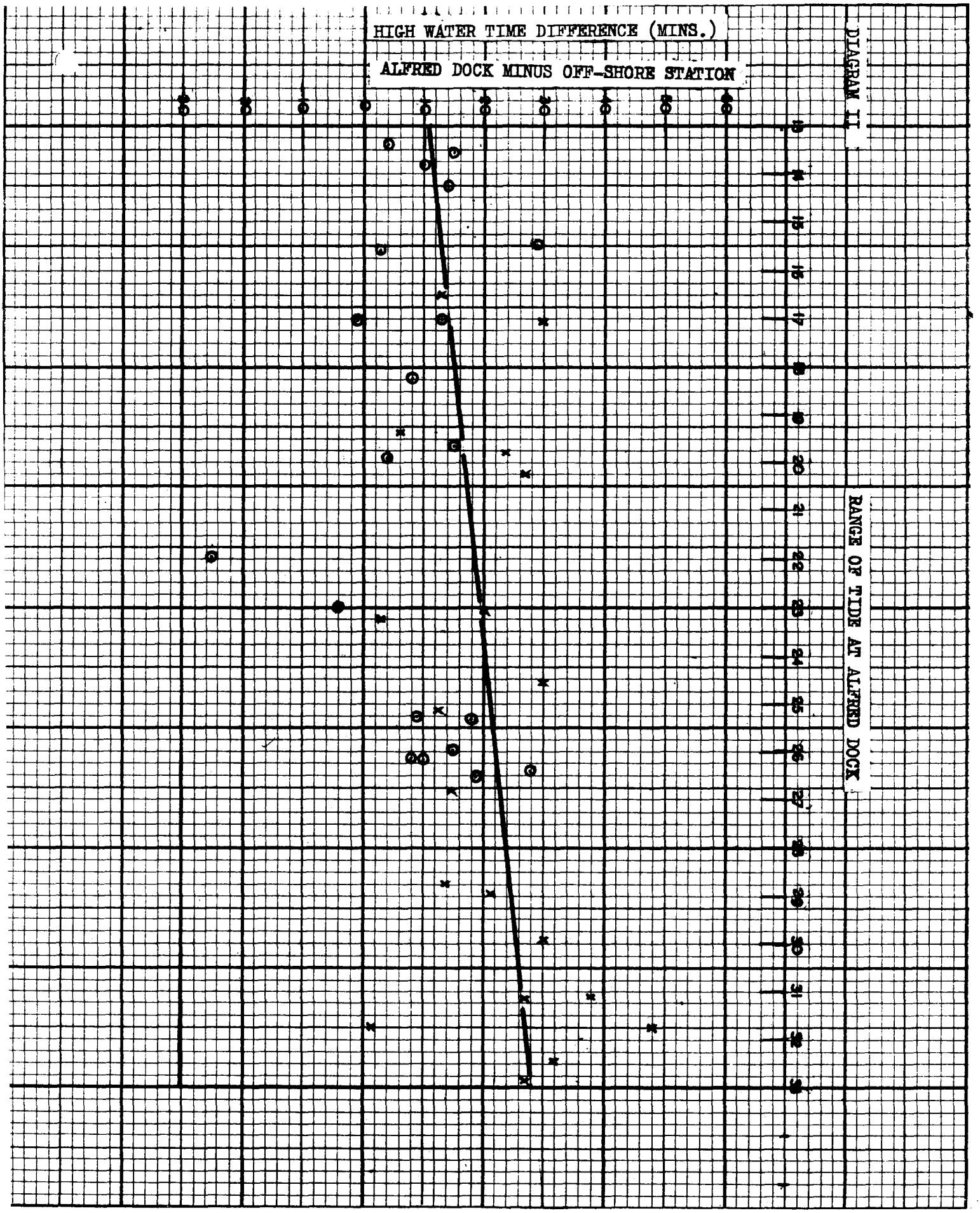
3) An alternative which would be preferred to 1) and 2) above would be to design the equipment so as to record on the sea-bed. Such a system would obviate cable damage and the risk of 'dragging' of the buoy in a heavy sea.

The above comments are not intended as a criticism of the invaluable work which the National Institute of Oceanography have put into the design and manufacture of the Off-Shore Tide Gauge. In fact these are conclusions which have come from experience gained in these trials and have been reached jointly by N.I.O. and T.I. staff. We believe the equipment to have a considerable potential and feel privileged to have been associated with this first fully operational trial of the gauge.

DIAGRAM V


TIME OF LOW WATER AT ALFRED DOCK (HOURS)
0
1
2
3
4
5
6
7
8
9
10
11
LOW WATER TIME DIFFERENCE (MINS.)
ALFRED DOCK MINUS OFF-SHORE STATION
+50
+40
+30
+20
+10
0
-10
-20
-30


RANGE OF TIDE AT ALFRED DOCK
RANGE OF TIDE AT OFF-SHORE STATION


HIGH WATER TIME DIFFERENCE (MINS.)
ALFRED DOCK MINUS OFF-SHORE STATION
RANGE OF TIDE AT ALFRED DOCK
DIAGRAM II.

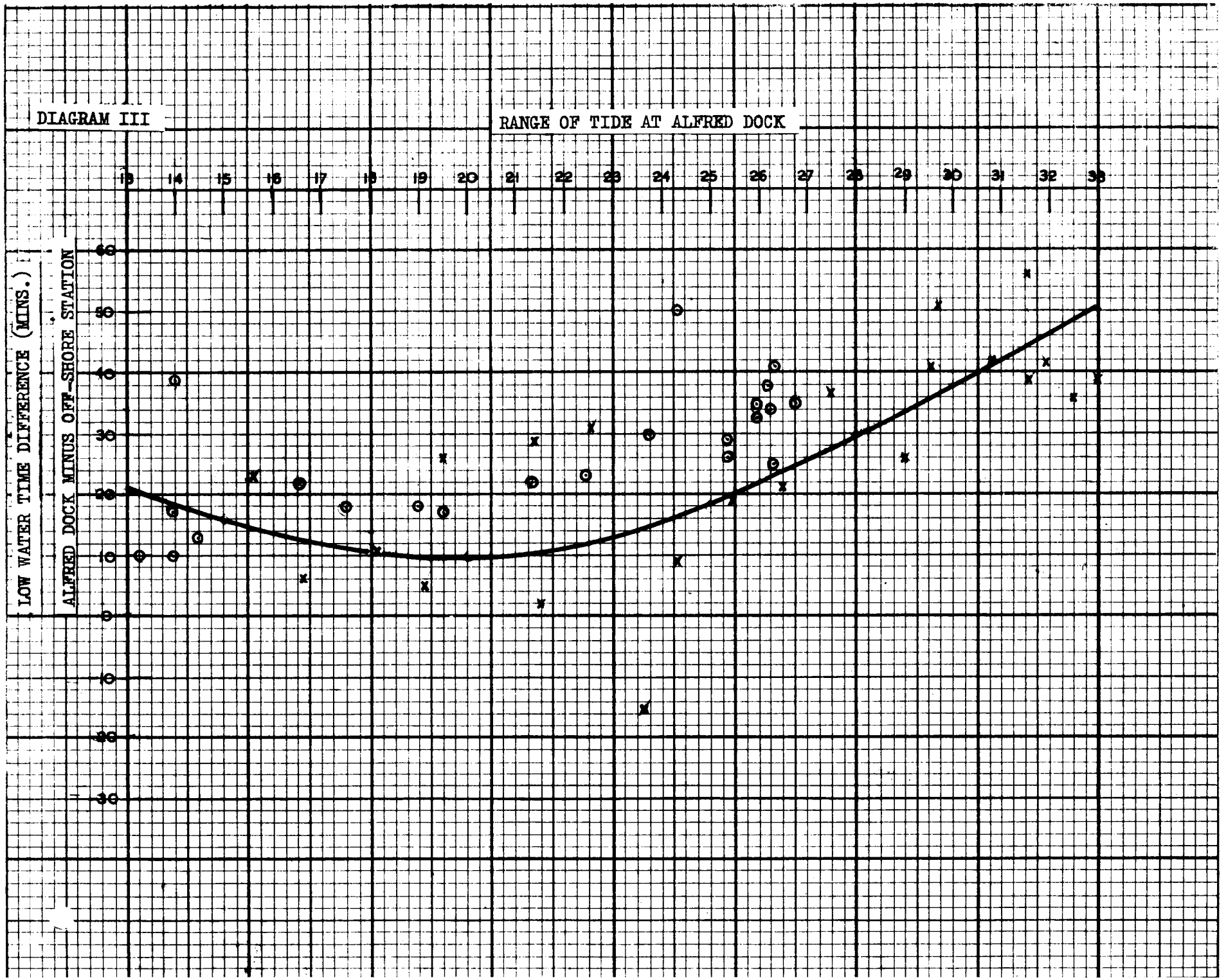


DIAGRAM III
RANGE OF TIDE AT ALFRED DOCK
LOW WATER TIME DIFFERENCE (MINS.)
ALFRED DOCK MINUS OFF-SHORE STATION
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
60
50
40
30
20
10
0
10
20
30

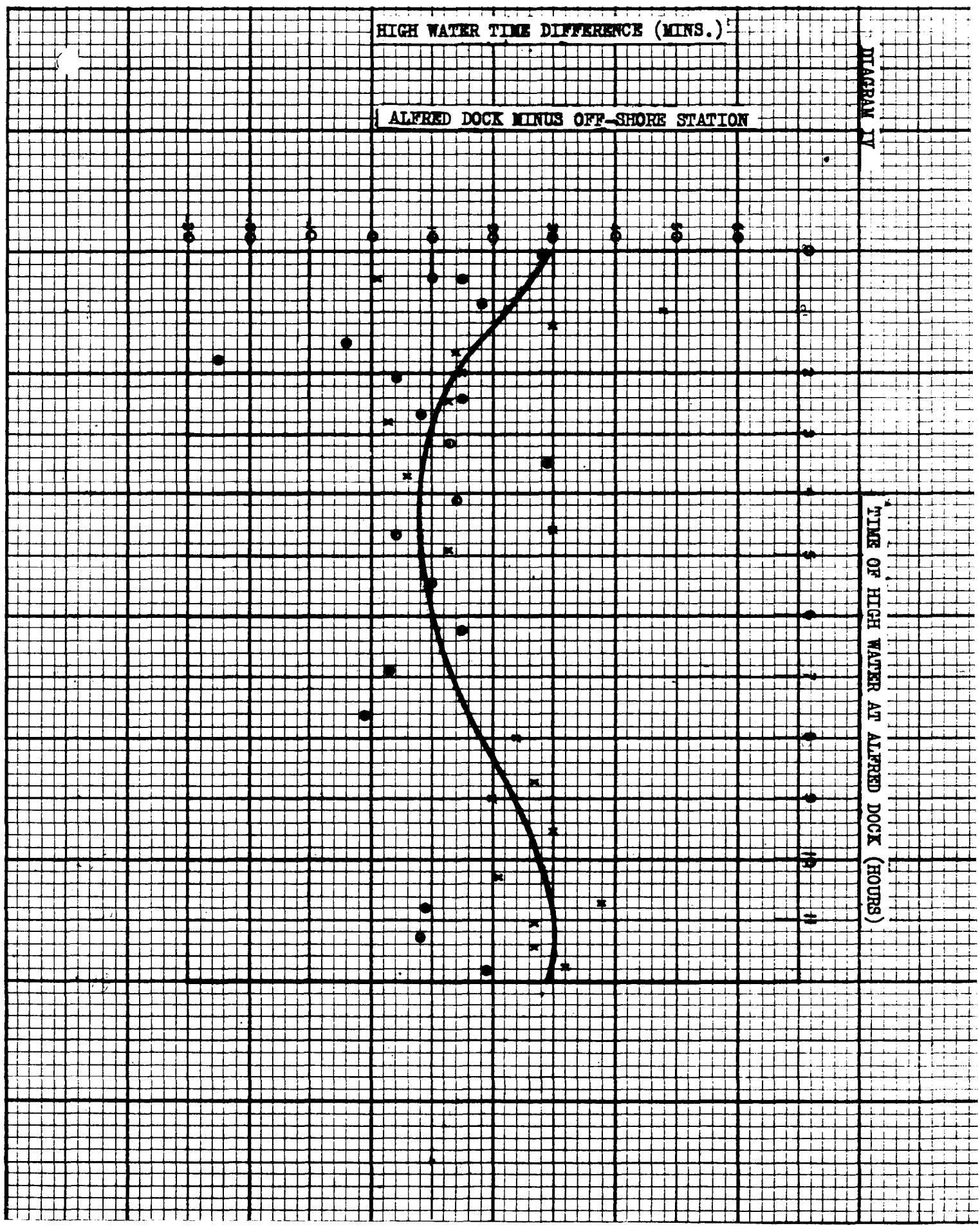

HIGH WATER TIME DIFFERENCE (MINS.)
ALFRED DOCK MINUS OFF-SHORE STATION
TIME OF HIGH WATER AT ALFRED DOCK (HOURS)

DIAGRAM IV