THE TELLUROMETER AFLOAT

by Lieutenant Commander P. C. TREHERNE

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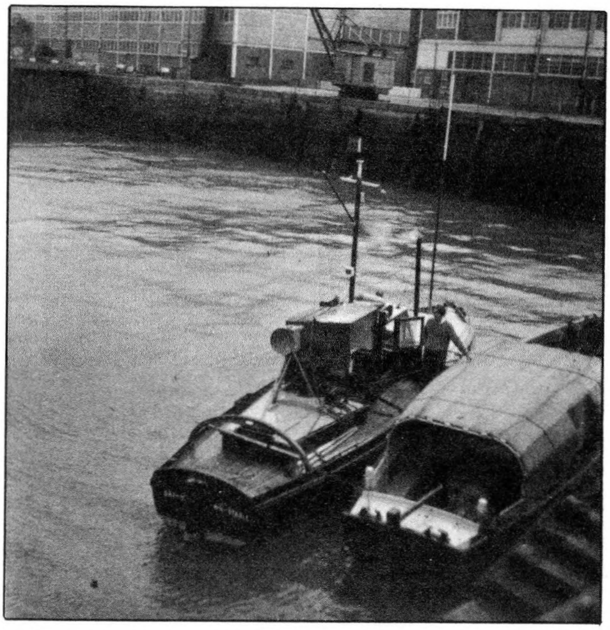
Since the introduction of the tellurometer in 1957 many words have been published describing the instrument, and on all the vairous ways in which it can and has been used. There is no doubt that it has proved to be a great success, and is now widely used throughout the world. However, very little mention is ever made as to its value afloat, and, although the need for it does not often arise, it would be useful to know exactly what the instrument can and cannot do once taken off dry land.

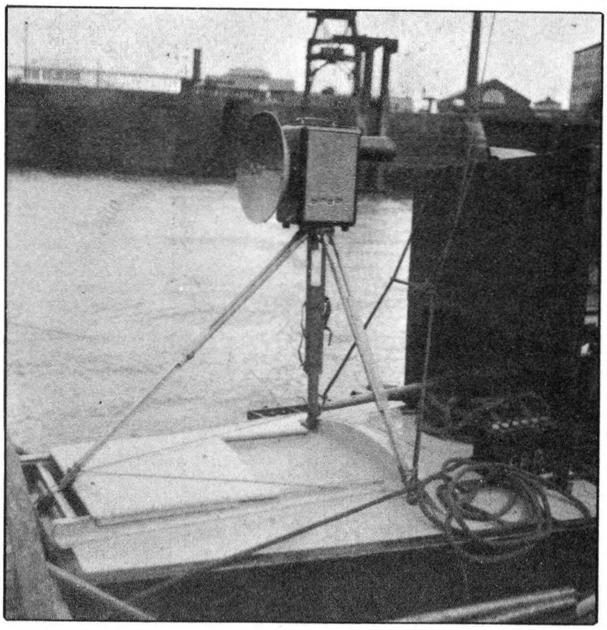
Occasionally a situation presents itself when the tellurometer could prove itself extremely useful. For example, a beacon may have to be fixed when it is not possible to set up any instrument, and a triangulation or intersection cannot be carried out; a buoy may have to be fixed precisely a large distance from shore in poor visibility; ships laying pipelines or cables may wish to fix themselves accurately when moving through the water. In fact one can imagine many cases when one could make use of the tellurometer if it were possible to do so without any appreciable error. The surveyor may already be in possession of one or two sets of tellurometers whereas to purchase or hire one of the various types of radio fixing aids available may prove to be too expensive for a small survey.

In May 1961 it was decided to carry out trials to discover exactly what the limitations were, and also to see if it were possible to operate at slow speeds. A small 36-foot tug was used for these trials, and the master instrument was set up on a tripod well lashed into position abaft the wheelhouse. The remote instrument was set up alongside the radio mast of Garrison Point Signal Station in Sheerness.

The first trial was to test the instrument with the boat secured to a buoy and no difficulties were experienced. Several sets of observations were taken at two positions, and all results agreed with those obtained from resection. The best procedure found for observing was that as laid down on form A where every alternate reading is an A+ reading. This gives 4 sets of A+ and A— readings to be meaned. Before and after each B, C and D reading there are two A+ readings and these pairs should also be meaned. The B, C and D readings are then subtracted from these means. It is essential that this be done, for, should the boat be moving during the observations, then the calculated mean value of A+ should be approximately



Motor Tug *Sally* with tellurometer secured abaft the wheelhouse and plotting table.



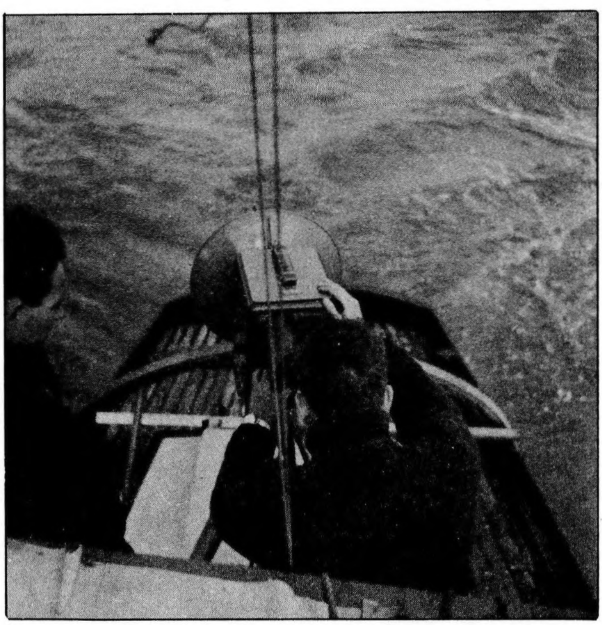
Close up of tellurometer lashed into position over the engine room.

Form A for fixing with tellurometer when at anchor.

SURVEY MEDWAY DATE 15 May 1961 TIME 1210 GMT

No 11 Buoy

Pattern	Observed Readings	A Diff.		
A +	09. 5	17. 0		
A -	92. 5			
A +	09. 0	16. 5		
D	8 0. 0		Mean A 08. 0 D 80. 0	
A +	07. 0		A-D 28. 0	
C	87. 0		Mean A 08. 0 C 87. 0	Distance 12 308 6 μ ns.
A +	09. 0		A-C 21. 0	
B	97. 0		Mean A 10. 0 B 97. 0	
A +	11. 0		A-B 13. 0	
A -	93. 0	18. 0		
A +	10. 0	17. 0		
	8 A)	68. 5		
Accepted A		08. 6		



Tellurometer being operated at two knots.

the value of A+ at the same time as the bracketed pattern is being read. There should then be little or no error in the different readings providing that the readings are taken as quickly as possible.

To make this clear, take the case of the C reading in the example. Before C was read, A+ was reading 07 and after C was read A+ was reading 09. It is, therefore, fair to assume that at the same time as C was being read then A+ would be 08, and the A-C difference of 21 can be taken as correct. Using this method no trouble was ever had in relating the 4 pattern readings to each other.

When adjusting the master instrument, it is important that the circle should be as near the centre as possible so that the sum of A+ and A— is close to 100. If this is not the case, the A+ reading would be in error, and would affect the accuracy of the different readings. It is quite easy to check this as the two A readings can be read in quick succession.

Under way

Several methods of reading were tried out with the boat moving at speeds of from one to four knots, and the procedure given below was found to be the most successful.

(1) Before commencing, that boat should be stopped so that the circle can be centred, as the A— readings are not used in the observations.

(2) Set pulse amplitude to maximum. This was found necessary mainly because of vibration in the boat. However, it does make the circle break easier to read when it is moving around at speed.

(3) With the assistance of a timekeeper, readings in the order shown on form B are taken at intervals of exactly 3 seconds. Intervals of exactly 4 seconds were tried later, and this was preferred as it then gave ample time for the remote operator to change patterns.

At this stage it might be of assistance to go back to the measuring principles of the tellurometer. When both instruments are set up ashore, the breaks in the 4 pattern circles are stationary, but once the master starts moving, the break in the A circle also moves and rotates approximately once every 50 feet or every 100 millimicroseconds of measurement. At the same time the break in the D circle moves, but at a slightly slower speed of 9/10 of a revolution every 50 feet and similarly the C and B breaks rotate at 99/100 and 999/1 000 of a revolution respectively. So in actual fact all four breaks are moving continuously, but at different speeds. As it is impossible to read all the patterns at the same time to obtain a fix, some other method has to be devised.

After several trials, it was found best to read the A+ circle before and after each B, C and D circles, and to take the mean of each pair of readings for computing the A-B, A-C and A-D differences (see fig. 1). For example, in the case of the D pattern; if an A reading were taken at equal intervals before and after the D reading, then we can say that the mean of the two A readings is the value of the A pattern at the same time as the D circle is being read. The same would apply to the C and B patterns which are then subtracted from their respective mean A readings.

Form B for fixing with tellurometer when under way.

SURVEY MEDWAY		DATE 15 MAY 1961				TIME 1309 GMT	
		Readings observed every 4 seconds					
A Revs	Observed Readings			Corrected Readings		Distances	Check Difference
A1 0	42			42	A 1		
		Mean A 89	Mean A-A1	47			
D	77	D 77	÷ 10	4.7 (a)			
		A-D 12.0	(A-D) ± a	07.3	A-D		
A 1	36						
		Mean A 182.5	Mean A-A1	140.5			
C	89	C 89	÷ 100	1.4 (b)			
		A-C 93.5	(A-C) ± b	92.1	A-C		
A 2	29						
		Mean A 278.5	Mean A-A1	236.5			
B	40	B 40	÷ 1000	0.2 (c)			
		A-B 38.5	(A-B) ± c	38.3	A-B	A1 39 042	Accepted Distance
A2 3	28			28	A2		
		Mean A 376	Mean A-A2	48			
D	41	D 41	÷ 10	4.8 (a)			
		A-D 35.0	(A-D) ± a	30.2	A-D		
A 4	24						
		Mean A 466.5	Mean A-A2	138.5			286
C	74	C 74	÷ 100	1.4 (b)			
		A-C 92,5	(A-C) ±b	91.1	A-C		
A 5	09						
		Mean A 558	Mean A-A 2	230			
B	19	B 19	÷ 1000	0.2 (c)			
		A-B 39.0	(A-B) ± c	38.8	A-B	A2 39 328	
A3 6	07			07	A3		
		Mean A 654.5	Mean A-A3	47.5			
D	92	D 92	÷ 10	4.8 (a)			
		A-D 62.5	(A-D) ± a	57.7	A-D		
A 7	02						
		Mean A 745.5	Mean A-A3	138.5			279
C	48	C 48	÷ 100	1.4 (b)			
		A-C 97.5	(A-C) ± b	96.1	A-C		
A 7	89			229.5			
		Mean A 836.5	Mean A-A3				
B	94	B 94	÷ 1000	0.2 (c)			
A 8	.84	A-B 42.5	(A-B) ± c	42.3	A-B	A3 39 607	
		Speed	3.41 kts.				

We now have an A reading, and 3 difference readings, A-D, A-C and A-B for each fix. However, these are all values for different times and positions and will have to be related to one position only. The next step is to consider the relationship between the A reading and the three difference readings. The A circle gives the reading in millimicroseconds; the A-D difference is the distance in tens of millimicroseconds; the A-C difference in hundreds of millimicroseconds, and finally the A-B difference in thousands of millimicroseconds. Therefore if, for example, the A pattern reading were to increase by 50 millimicroseconds, then the A-D difference would be 50/10 or 5 greater, the A-C difference 50/100 or 0.5 greater, and the A-B difference 50/1 000 or 0.05 greater. Now in the case of our fix under way, we accept the first A reading of each fix and plot back the difference readings A-D, A-C and A-B when the first A was taken (see fig. 2). This is best achieved by calculating how far the A reading has increased or decreased from the time the first A reading is taken to each D, C and B reading.

Form B for fixing with tellurometer when under way.

SURVEY MEDWAY DATE 15 MAY 1961 TIME 1340

Readings observed every 4 seconds

A Revs	Observed Readings			Corrected Readings		Distances	Check Difference
A1 0	82			82	A1		
D	47	Mean A 117.5 D 47	Mean A-A1 ÷ 10	35.5 3.6 (a)			
		A-D 70.5	(A-D) ± a	66.9	A-D		
A 1	53						
C	61	Mean A 188.0 C 61	Mean A-A1 ÷ 100	106 1.1 (b)			
		A-C 27.0	(A-C) ± b	25.9	A-C		
A 2	23						
B	02	Mean A 257.5 B 02	Mean A-A1 ÷ 1000	175.5 0.2 (c)			
		A-B 55.5	(A-B) ± c	55.3	A-B	A1 52 682	Accepted Distance
A2 2	92			92	A2		
D	36	Mean A 328.0 D 36	Mean A-A2 ÷ 10	36 3.6 (a)			
		A-D 92.0	(A-D) ± a	88.4	A-D		
A 3	64						
C	71	Mean A 400.0 C 71	Mean A-A2 ÷ 100	108 1.1 (b)			210
		A-C 29.0	(A-C) ± b	27.9	A-C		
A 4	36						
B	19	Mean A 469.5 B 19	Mean A-A2 ÷ 1000	177.5 0.2 (c)			
		A-B 50.5	(A-B) ± c	50.3	A-B	A2 52 892	
A3 5	03			03	A3		
D	29	Mean A 542.0 D 29	Mean A-A3 ÷ 10	39 3.9 (a)			
		A-D 13.0	(A-D) ± a	09.1	A-D		
A 5	81						
C	86	Mean A 618.0 C 86	Mean A-A3 ÷ 100	115 1.2 (b)			211
		A-C 32.0	(A-C) ± b	30.8	A-C		
A 6	55						
B	37	Mean A 693.5 B 37	Mean A-A3 ÷ 1000	190.5 0.2 (c)			
		A-B 56.5	(A-B) ± c	56.3	A-B	A3 53 103	
A 7	32						

Speed 2.63 kts.

This is done by subtracting the first A reading for each fix from the mean of the two A readings taken before and after each D, C and B reading. A seperate column is included on the form showing the number of times the A circle break has rotated since the beginning of each set of observations. These amounts of increase or decrease of A are then divided by 10 for the D pattern, 100 for the C pattern, and 1 000 for the B pattern. The resultant figures are the corrections to be applied to the A-D, A-C and A-B differences, subtracted if the boat is steering away from the remote and added if steaming towards. Finally the distances are taken out from these corrected figures.

On the form 3 fixes make up a set (see fig. 4). In actual fact the accepted fix is the first observed, the time of which is when the first A reading is taken. The remaining two fixes are really checks on observations and computations, and in some cases could be dispensed with.

Conclusions

Both methods appear to be successful although when under way one must accept a possible error of up to 1-2 feet as only the A+ reading is used. It is imperative that checks should be made fairly frequently when stopped so that the circle is centred, as any large error in the A+ reading would obviously place the difference readings in error, and this could make the extractions of the distances impossible.

An assumption made when fixing under way is that the boat is travelling at a constant speed between A readings for periods of 8 seconds, but this seems reasonable.

Five observations were taken at buoys with complete success. Twelve fixes were taken under way, and only in one was there any doubt in the correct distance. In this case the boat was travelling at 4.03 knots when vibration was excessive, and paper had to be jammed in behind the reflector dishes in order to keep the circle steady. The final answer could have been 50 000 millimicroseconds in error, but this was obviously corrected from studying previous fixes.

It does appear, therefore, that the tellurometer could become useful afloat and it is satisfying to know that it can be used under certain conditions.

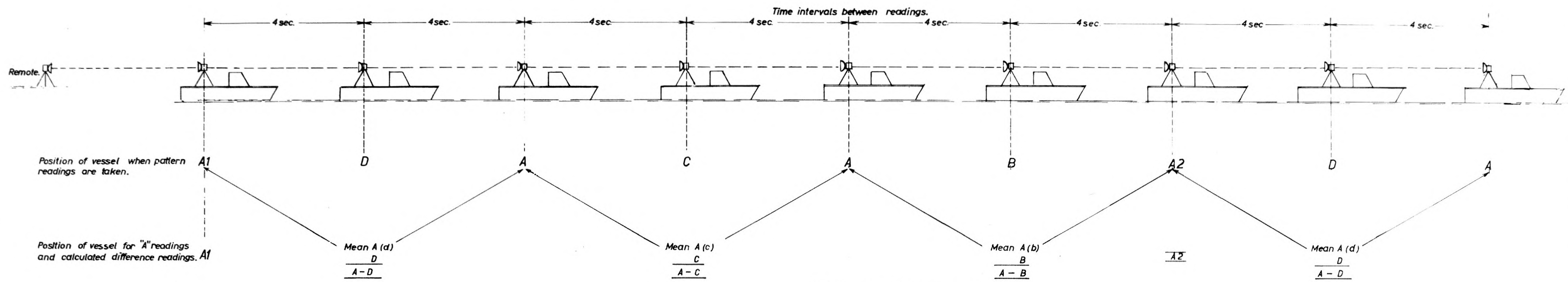


FIG. 1. to calculate difference readings

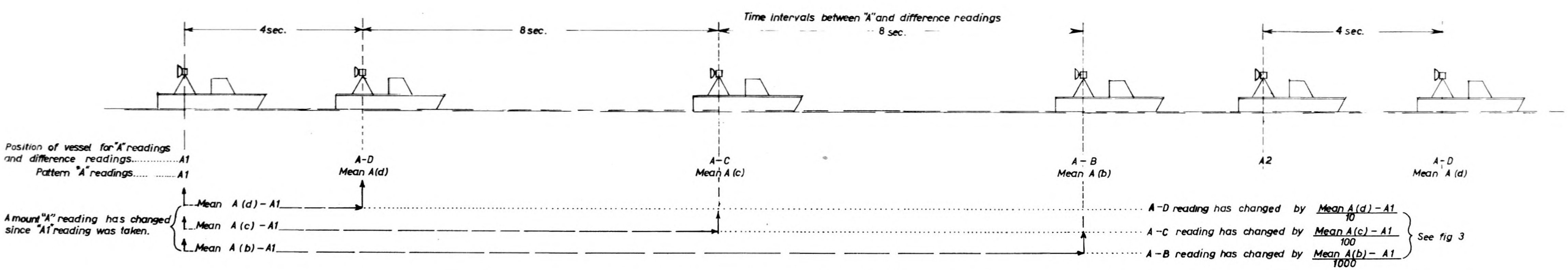


FIG. 2. to adjust difference readings due to movement of vessel

$$\frac{A}{10} = A - D$$

$$\frac{A}{100} = A - C$$

$$\frac{A}{1000} = A - B$$

FIG. 3. relationship between "A" and difference readings.

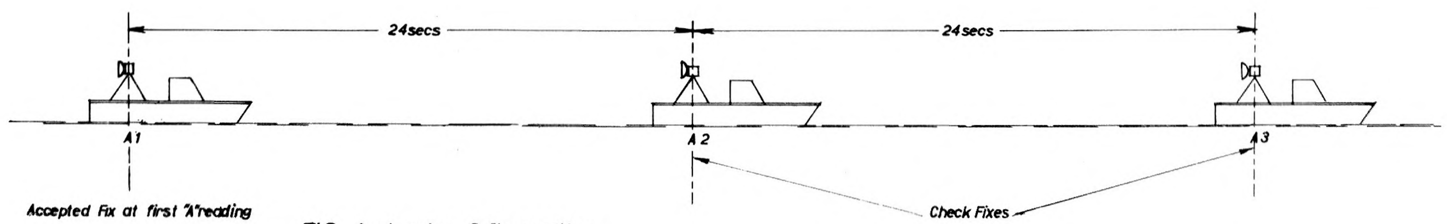


FIG. 4. showing 3 fix positions.