THE USE OF LORAN FOR SURVEY WORK IN THE PACIFIC

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(Reproduced from *The Journal of the Institute of Navigation* Vol. VI, No. 3, London, July 1953, page 307).

1. *Introduction.*

During the course of recent hydrographic and oceanographical investigations (1) in the Pacific, H.M.S. *Challenger* made considerable use of the extensive Loran coverage now provided by the United States. This marine radio position-fixing aid was particularly useful in the west Pacific in the area between Japan and New Guinea where the coverage of ground-waves is considerable. In this article an attempt is made to describe some of the work for which Loran was used, the principles on which it was used, and the accuracy expected and errors obtained. No attempt has been made to describe the operation of the system, which has been adequately covered in this Journal (2) and in numerous other publications.

2. *The requirements for Loran.*

H.M.S. *Challenger* was carrying out continuous echo-sounding and numerous other oceanographical observations, some of a daily routine nature and others of a less regular character. Almost all the observations required the position to be known as accurately as possible. Astronomical fixes were normally the only ones other than Loran available in deep water; these gave the two accurate twilight positions, perhaps a less accurate Sun-Moon or Venus sight, and a number of Sun position lines which could only be related by making somewhat arbitrary assumptions about the effect of currents, which in the areas of strong currents such as the Kurosiwo and the Pacific equatorial and counter-equatorial currents, and particularly near their boundaries, was an unreliable process. Loran frequently provided a continuously available alternative, which in many areas proved to be (relatively) very accurate. Under conditions of extensive cloud when celestial observations were unobtainable there might have been a considerable wastage of effort, but, with Loran, work could proceed uninterrupted.

3. *Uses.*

When available Loran was as used continually on passage between stations for the constant sounding and routine observations such as bathythermograph dips and plankton hauls. It became of the greatest value when the ship was engaged on other types of work, amongst which were the following:

(a) Searches of areas for dangers or *vigias* that had been reported and required confirmation and, if necessary, survey.

(b) Delinations of the shape and searches for the shoalest part of sea-mounts, some of which were of considerable extent.

(c) The survey of the Mariana trench, where H.M.S. *Challenger* located the deepest sounding so far discovered (1, 3).

(d) Surface-current observations using the normal dead-reckoning and track-made-good method.

(e) When stopped and engaged on lengthy observations in one locality, where drift over a period of hours might be considerable and positions of commencement and completion and probably during the operation, were required.

(f) Observing seismic-refraction lines for the determination of the local submarine geoglogy (1).

4. *General principles of use.*

Ground-waves only were employed as sky-waves were not considered to be sufficiently accurate; only one chain was therefore used at a time. The observations were made at regular intervals, normally once an hour when surveying or on certain current profiles, and every two or four hours when on passage. Checks against celestial observations were made at frequent intervals (at least once every twenty-four hours unless the weather prevented it) and an alignment check was made on the Loran receiver before each fix. The readings were made by one operator and the U.S. Hydrographic Office Loran tables (4) only were used to plot the readings. This is almost obligatory in the Pacific although American and Canadian charts, usually on too small a scale for accurate navigation, are published and were carried. When feasible the technique of running Loran lines, as is done with Decca, was used. With Loran this is only slightly more difficult than with Decca and gives good control. The profiles run across the Mariana trench were obtained in this way (3).

5. *Methods of use when sounding.*

When observations, particularly searches for reported dangers or *vigias,* or the surveying of sea-mounts are being carried out over a period of probably twelve or twenty-four hours in an area where the currents may be comparatively strong, a major problem is to remain in the area and to prevent the sounding lines becoming too widely separated or too congested because of an unknown set. This was particularly important in view of *Challenger*'s low speed. Using celestial observations a certain amount of control is possible during the day; at night between the evening and the next morning's star sights it is impossible except by dead reckoning and estimation. Subsequent plotting may reveal that much sounding work has been wasted effort. With Loran the difficulty of area is removed and that of the sounding lines greatly eased by the constant control that becomes possible.

The only other method of control in deep water is with dan buoys, which were used on occasion — in one case in conjunction with Loran in a depth of 5 868 fathoms. However, the dan-buoy method is subject to several disadvantages, such as the short range of vision and radar reflection (especially in higher sea states), the length of time required to lay them (the one mentioned took 1 3/4 hours), the lack of knowledge of the effect of their scope, and the uncertainty as to whether they have remained moored.

The normal method employed when using Loran for this type of survey was to keep a continuous rough plot of D.R. with Loran fixes each hour; this ensured the necessary control. Subsequently an accurate D.R. plot was drawn, normally on a scale of four miles to one inch, and all Loran position plotted on it (after checking). The general tendency of the set was usually immediately apparent and any discordant Loran fix easily spotted. The track was then corrected to the fixes and a reasonably accurate relative plot for the soundings resulted. Generally an observed position from star sights would also be available during the investigation and could be correlated with the Loran fixes to give a good geographical position.

6. *Accuracy.*

Two types of error are likely to occur with this procedure : (1) those inherent in the system, which are liable to cause variations between successive position lines, and (2) a possible geographical error.

The errors of the system are standard and affect the accuracy of each position line. They are a combination of :

(1) synchronization error between the master and slave stations, which should normally be less than ± 2 microseconds ;

(2) matching and reading errors which, with an experienced operator and a reasonable signal-to-noise ratio should be accurate to ± 1 microsecond ; and

(3) errors in the tables ; the tables are, however, calculated to a small fraction of a microsecond, so that these errors can be neglected.

Thus a maximum error for ground-waves of ± 3 microseconds can be expected ; this will produce a varying error in distance dependent on the stations being used and the ship's position relative to the station. In the majority of the cases in which *Challenger* used Loran this was within ± 1 mile and in some cases within $\pm 1/2$ mile, although the possibility of an error of considerably more had to be borne in mind. Thus the total diamond of error resulting from the use of the two positions lines in each fix was small, though not as small as could be desired. Where there were a number of readings taken, or of fixes plotted, accuracy should improve. As far as could be determined few worse errors were experienced.

With regard to the error due to synchronization, a visit was made, by the courtesy of the U.S. authorities, to the master Loran station of the Aleutian Islands' chain at Adak. All the stations are manned by the U.S. Coastguard Service and Adak, although in a very isolated position, made a typically efficient impression. Two transmitting sets are available, one operating and the other in a stand-by condition enabling a swift change to be made if necessary. Constant supervision is maintained particularly on synchronization between the master and slave stations' signals which are displayed visually and resemble the two signals obtained in a fast sweep on a receiver. If these diverge more than the two microseconds permitted, the « blinking » switch is operated and all users warned.

The possibility exists of a geographical difference between Loran fixes and celestial fixes due to an incorrect geographical position having been used for the Loran station(s) and thus for the computation of the time-difference hyperbolae. When this occurs it can be shown that the calculated time difference at any point is in error by a quantity related to the bearing of the point from the station in error. A typical correction diagram is shown (Fig. 1), the errors being in microseconds. The diagrams are given for several stations in the U.S.H.O. Loran tables. If, however, both stations are in error the correction pattern results from

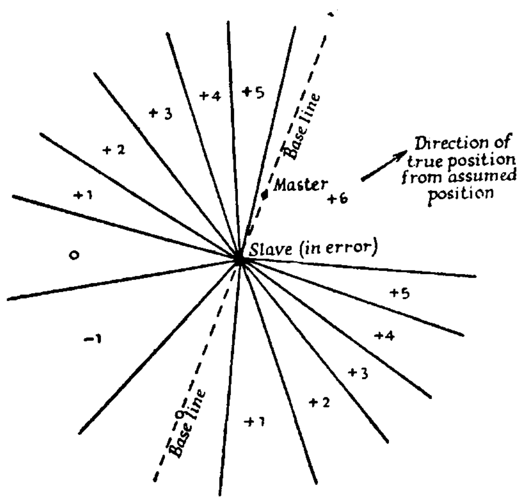

Fig. 1.
A typical correction diagram when one Loran station has an error in position.

a combination of two such diagrams and a much more complicated pattern results. The only certain thing about this is that the correction is zero along the slave station's base-line extension (Fig. 2).

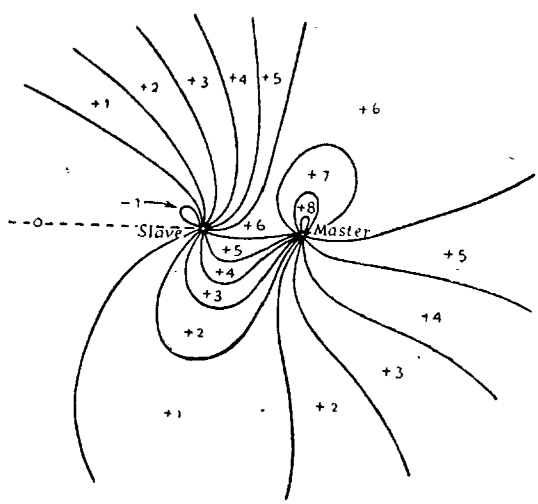

Fig. 2.
A form of correction diagram when both Loran stations have an error in position.

Comparisons between various types of celestial observations and Loran fixes were made and some examples are given in Table I. The errors were plotted and resolved to find the equivalent correction in microseconds for each pair of stations and the plotted to show their relation to the station pairs. These corrections show no pattern of regular variation, and there must, therefore, also be errors in the actual fixes, celestial and/or Loran. This is to be expected, but if allowance is made for these, certain general tendencies are apparent in the Mariana chain. Without specifying distances these could indicate displacements of H in a north-easterly direction, V in an easterly direction and S in a westerly direction (i.e. the assumed position of H is north-east of its true position, etc.). However, for more exact corrections the analysis of more observations more widely distributed through the chain is required.

Table I. *Loran fixes compared with various sights*

Date			Approx. position		Astro fix	Displacement		Corrections	
			° '	° '		'	°	HV	SV
1951	October	27	N. 11 23	E. 142 27	Mer. alt. Venus. Moon	2.6	127	10	3
	June	12	14 16	140 46	Sun-run-mer. alt.	2.4	100	17	1
	October	31	14 32	140 46	p.m. stars	1.9	138	4	4
	June	10	17 11	139 57	p.m. stars	0.9	070	4	-1
	June	10	18 10	139 24	Sun-run-mer. alt.	1.3	130	2	0
								Ko	Kf
	June	8	25 27	135 44	a.m. stars	2.0	100	-10	-22
	June	7	26 48	135 22	p.m. stars	2.0	190	-14	0
1952	April	17	27 30	131 50	a.m. stars	1.5	020	7	-4
	April	16	30 53	132 45	Sun-run-mer. alt.	1.5	066	4	-11
	April	16	30 53	132 45	p.m. stars	2.4	065	7	-17

Note. — The top half of the table refers to the Mariana's chain, the bottom half to the Japanese chain.

It can thus be seen that, quite part from errors between successive fixes, more general displacements can exist in an area. This inevitably produces problems when surveying which can only be reduced by constant position-finding by all available means. Even then the cumulative error can be considerable.

7. *Day and night differences.*

Using ground-waves only, it was found that day and night did not make any noticeable difference to accuracy. At night interference, both internal to the ship and external, decreased considerably and permitted easier matching. In daytime the signal strength increased, as would be expected, and greater ranges from the stations could be used.

8. *Conclusions.*

Loran used in conjunction with celestial observations for deep-sea hydrographic and oceanographical work is an invaluable help and is probably the best method of control that can be used today at considerable distances from the land. However, it does not produce the extremes of accuracy that are desirable and this must constantly be borne in mind. Nevertheless, those aboard H.M.S. *Challenger* found it of very great assistance and were grateful that such a facility existed in areas where a considerable amount of their work was carried out.

9. *Acknowledgements.*

The assistance of Mr. B.W. Adams of the Hydrographic Department of the Admiralty in the preparation of this paper is gratefully acknowledged. Acknowledgement is also made to the Admiralty for their permission to publish the paper, which, however, does not necessarily represent their views.

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