HYDROGRAPHY WITH ER-TYPE RAYDIST

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During the summer of 1954, the ship *Sosbee* was assigned the project of conducting evaluation tests for hydrographic surveys with the ER-type Raydist System. The *Sosbee* was then operating out of Sarasota, Fla., engaged in visually controlled hydrographic surveys in the Gulf, offshore to a distance of approximately 10 miles. Terrain, humidity, high electrical disturbances, and the opportunity afforded to complete offshore hydrography heretofore hampered by poor visibility, were influencing factors in the selection of the *Sosbee* and locale for the tests. It was believed that if Raydist proved practical under these extreme conditions, it would have demonstrated its capability for the Bureau's hydrographic operations elsewhere.

Since the contract for rental of the Raydist equipment provided for a maximum usage of 3 months, it was essential that the contract time be utilized to the fullest extent. Prior to arrival of the equipment and the two company technicians several weeks were devoted to preliminary preparations. Sites for the three unattended shore stations were selected in accordance with instructions issued by the manufacturer. Although not strictly complying with all requirements, these sites were considered the best available in the locality and capable of controlling the hydrography in the selected test area. The exact location for the antennas at each site (designated *Albert, Baker,* and *Charley*) was marked and triangulated in. As it was planned to carry on the hydrography simultaneously with the evaluation tests, the computed positions were plotted on both 1/10 000 scale projections on aluminum-mounted sheets for the evaluation tests and a new 1/20 000 scale boat sheet of the uncompleted offshore hydrography. On all sheets, 100-lane (1 812.2 m) arcs were inked in from stations *Albert* and *Baker,* the first pair of sites to be used. (The lane values for the hyperbolic system vary with distance and therefore are not given in all cases in this paper.)

During the *Sosbee* tests, a 4' by 4' by 4' plywood shelter, housed each shore station equipment (fig. 1). Shelters are bolted together, and can be easily taken apart for transportation to a new site.

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For the purpose of the evaluation tests, and in order to set the two phasemeter dials to correctly represent the ship's position, it is necessary to know the position of the vessel at several locations. For this purpose,

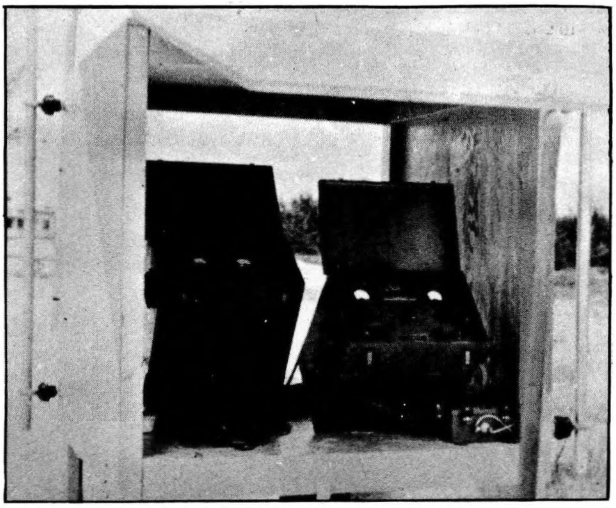

FIG. 1. — Range shore station showing instruments set up in shelter.

and also in order to determine the necessity and frequency of additional check-points required in the hydrographic test area, four Dial Calibration Stations (DCS) were established and triangulated in (fig. 2). DCS 2A, 4A, and 6A were ship stations in open water alongside fixed navigational aids. DCS 3A was a fixed position of the vessel alongside the mooring pier. The correct lane settings of both *Albert* and *Baker* dials were computed for each DCS.

PRELIMINARY TESTS

Upon completion of the ship and shore installations at *Albert* and *Baker,* the first tests were carried on in Sarasota Bay. With the vessel on station at DCS 3A, both dials were set to their correct readings. The vessel then proceeded to each DCS in the bay and dial readings were observed and compared with the computed (true) values. The results were as follows :

The equivalent linear distance in meters is shown in the following tabulation for *Baker* dial only, as this dial read range values direct. Since the hyperbolic reading of *Albert* dial represents a difference in distance involving both *Baker* and *Albert* dials, the conversion to meters has no particular significance for this preliminary test.

DCS	Difference (Computed reading minus actual reading)		
	Albert (Hyperbolic)	*Baker* (Range)	
	(Lanes)	*(Lanes)*	*(Meters)*
	Going Out		
3A	0.00	0.00	
2A	0.00	+ 0.20	+ 3.6
4A	— 0.06	— 0.24	— 4.3
6A	+ 0.23	— 0.16	— 2.9
	Coming Back		
6A	+ 0.23	— 0.16	— 2.9
4A	— 0.06	— 0.24	— 4.3
2A	+ 0.03	+ 0.20	+ 3.6
3A	+ 0.07	+ 0.09	+ 1.6

The ship cruised off station and back on again at DCS 6A prior to making the return run. The total time consumed for the test was approximately 4 hours. These results showed that the Raydist is capable of repeatability within close tolerances. Since these differences at each DCS represent corrections of the dial readings for the respective locations at that particular time, it was evident that several offshore check points in the hydrographic test area would also be required at intervals of time in order to secure true positions. This was later confirmed by results secured at DCS 2A on 5 different days.

To obtain these required offshore check points in the hydrographic area devoid of stationary objects for the ship to come alongside, it was necessary to compute the dial setting for points on each of three ranges (broken triangles, fig. 2). To reset or check dial settings at these points it was only necessary to run the ship on the range and with the observers stationed up the mast between the antennas, « mark » at the time the preselected angle would occur on the sextant. The three successive readings obtained on each range furnished a necessary check for rejections and reruns. This method was adopted after attempting to use sextant fixes taken on triangulation stations, plotting on an aluminum sheet, and scaling the required lane values directly from the sheet.

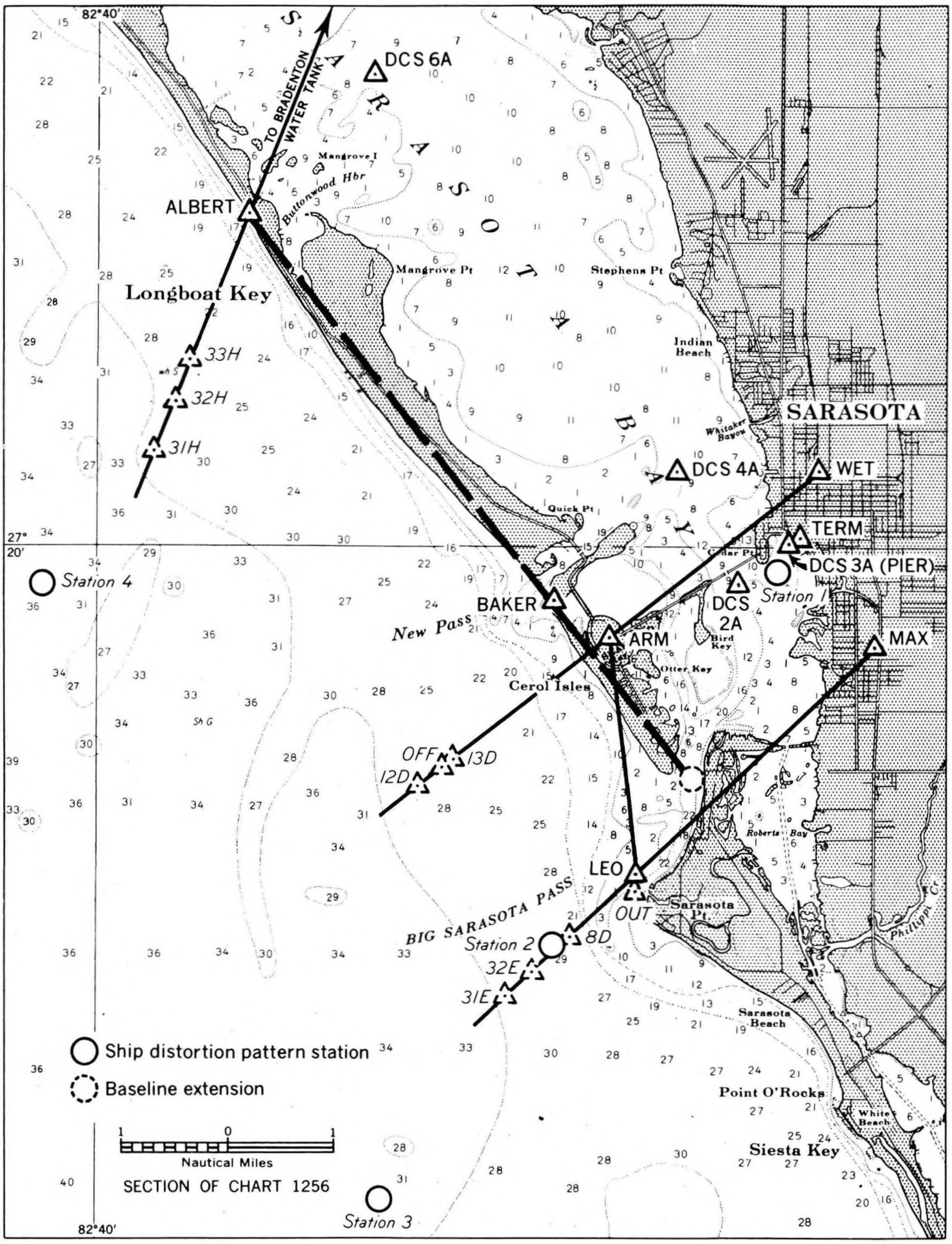

Fig. 2. — Chart of northern or first test area.

INITIAL OPERATING PROCEDURE

The method of running ranges combined with preselected sextant angles was therefore adopted as normal operating procedure for dial calibration and evaluation of instrumental error of the Raydist equipment during the period in which hydrography was in progress on hydrographic sheet No. H-8043.

At the start of each day's operations while the ship's engine was warming up alongside the pier on DCS 3A, both *Albert* and *Baker* dials were set. From the beginning, and up to the morning of July 8, the dial settings were made to agree with the computed values. The vessel would then proceed out of Big Sarasota Pass checking the hyperbolic dial reading when the baseline extension was crossed; the reading was nearly always close to its correct value of 0.00. Sometimes high electrical disturbances would cause the dial to jump or oscillate in this vicinity, therefore, to safeguard against loss or gain of a lane, an additional check was made at station *Out*. The vessel then proceeded to the offshore check stations where the dial readings were compared against their computed values. At times, all of the check stations would be visited, but more often only a few would be occupied while the vessel was completing the offshore hydrography. In all cases, the operations would again be conducted in reverse procedure as the ship proceeded back to its berth at DCS 3A.

DIAL CALIBRATION

Initial Hydrographic Test Area

An analysis of the results obtained at these offshore check stations lying in the initial hydrographic test area for the period July 2 to 8, inclusive, (with the initial dial settings at DCS for *Baker* on 233.43 and *Albert* 50.06) showed from an average of 38 values that the *Baker* dial was reading 0.17 lane (3.1 m) too low and *Albert* 0.16 lane (2.7 m) too high, hyperbolic. The maximum divergence from these values were 0.39 lane (7.1 m) for *Baker* and 0.13 (2.3 m) hyperbolic for *Albert*. These values could have been reduced by setting an appropriate rejection limit.

Therefore, starting on July 9 the initial dial settings at DCS prior to departure were changed accordingly with *Albert* dial set on 49.90, and *Baker* dial on 233.65 as influenced by a weighted mean. These initial dial settings were unchanged from July 9 to 19, inclusive. For this period the average of 36 values showed that *Baker* dial was still reading too low by 0.08 lane (1.4 m), and *Albert* too low by 0.06 (0.7 m) hyperbolic reading.

On July 20 the locations of the ship AM-whip antennas were changed to remedy jumping of the dials thought to be caused by improperly grounded ship components. DCS 3A *(Pier)* could then no longer be used for initialing the dial settings, consequently a new calibration station, *Term*, was established for the vessel alongside the pier. For the period July 20 to August 4, inclusive, the initial dial settings were made with the ship on station *Term; Baker* dial was set on 233.83 and *Albert* on 49.99. During this period the average of 45 values at the offshore check stations showed that *Baker* dial was reading 0.16 lane (2.9 m) too low and *Albert* hyperbolic reading was 0.09 lane (0.3 m) too low.

Ship Distortion Patterns

On July 12, prior to the start of hydrography, there appeared to be slight deviations in the dial readings for different headings of the ship, when on station. This was evident alongside the dock and also while running the check stations on the offshore ranges in both directions. To determine the extent of this deviation for the various ship's headings, a series of tests were run at four ship distortion pattern stations, three of which were in the initial hydrographic test area.

The tests were made at survey buoys planted with special short-scope anchoring gear. The vessel proceeded to pass close alongside the buoy on both port and starboard sides at every 45° heading. Readings of both dials

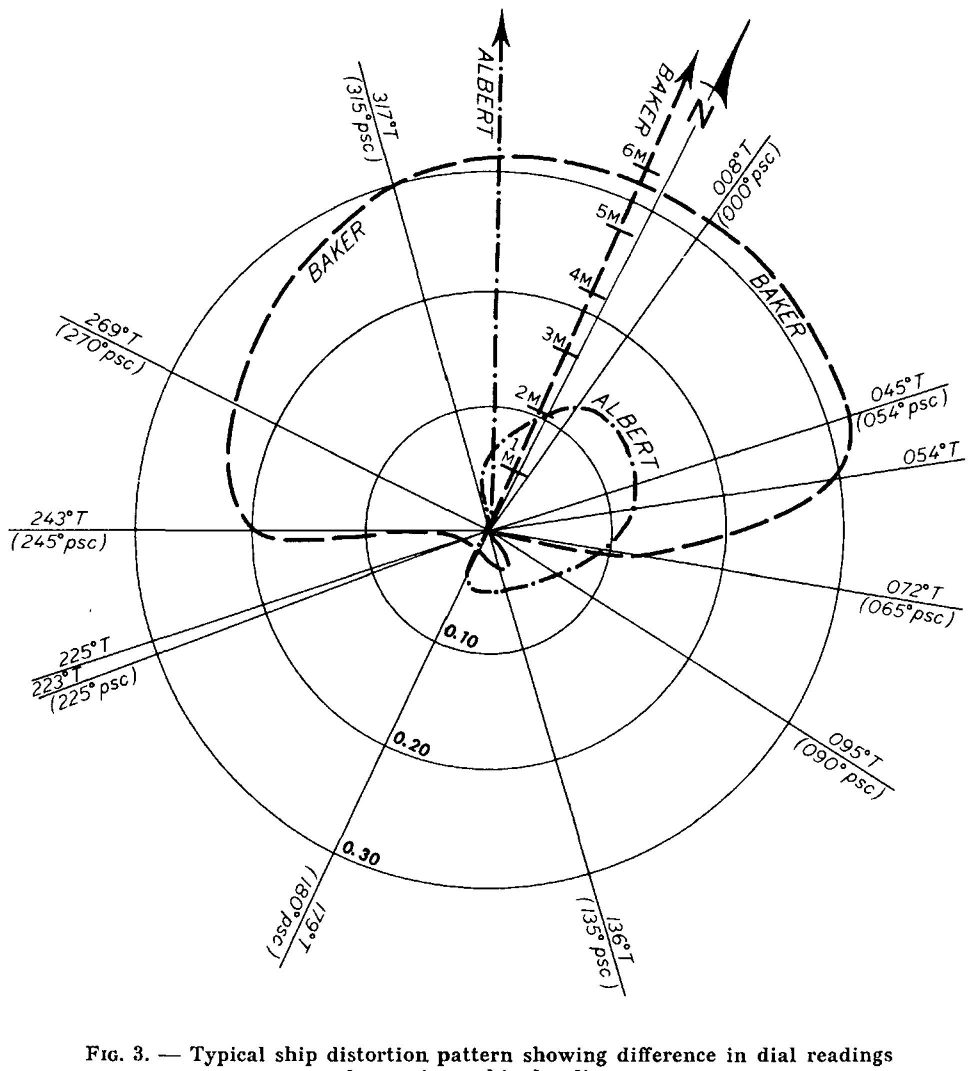

FIG. 3. — Typical ship distortion pattern showing difference in dial readings for various ship headings.

were taken when abeam the steering wheel; this point was considered to be in the center of all four antennas. By holding the lowest dial reading as zero, the ship distortion patterns were plotted (fig. 3 is an example); for *Albert* dial the readings are hyperbolic differences while for *Baker* dial the readings are range differences. At all four stations, it was noted that *Baker* dial readings were greater by approximately 0.3 lane (5.4 m) when the ship's heading was towards *Baker* shore station; they were at a minimum when on the reverse heading. These tests showed that the « electrical center » of the ship installation was actually about 9 feet aft of the steering wheel, rather than at the previously assumed physical center.

Inasmuch as these four ship distortion patterns were fairly consistent, it was, at first, surprising to find a departure in the pattern taken September 13 at station 5 at the close of the season's work. Dial readings for the range station then read up to 0.4 lane (7.2 m) greater when the ship's heading was 45° left of its shore station, than when on an opposite heading. The hyperbolic dial read 0.5 greater (or 12 m less in range) when the ship heads 90° to the right of its shore station (or directly towards the range station), than when on an opposite heading. In analyzing, it is noted that in the first tests taken at stations 1 through 4 in the earlier part of the summer, the angle between the shore stations was less than 60°, whereas in the test at station 5 the angle was in excess of 90°. In all five patterns, when the angle between the shore stations increased so did the maximum hyperbolic correction increase; this is reasonable and shows consistency.

On the ship distortion pattern, the Raydist coefficients have been plotted as differences of dial readings in lanes (range and hyperbolic). An equivalent scale in meters has been shown for the range station only; the hyperbolic station varies in metric scale with orientation, and therefore is omitted.

Second Hydrographic Test Area

Upon completion of the initial tests and offshore hydrography from Sarasota Key to Longboat Key, shore station *Albert* was dismantled and moved southward to the new site where it was placed in operation as *Charley*. Thereupon, the combination of *Baker* (range station) and *Charley* (hyperbolic station) were utilized similarly to previous procedures. Dial readings were also observed at the two test buoys placed in the new area to be hydrographically developed to the southward. This method established an interlocking tie-in of the Raydist control between these adjoining hydrographic surveys.

Shore station *Baker* was then dismantled and moved to the new site where it was placed in operation as *Del*. Thereafter, hydrography on boat sheet H-8152 and tests were resumed in this southern area with *Del* (range station) and *Charley* (hyperbolic station).

To obtain dial settings which would be truly representative of this hydrographic working area, and to minimize corrections to the dial readings, a series of seven calibration test stations were established in the offshore area where the hydrography was to be performed. The use of such a series permitted rejection of « wild » readings and establishment of accurate mean values.

On the first day of hydrographic operations in this southern area, the dials were set to the computed values at *Term* prior to departure from the Sarasota City Municipal Pier. Going out, the reading of *Charley* (hyperbolic), in crossing the baseline extension in Big Sarasota Pass, checked well with the computed value. Readings of both dials were taken at computed station *Out* and at Big Sarasota Pass Entrance Buoy No. 1, for the purpose of verifying the correct lane count. The scope of the buoy prohibited placing too much reliance on the readings, although they were helpful as a rough check. Proceeding southward to the working grounds, it was found in checking in on test buoys Nos. 1 and 2, that dial readings did not agree with computed readings; therefore, both dials were reset to the correct computed values at test buoy No. 2. Although test buoy No. 2 was placed with short-scope anchor gear, and therefore restricted to small horizontal movements, the sextant angles determining its position were rechecked prior to runs on the buoy. Runs were then made on the fixed-location test stations and correct dial settings were confirmed. Immediately thereafter, a series of dial readings were taken on a more sensitive range at five points, using fixed sextant angles on a conspicuous house cupola. These dial readings, although not computed, were used as a standard in checking the dial readings at subsequent periods and determination of applicable corrections.

DISTRIBUTION OF SHORE STATIONS FOR HYDROGRAPHIC CONTROL

Only two shore stations were used to control the hydrography on each of the hydrographic sheets H-8043 and H-8152. This is not advocated where intersecting range arcs are less than 15°. However, the time limit set on use of the Raydist equipment, and the method of overlapping with strong control from the adjoining sheet, justified the procedure. All intersecting arcs are strong throughout the area except at the inshore southeast corner of each sheet, where they approximate 10°. A quarter of a lane error in protracting would result in 1.3 mm error in position along the range station arc. Since the development of the hydrographic areas on both sheets was attained by running range arcs, the plotted position from the hyperbolic dial readings are time intercepts producing very nearly constant distances. These were extended as checks into the progressively weaker area from the strong intersection area.

On field sheet H-8043, this weaker area has been well overlapped by the strong intersecting arcs of sheet H-8152. No discrepancies in the applied soundings resulted, showing that the method is practical for this locality, and is within hydrographic requirements.

CORRECTIONS FOR HYDROGRAPHY

Since approximately 2 mm represents the space covered by a two-digit sounding on a 1/20 000 scale hydrographic sheet, it would appear that one-third of this amount, 0.7 mm (representing 14 m or about 0.8 lane) could well be tolerated without unduly influencing the horizontal position of the plotted sounding. Moreover, the inherent error of the plotted arcs, plotted under most favorable conditions, will amount to about half this value, which combined with the error in plotting a Raydist position would also justify disregard of aggregate corrections below 0.8 lane, or 14 m.

The analysis of corrections to the dial readings for the period starting with the first day of hydrography on June 29, 1954, « B » day on boat sheet H-8043, until August 4, inclusive, is contained in the preceding section *Initial Hydrographic Test Area*. These corrections did not take into account the influence of the ship's distortion pattern for various headings of the ship. If the two distortion patterns, obtained on August 3, are considered representative of the hydrographic area of that sheet, the maximum divergence from the mean values will amount to ± 0.11 lane hyperbolic (± 6.7 m) for *Albert* and ± 0.15 lane (± 2.7 m) for *Baker*. The effect of applying these values for hydrographic purposes was considered impractical and unwarranted; they were, therefore, disregarded.

On the last day of hydrography on H-8043, checks at three offshore calibration stations showed that *Baker* dial was reading too low by 0.11 lane (2.0 m) and *Albert* too low by 0.04 hyperbolic (0.5 m), all values being close to the means. Therefore, on hydrographic sheet H-8043, since the sum of corrections for either dial reading was never in excess of 0.8 lane (14 m), no corrections to the original dial readings were applied.

For hydrographic sheet H-8152, the average correction obtained over a period of 10 days showed a 0.0 lane (0.0 m) correction for the range station and + 0.34 lane correction to the hyperbolic station readings. Since the hyperbolic reading is not used for plotting, the converted range correction of — 0.68 lane (— 12.3 m) was applied in the sounding volumes in order to improve plotted position accuracy, especially where the intersecting range arcs are weak in the southeast inshore area. For the determination of these corrections, mean values of 0.25 lane for *Charley* and 0.20 lane for *Del* were used as determined at ship distortion station No. 5.

STANDARD OPERATING PROCEDURE

Although it was not so apparent during operations in the first test area, at the start of work on the second hydrographic sheet, it became evident that dial readings were sometimes appreciably inconsistent with their computed values at various localities. This variance, of over 1 lane, appears to be caused by differences of topographic detail along the wave paths. Over water areas the differences are small. Therefore, in applying the ER-type Raydist System to hydrographic surveys, the following standard operating procedure has been successfully used by the ship *Sosbee :*

(1) After ship and shore stations have been adjusted for maximum antenna loadings, ship distortion patterns should be secured at two separate representative locations in the hydrographic area. Port and starboard runs on a buoy for every 45° ship's heading will suffice for a good determination. The distortion patterns are then plotted. Where the variance is appreciable, a new electrical center of the ship should be selected from which point the fixes are secured. This will result in an improved pattern to avoid the necessity of requiring the application of these ship distortion corrections.

(2) The ship is then run on a range for which dial readings have been computed for successive sextant angles to visual-control objects. If possible, more than one series of dial calibration stations should be secured at different localities in order to be representative of the hydrographic area. The settings of the dials are made to correspond to the computed readings which have been adjusted to the mean accepted value of the ship's distortion.

(3) Once the dials have been set correctly for the hydrographic area, the vessel proceeds to at least two localities where a test buoy with short-scope anchor gear is set out. Passes are made on each buoy at several ship's headings which are recorded along with the distance off the buoy and dial readings. This information is used for future reference in the event it is necessary to reset or check the lane count against the dials during the course of hydrographic operations. These buoys have proved valuable to reset the lane count after the ship generator has either failed or has been temporarily shut down.

(4) The vessel then proceeds to its mooring pier, taking readings at points en route which can be reoccupied by the vessel. In crossing the baseline extension, the hyperbolic reading is taken as well as readings alongside the dock. It is unnecessary for the dial readings to be computed to these points; they are used only to again set the dial count prior to departure to the hydrographic area. Such conditions may not prevail as favorably elsewhere, although suitably placed test buoys will serve equally well.

(5) During the course of hydrography it should be unnecessary to check-in each day on the dial calibration points. Frequent checks are made in this area for test information. The frequency of required checks will depend upon variance of readings for the locality of operation. In Florida, during the summer months, conditions are probably more unstable, with variations of temperature, humidity, static, and storms, than will normally be encountered elsewhere.

(6) For the practical and most economical coverage of an area, hydrography with the Raydist system is best accomplished by the vessel traversing the arcs rather than attempting straight lines (fig. 4). When a voltmeter is connected into the system the pointer can be made to center at each half-lane dial reading of the range station used as the « arc » station. With the meter before him, the helmsman is then able to follow along the selected half-lane arcs within a few metres; once placed on the arc with an approximate course at the start of each arc line, no further attention need be directed to the helmsman.

EVALUATION

On the basis of the test data and over 1 600 miles of hydrography obtained with the ER-type Raydist System from the middle of June to the middle of September, 1954, the following evaluation is concluded :

(1) The system is dependable. There are few moving parts subject to wear. Components used have several hundred percent safety factor. In general, the circuits are conventional and familiar to most radio technicians. Instrument operation was very satisfactory. No time was lost due to equipment failure except portable generator trouble; this was later minimized by periodic overhauls. It is essential that the ship power be as dependable as the power used for the shore stations.

(2) The accuracy of the system is well within requirements for hydrography. By following the standard operating procedure outlined, corrections to dial readings in the hydrographic area can be minimized to the point of disregard. As the system is more accurate than shoran, it could

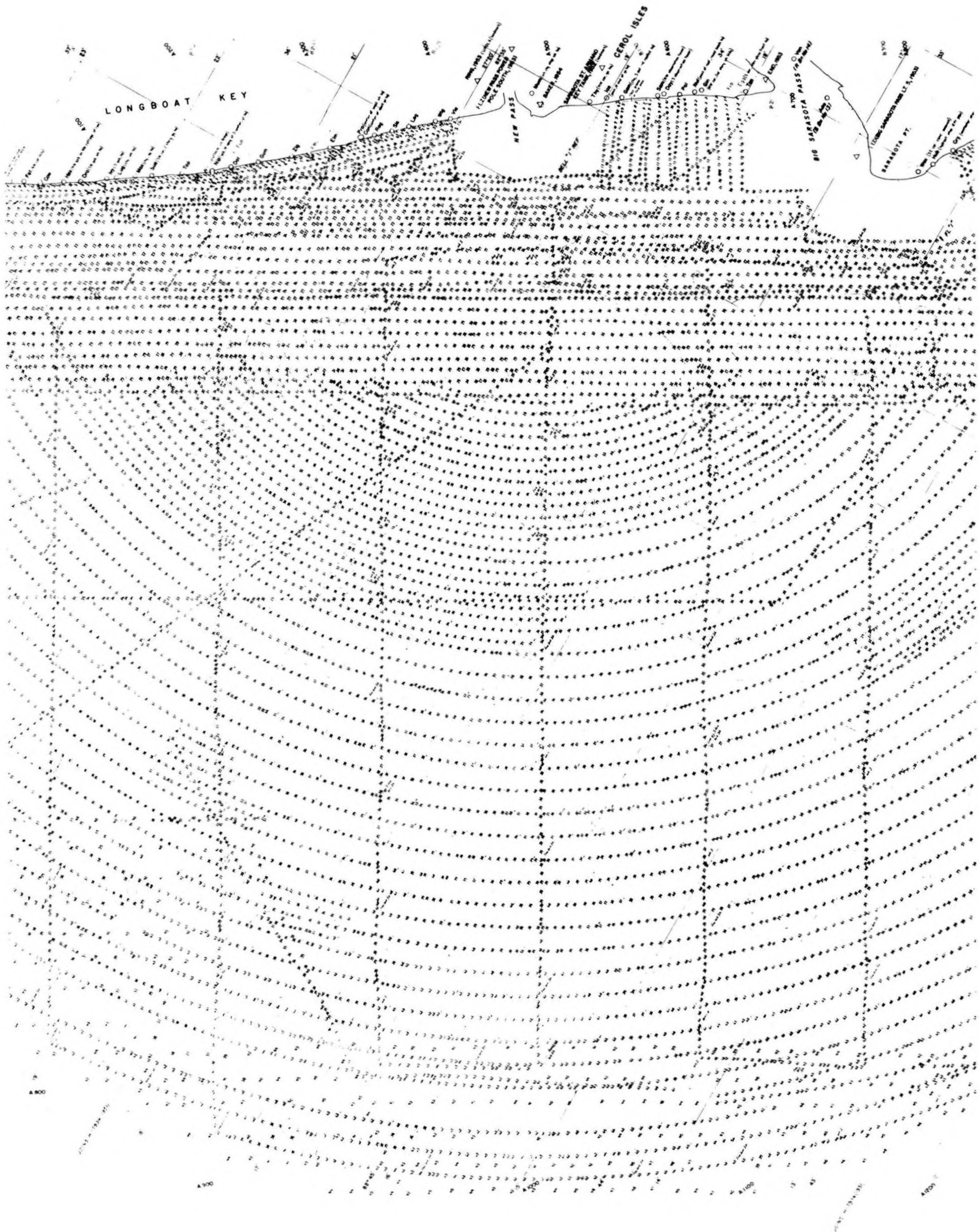

Fig. 4. — Hydrographic Survey using Raydist system of control. Note that sounding lines follow concentric arcs.

be best used for inshore surveys of harbors, bays, entrances, and so forth, where accuracy is paramount.

(3) The system operated during periods of both good and bad weather. Lightning had less effect on dial fluctuation than high static level. Only three times during unusually bad electrical storms was it necessary to discontinue operations.

(4) Operation of the unattended shore stations was reliable. Both stations *Del* and *Charley* were in continuous operation for over a month. No adjustments other than slight adjustments of antenna loadings were made; this was not essential except to give peak output performance. All shore stations (10 w) were unattended for their entire duration; standard 110-volt a.c. commercial power was used. If gasoline-driven generators are used, attendance ashore is necessary, and there would be little advantage of the Raydist shore station over the shoran shore station. It would be possible to run the system from chargeable-type batteries.

(5) Aboard ship, the time to install Raydist is about the same as that of shoran. While it is not as essential that the antennas for Raydist be elevated as high as those for shoran, it is still important, for better operation, that the FM relay antennas be as high as possible.

(6) A little less time is required in setting up the ground station for Raydist than for shoran. Assuming the shelter problems about the same, the time of erecting the shoran mast is nearly offset by the time to put in the Raydist ground system. The Raydist has the advantage where a shoran personnel shelter is required.

(7) Although tests for maximum range of this system were never concluded due to storms, the following distances in nautical miles were obtained aboard ship from the range and hyperbolic shore stations, respectively, on three different occasions : 11.1, 13.9, and 14.1 and 18.6, 14.2, and 16.0. It is believed this low power Raydist system is capable of operation up to 20 miles, provided the atmospheric noise level is low.

(8) While the ER-type Raydist controls hydrography well, it has certain unsatisfactory features which make operations difficult.

(a) At fix time both range hyperbolic phasemeters are read. These readings, along with the baseline distance, are used to compute the range distance to the hyperbolic station. Range and hyperbolic station range distances are then used by the hydrographer to plot the position in the same way as EPI and shoran. The time required to make these computations and to pass the data along to the hydrographer is about 30 seconds. This loss of time can be serious in controlling the vessel on a large-scale survey, unless arc-hydrography is used. The manufacturer recognized this weakness and has revised the system with a new DM-type Raydist which is not hyperbolic, but furnishes position data from both dials directly in terms of range.

(b) Two men are required to read the phasemeters at fix time. This is primarily because of the fast moving dials. Due to their size and arrangement, the small dials are difficult to read. Even with two men reading the instrument it is only possible to estimate the reading from the range phasedial; therefore the method of conducting hydrography on the range arc was used to overcome this. If the system operated on a lower radio frequency, wider lanes would result and dial speed would be reduced. Also, the wider lane spacing requires less accuracy in the fix used to set the phasedials or checking the lane count. It is only necessary to identify the whole lane; the phasemeters actually indicate the fractions of the lane. The lowest frequency now obtainable would mean that the dials would turn only about one-half as fast as they now move, which is still too fast for one man to read. It has been proposed that the dials be geared down to move slower, with corresponding loss in reading accuracy. Also, it was proposed that the phasemeters print out their readings.