SOME ACCURACY TESTS WITH HYDRODIST AND HI-FIX FOR POSITION DETERMINATION IN HYDROGRAPHIC SURVEY (*)

(Spring 1960)

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GENERAL

Positioning in offshore survey has become much more accurate and the efficiency of the offshore operations has been greatly increased through the use of electronic methods. Great advantages also in inshore surveys and those within sight of land could be gained if an easily transportable electronic system for accurate positioning were available.

The intricate waters around the coast of Sweden call for very extensive surveys where such new methods would be very profitable. That is the reason why the Swedish Hydrographic Department, amongst several other organizations, has taken an active part in encouraging the appropriate industries to develop systems, as well as in the testing of such systems. We are very pleased to have had the opportunity to test prototypes of the two excellent systems mentioned in the heading, in close cooperation with the manufacturers.

The archipelago outside Stockholm is very suitable for such tests, for two reasons : firstly, a dense and accurate net of triangulation points, partly on small islands and islets, permits accurate geodetic positioning at rather long distances without interferance from large land masses in the path of the radio waves; and secondly, poor ground conductivity exists, if needed, which creates realistic testing conditions.

Description of the two systems

Generally speaking, Hydrodist is a two-range system (developed from the well-known Tellurometer) of 10 cm wavelength. Signals are transmitted

(*) A mimeographed report containing the results in greater detail but with a similar text was issued in September 1960 by the Swedish Hydrographic Department, and was distributed to States Members by the IHB. A limited number of copies are still available for institutes desiring details of the results.

from a double master station on board the ship or launch to two remote stations ashore placed at known points within sight (or nearly so) of the ship.

The Hi-Fix is a further development of the well-known Decca Navigator System using any one of five frequencies (wavelength 160 m) of about 1 900 kc for its consecutively alternating signals from the master equipment (on board the survey craft in the two-range system, ashore in the hyperbolic system) and from the two slave stations.

Further descriptions of the systems have been given respectively in Supplementary Papers 2 and 3 published by the IHB.

Organization of the test

The project engineer was state hydrographer A. THUNBERG, head of the Research and Development Section of the Swedish Hydrographic Department.

The survey ship *Nils Strömcrona* (fig. 1) of about 150 tons deadweight with its crew of 3 surveyors and 8 men was assigned for the trials. Additional personnel from the Department, another survey ship and specially engaged surveying students cooperated.

From the two manufacturing firms involved, one sent two specialists and the other ten, to participate in the work.

During the tests many foreign and Swedish specialists (30 and 50 respectively) took the opportunity to study the equipment in operation.

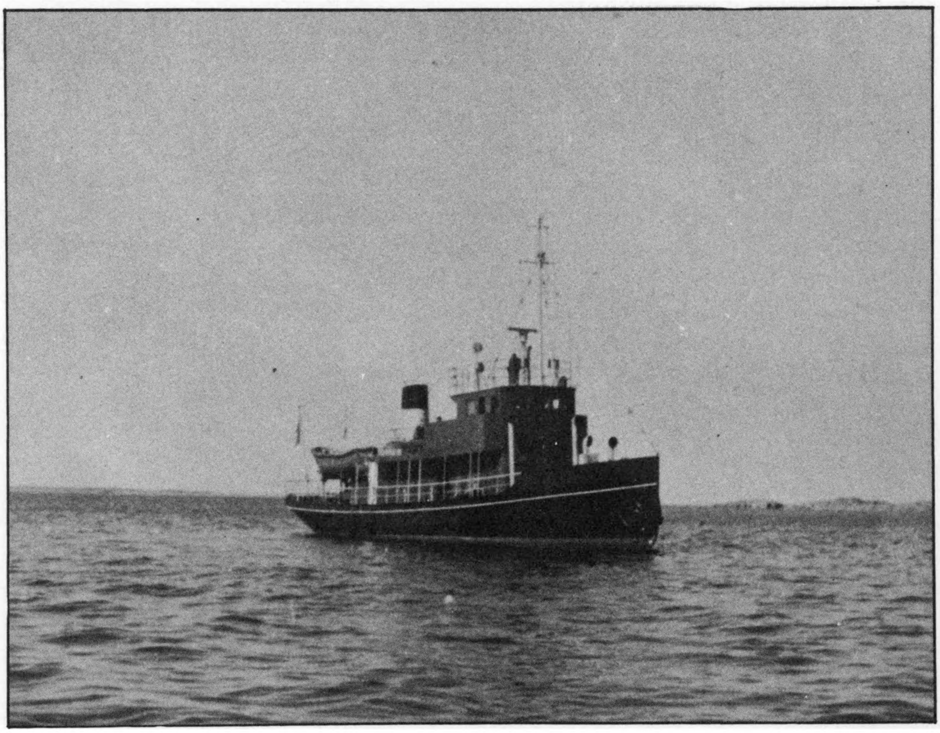

FIG. 1. — The survey ship *Nils Strömcrona*.

Test area

About 60 kilometres NE from Stockholm there is a rather open part of the archipelago east of the main islands Rådmansö, Blidö, Möja containing many small islands and islets. The test area was extended out into the open sea, and for certain range tests we also included the south-western part of the Åland Archipelago, another 50 km ENE.

In the area a dense geodetic triangulation net with a standard error of about ± 0.2 m exists.

For detailed tests, certain districts were chosen in which a sufficient number of triangulation point beacons were established, from which suitable triangulation stations were selected as theodolite stations or remote stations for the Hydrodist, etc.

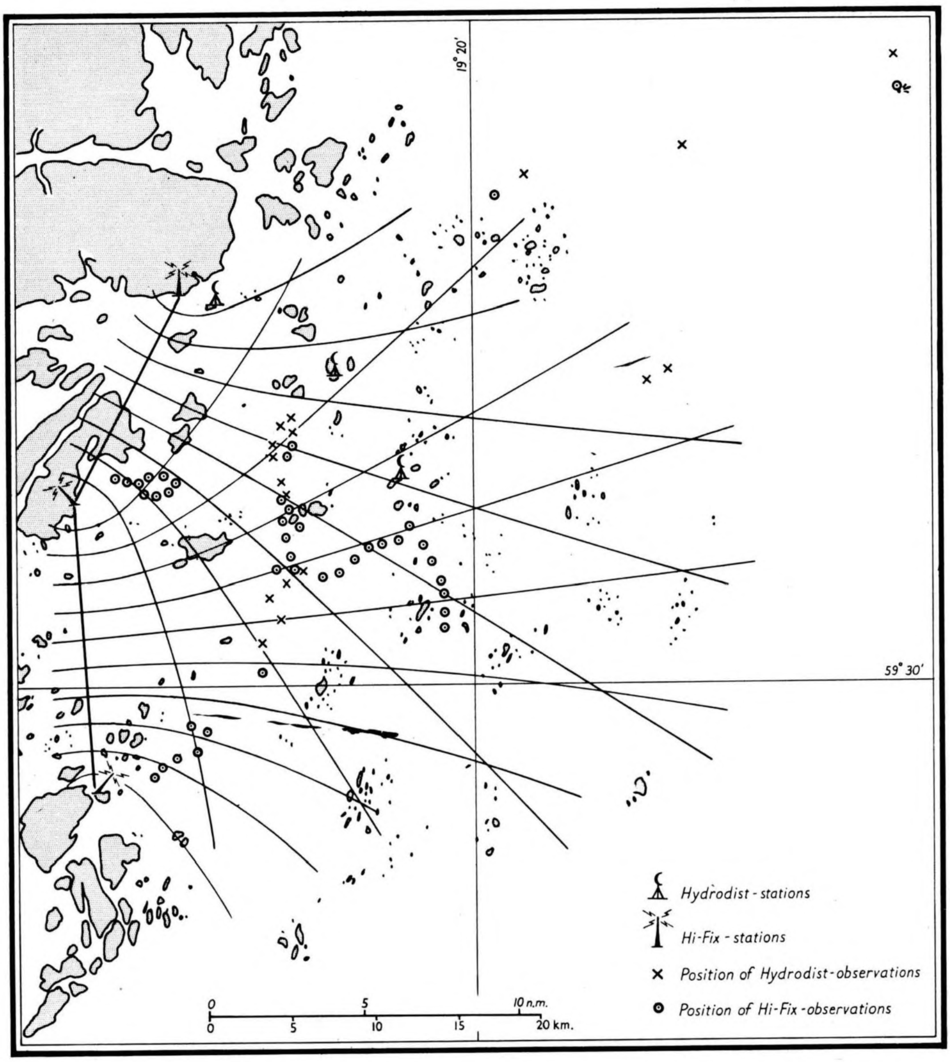

FIG. 2. — The test area with Hi-Fix stations and Hi-Fix lattice as well as various Hydrodist sites and the location of check points.

Earlier in the spring, before the ice had disappeared, the sites for the Hi-Fix stations were selected using aerial photographs, inspected on the ground, and accurately positioned by geodetic survey (point standard error ± 0.06 m) so that the hyperbolic pattern (demonstrated in fig. 2) could be calculated and plotted at a scale of 1/10 000.

General dates for the tests

The Hydrodist equipment arrived in Stockholm on 26 April 1960 and was fitted in the ship (figs. 3 and 4) on the 27th, after which our personnel was trained in operating the instrumentation. The real tests started on 2 May and went on, with a break for the week-end, until the 11th. During

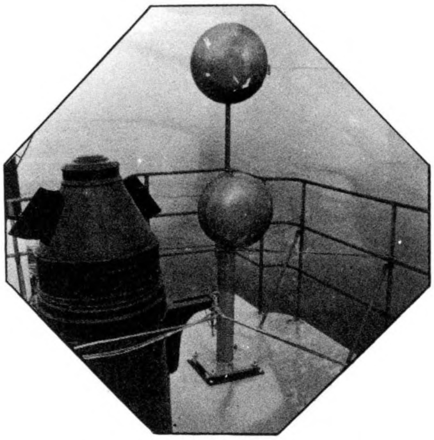

FIG. 3. — The Hydrodist antenna (prototype) on top of the bridge.

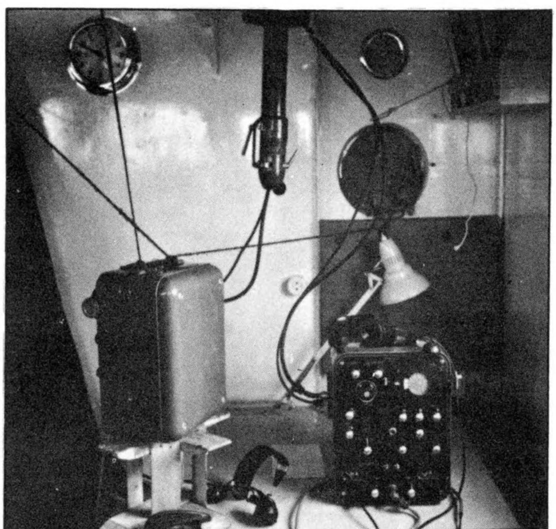

FIG. 4. — Temporary installation of the two Hydrodist ship stations in a corner of the wheelhouse.

the last two days some limited operational trials (buoying out for close running sounding lines), as well as a functional test at a high speed (25 knots), were performed.

The Hi - Fix shore-station equipment, mounted in small caravans (fig. 5), arrived in Stockholm on 16 May and the next morning it was

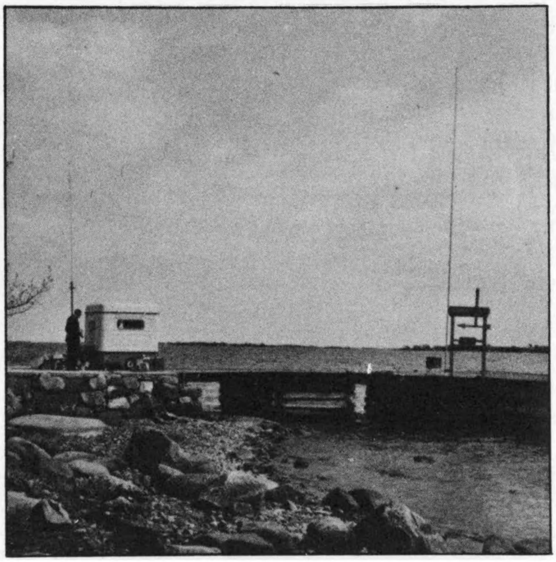

FIG. 5. — Hi-Fix master station in a caravan with the aerial on the jetty.

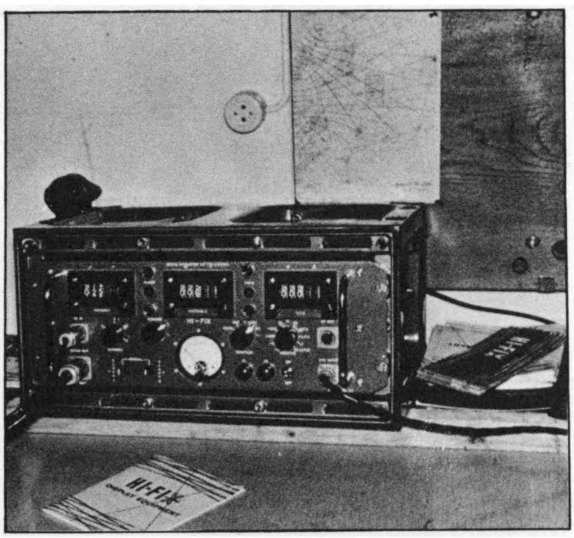

FIG. 6. — Hi-Fix receiver on the chart table in the wheelhouse.

transported to the shore-station sites. This was found to be somewhat complicated for the two slave stations, as one site was on a flat rock on an island without roads, and the road to the other site was so bad that the equipment had to be unloaded from the caravan, carried to the site and placed in a tent. Further equipment was received on the 22nd and the entire system was ready for trials in the evening of the 23rd (fig. 6). With breaks for week-ends, the trials went on until 2 June. At the end of that period high speed trials were carried out with a speed of up to 22 knots.

During the trials, preliminary calculations had to be made using an electronic computer in Stockholm (Facit EDB). The personnel involved worked almost unceasingly both day and night in order to take full advantage of suitable weather, etc. The total number of ship hours was about 200; the distance covered by the ship 1 500 kilometres; and transport by speedboat about 1 000 km.

Check measurements and their calculations

Radio communications between the ship and the theodolite stations (fig. 7) guaranteed coincidence of all theodolite readings as well as sextant

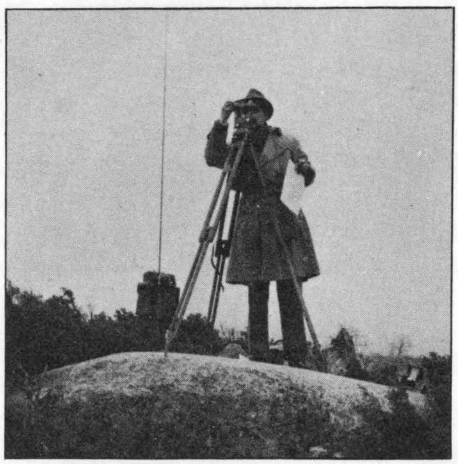

FIG. 7. — Theodolite check measurements, UKV radio behind.

readings normally within about half a second. As the ship was stopped for each group of test points and was only allowed to move with wind and current, small losses in coincidence could not cause any great errors. On the other hand, bad visibility sometimes caused poor sighting both to and from the ship. As far as resources and conditions permitted, the measurements were made with an excessive number of observations. In some cases both sextant measurements from the ship and theodolite measurements from shore were used, *indicating an accuracy at least five times lower with the sextant method.* Great care was taken to avoid longer sights than 6 km. The quality of all check measurements has been estimated with an excessive number of observations and is listed in the tables of full results as an *estimated standard error*. On an average, these standard errors in the theodolite measurements were of the magnitude $\pm$ 0.3 m.

As the tests were somewhat delayed and involved the employment of a rather costly group of specialists and material, the principle adopted was to take the maximum number of measurements as often as possible. This naturally resulted in measurements of varying standards and also in a large number of readings. A rough estimate gives about 500 checkpoints, each one determined on an average with 2 or 3 sextant readings and/or 2 to 3 theodolite readings. Due to the varying standards, which called for an individual analysis of each series in order to exclude poor measurements, electronic computation could be used only to a limited extent. The calculations took about 300 man hours and 100 electronic-computer minutes.

Further remarks on check measurements will be found below.

OBSERVATIONS ON THE PERFORMANCE OF HYDRODIST

The shipboard installation was temporary, but a permanent installation should be quite simple and the space required not very great. The *two* operators must have comfortable working conditions as the work is rather tiring.

Very soon it was realized that the hand-operated cursor should be motor driven and semi-automatic.

The rotation of the antennae was also rather difficult, in spite of the rather wide beam.

Both these drawbacks in the prototype and some others will probably already be eliminated in the first series. A need for a remote display in front of the surveyor (who was also the officer on watch) was also found, and might easily be arranged in combination with a semi-automatic cursor.

FIG. 8. — A Hydrodist shore station. The attendant is just talking with the ship.

The shore stations (remote) were very easily transported (fig. 8) and could be mounted within a few minutes. The storage battery (a normal

TEST-VALUES. Trials with Decca Hi-Fix and Hydrodist in Sweden 1960.

Date	Time	Hydrodist observations		From theodolite observations computed values						From sextant angles computed values					
		Remote 1	Remote 2	Remote 1	Remote 2	Diff. 1	Diff. 2	$m_r^{1)}$	Excessive observ.	Remote 1	Remote 2	Diff. 1	Diff. 2	$m_r^{2)}$	Excessive observ.
5.5	12.20		20193,0												
	21	12791,0	20204,0	12795,9	20203,2	-4,9[3)]	+0,8	-	-						
	22	12812,0	20215,8	12812,0	20215,2	+0,0	+0,6	-	-						
	23	12828,5	20228,0	12828,6	20226,5	-0,1	+1,5	0,2	1						
	24	12844,3	20239,0	12845,7	20237,5	-1,4	+1,5	0,4	1						
	25	12863,5	20250,0	12863,5	20249,1	+0,0	+0,9	0,1	1						
	12.40	11030,5	19008,5	11030,2	19008,4	+0,3	+0,1	-	-						
	41	11022,0	19005,0	11023,2	19004,6	-1,2	+0,4	-	-						
	42	11020,9	19004,0	11020,4	19004,1	+0,5	-0,1	-	-						
	43	-	19005,0	11021,7	19006,1	-	-1,1	-	-						
	44	11026,0	19010,0	11026,4	19009,8	-0,4	+0,2	-	-						
	13.10	10443,0	17533,5	10443,2	17533,0	-0,2	+0,5	0,2	1						
	11	10454,0	17530,0	10453,5	17530,0	-0,5	+0,0	0,3	1						
	12	10464,6	17527,5	10465,0	17528,1	-0,4	-0,6	0,5	1						
	13	10477,0	17526,9	10476,8	17527,0	+0,2	-0,1	0,3	1						
	14	10489,5	17526,5	10489,1	17526,9	+0,4	-0,4	0,2	1						
	13.35	9177,0	16977,9	9176,4	16976,5	+0,6	+1,4	-	-						
	36	9183,3	16975,1	9183,1	16975,1	+0,2	+0,0	0,1	1						
	37	9191,2	16975,0	9192,1	16974,9	-0,9	+0,1	-	-						
	38	9201,7	16974,0	9201,8	16975,0	-0,1	-1,0	0,1	1						
	39	9212,0	16976,0	9212,4	16975,8	-0,4	+0,2	0,2	1						

m_r = Estimated radial standard error in geodetic positioning.

1) estimated by means of a graphical plót of the intersections.

2) estimated from differences in the x- and y-coordinates from computations of various combinations of angles.

3) probable reading error of -5 m.

FIG. 9. — Hydrodist results from 5 May for distances between 9 000 and 20 000 metres. Only theodolite checks, partly from 3 trig points.

car battery) sometimes failed, probably due to all the calls made from the ship stations which caused increased power consumption.

Some details could of course be modified in order to make the operations more efficient, but they will not be dealt with in this report.

In some cases, the branches of deciduous trees, although still without leaves, interrupted the direct line of sight and decreased the signal strength or even blocked the signal.

Reflection phenomena from the sea surface or flat hilltops were not observed and should have very limited or almost no influence when the ship is moving.

The influence of differences in atmospheric conditions from those for which the instrument is calibrated could, according to information from the manufacturer, in this case reach the magnitude 1 cm/km. This correction, if applied, will neither increase nor decrease the accuracy values obtained for the Hydrodist equipment.

A drawback of this instrument is the need for *two* operators on board the ship and for *one* attendant at *each* shore station. The qualifications of the personnel need not, however, be very high.

Results of Hydrodist distance tests

The trial could, of course, have been performed with only one remote station, as the position accuracy is a purely geometric function of the distance accuracy and of the shape of the triangle formed by the two remote stations and the ship. The trials were, however, normally arranged with two shore stations. As no influence on the accuracy should be expected to result from variations in ground conductivity where the path passed over land without being obscured, the number of check points could be kept within a reasonable limit.

After the final analyses, about 50 check points with 80 distances between 4 and 43 km in 10 point groups are available. A few gross errors, mainly in the results acquired during the first few days, have been excluded as they could be traced back to inexperience of the personnel.

The results show that distance errors above two metres are *very rare* and that a standard error (mean square error) of about 1/2 metre (2 feet) can be expected. On the other hand it should be observed that the slow movements of the ship certainly somewhat increased this figure. The personnel was also inexperienced and the arrangement of the instruments on board was rather inconvenient.

The results have been condensed in tables of which fig. 9 is an example.

Hydrodist at high speed

The above mentioned motor boat (fig. 10) — only 5 metres long — was a speed-boat equipped with two 80 h.p. motors. One instrument had to be fastened on top of one of the motor housings (fig. 11), the other just in front of it. Due to the lack of time, interference suppressors could only be installed for the spark plugs and the distributor but not on the generator.

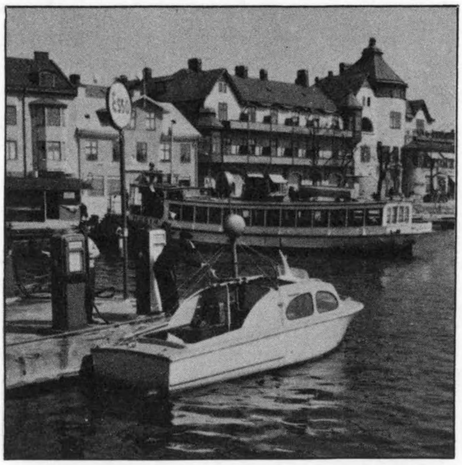

FIG. 10. — Hydrodist, with temporarily mounted antenna, in the speed-boat.

FIG. 11. — One of the boat-instruments placed on the top of the port-side motorcase — no ideal place indeed !

In spite of this, quite an acceptable circle was obtained on the cathode ray tube at moderate speed, and it was still acceptable at 25 knots. Following the gap with the hand operated cursor was naturally somewhat difficult and inaccurate, but this was due to the movement of the boat and to the above mentioned disturbances from the electrical parts of the motors.

Hydrodist in buoying operations

The positions (distances from two shore stations) of the self-anchoring survey buoys (plastic balls) were chosen from the boat sheet beforehand. The motor boat — in which the double master station had been installed — was guided to these positions by the Hydrodist operators. A few short trials gave a very favourable impression as to efficiency and ease of operation.

OBSERVATIONS ON THE PERFORMANCE OF HI-FIX

The installation on board was quite simple and space requirements very limited. The apparatus could easily be placed in front of the officer on watch (who was also the surveyor). The display of figures was excellent except for the red colour which was too dark. No special operation or adjustment of the instrument during a test series was needed as the system was fully automatic. The nomogram display, enabling a change in frequency to be made in the case of radio disturbance, seemed to be a good idea but more difficult and tiring to read.

The shore stations (master and two slaves) were well fitted in small caravans. This is certainly practical when there is a good road network along the coast, but in many cases a tent installation is preferable, especially as the Hi-Fix equipment as such is extremely light. The mounting of the aerials and the arranging of a ground net to get good and stable reference potentials around the aerials represented the major part of the work in establishing a shore station (fig. 12). The geodetic survey of the shore stations was completed in advance.

FIG. 12. — Hi-Fix green-slave antenna almost in the water.

The shore stations also worked fully automatically for several days, the attendant's only job being to switch the instruments on and off and to recharge the batteries from a small motor generator.

The influence of skywave reflection was once investigated by the manufacturer's personnel and was found to be very limited — about one or two hundredths of a lane — even at a distance of 70 km at sunset.

As Hi-Fix calls for special ground conditions, normally it cannot be placed close to existing triangulation points and a geodetic survey is there-

TEST-VALUES. Trials with Decca Hi-Fix and Hydrodist in Sweden 1960.
Final values

Date	Time	Decca observations		From theodolite observations computed values						From sextant angles computed values					
		Pattern 1	Pattern 2	Pattern 1	Pattern 2	Diff. 1	Diff. 2	$m_r^{1)}$	Excessive observ.	Pattern 1	Pattern 2	Diff. 1	Diff. 2	$m_r^{2)}$	Excessive observ.
1.6	11.37	13.170	189.035	13.024	189.146	+0146	-0111	-	-	13.022	189.145	+148	-110	3.0	1
	11.38	205	040	053	151	+0152	-0111	-	-	053	143	+152	-103	4.0	1
	11.39	220	035	081	156	+0139	-0121	0.2	1	081	153	+139	-118	2.0	1
	11.40	230	035	109	156	+0121	-0121	0.4	1	108	153	+122	-118	2.0	1
	11.41	235	035	140	148	+0095	-0113	0.1	1	140	147	+095	-112	2.0	1
	11.52	14.190	183.310	14.101	183.418	+0089	-0108	0.2	2						
	11.53	270	205	209	307	+0061	-0102	0.1	2						
	11.54	375	182.995	308	121	+0067	-0126	0.3	1						
	11.55	510	695	425	182.814	+0085	-0119	0.3	2						
	11.56	615	434	529	548	+0086	-0114	0.3	2						
	12.04	16.430	175.240	16.364	175.367	+0066	-0127	0.3	2						
	12.05	565	174.805	520	174.954	+0045	-0149	0.3	2						
	12.06	630	790	555	928	+0075	-0138	0.4	1						
	12.07	695	765	594	902	+0101	-0137	0.1	2						
	12.08	715	760	634	868	+0081	-0108	0.3	2						
	12.22	19.210	169.050	19.164	169.161	+0046	-0111	0.4	2						
	12.23	220	168.960	202	084	+0018	-0124	0.4	2	19.201	169.077	+019	-117	2.0	1
	12.24	-	875	237	010	-	-0135	0.3	2	237	008	+ -	-133	1.0	1
	12.25	315	820	275	168.942	+0040	-0122	0.3	2	274	168.943	+041	-123	2.0	1
	12.26	360	755	314	877	+0046	-0122	0.2	2	312	879	+048	-124	2.0	1

m_r = Estimated radial standard error in geodetic positioning.

1) estimated by means of a graphical plot of the intersections.

2) estimated from differences in the x- and y-coordinates from computations of various combinations of angles.

FIG. 13. — Hi-Fix results from 1 June. Theodolite measurements from 2-4 trig points (standard error ± 0.1 to ± 0.4 m) and partly simultaneous sextant angle readings with one redundant angle (standard error ± 1 to ± 4 m).

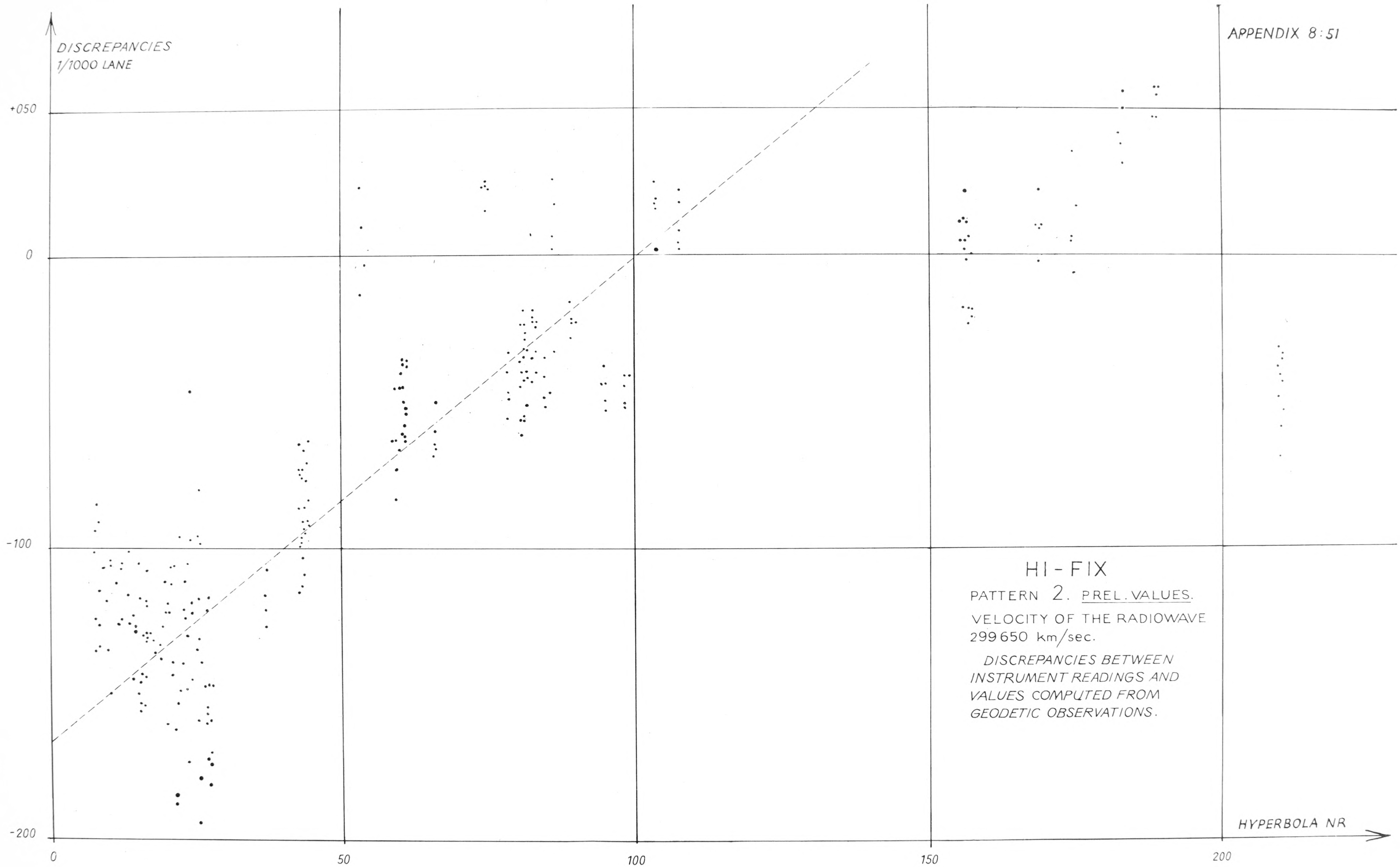

FIG. 14. — Preliminary results for Hi-Fix pattern 2 show a clear systematic trend due to wrong phasing and an error in assumed propagation velocity.

fore needed. On the other hand, the coverage is great and not limited to the line of sight.

The variations in conductivity of the ground where the path goes over land quite certainly has an influence on the accuracy which may limit the effective coverage when the highest degree of accuracy is called for (see below).

Results of Hi-Fix tests

A hyperbolic chart was plotted in advance but, due to a weak jetty, the master station had to be placed eccentrically with a few metres latitude allowed for. Consequently, each test position had to be recalculated in the final evaluation.

As the influence of ground conductivity was not exactly known, many more check points had to be determined for Hi-Fix than for Hydrodist in order to secure material for a study of the change in errors when the land path varied (see fig. 2). Such land paths could also be investigated on the baseline extension and behind some medium-sized islands. As an analysis of these errors was a rather time-consuming and intricate matter, the preliminary results thereof were given in the first report. A later analysis has given still more significant values for the differences in propagation velocity (see below).

The results of the check measurements were condensed in 49 tables, of which a typical one is shown as fig. 13. The distribution of the test points is shown in fig. 2.

The preliminary results were computed with an assumed propagation velocity of 299 650 km/sec. As can be seen from the graphic presentation of the discrepancies (between instrument readings and computed values), the discrepancies increase as the hyperbola-number increases (fig. 14) which points to an error in the assumed propagation velocity. A straight line has been drawn by eye between the points. The point where this line cuts hyperbola 0.00 gives the constant correction term for all the instrument readings. This constant error could have been corrected at the slave stations at the beginning of the trials, but was not discovered at once and we preferred to leave it in order to avoid changes during the tests. The inclination of the lines for pattern I and pattern II gives the correction to the propagation velocity. To all values computed from theodolite and sextant observations, corrections have been applied for constant error and erroneous propagation velocity. The final propagation speed used was 299 120 km/sec and is to be regarded as an approximate mean value for the test area according to the proportion of land and water. The influence of land on the Hi-Fix positions can briefly be described as follows : land between the ship aerial and the master station increases the lane number and land between the ship aerial and the slave station will decrease the lane number.

The final values show that under the conditions prevailing during these tests the discrepancies between theoretical and actual readings can rise to ± 0.10 lane but are generally of the magnitude ± 0.05 lane, equivalent to between ± 5 and ± 15 metres within the greater part of the normal operation area. It is to be observed, however, that the above mentioned values include large systematic errors resulting from rather poor ground conductivity where the wave paths cross the islands (see also the manufacturer's comments in appendix 2).

The standard deviation for a series of readings made at the same spot are of the magnitude ± 0.01 to ± 0.02 lane or ± 1 to ± 6 metres, an accuracy which is to be expected when there is no land between the ship and shore stations.

A final analysis of the differences in propagation velocity over land and water was later carried out according to the least-squares method. The land and water paths were determined for each check point and 4 unknown constants were determined from 76 redundant observations. The results show a low standard deviation. The propagation velocity over land was 298 069 ± 99 km/sec and over water 299 352 ± 24 km/sec.

Hi-Fix at high speed

The Hi-Fix was checked in the same way as the Hydrodist. Performance was good even at 22 knots. A momentary loss of the alternating signals introduced no errors.

VIEWS ON THE TWO SYSTEMS AS USED IN SWEDISH HYDROGRAPHIC SURVEYS

When studying the adaptability of the two systems it was found that they seem to be complementary rather than comparable. For a limited survey, the very rapid establishment of the remote Hydrodist stations at existing (or determined with the same instruments) fixed points compensates for the larger number of personnel required. The range will in most cases be quite good through the use of high points and — if necessary — simple lightweight towers (5-15 metres) to be clear of the vegetation.

In many cases, especially in archipelagos, it may be advantageous to place one station (parabolic aerial reflector) rather far away and use it as a range station for circular-arc sounding lines. A proposed special steering indicator, similar to that used in our ordinary Decca offshore surveys, placed in front of the helmsman, would give him constant steering instructions. The other remote station, which could be re-established every morning, should be placed so that its circles cross the sounding circles at an angle of a least 30°. This instrument might under certain circumstances be left unattended.

Some simple plotting devices should be designed if automatic plotters are not available. On the other hand, special plotting sheets can be made. A quite new approach to that problem will be described in a separate report in the near future.

According to the preliminary plan, the more open areas will be sounded from a large launch, carrying the Hydrodist, in the middle, and two smaller boats (only carrying fathometers) running parallel on each side at constant distances. When weather and depths permit, a speed of

15 knots is foreseen. Similar *parallel sounding,* positioned with ordinary Decca on offshore surveys and with sextant readings on inshore surveys, is a standard method in our operations.

In more intricate waters the bigger launch will drop self-anchoring buoys in a regular predetermined pattern, while other launches and boats will run the close sounding lines (very often less than 10 metres apart), developing the sounding still further and even bar sweeping when needed.

When a larger area is to be surveyed, the higher degree of automation of the Hi-Fix offers great advantages. Several ships or launches may operate at the same time on the hyperbolic or hyperbola-ellipsoid pattern. Positioning is possible even beyond the horizon and, with some losses in accuracy, behind islands.

The somewhat more time consuming establishment of the shore stations and the calculation (by electronic computer when available) and plotting of the pattern seem to be quite acceptable when the survey is to take some weeks and various preparations can be made in advance.

As a two-range system, Hi-Fix may be used in the same way as indicated above for Hydrodist, but in this case the advantage of its higher automation, its longer range, and its smaller dependence on unobscured sights must be balanced against the disadvantages of higher cost, the special requirements at the two shore-station sites as well as the geodetic survey needed before the hydrographic survey work can start.

It should be mentioned that both systems will be introduced simutaneously in Swedish hydrographic surveys as soon as sufficient funds are available. Operational trials with a modified Hydrodist set will begin in the early spring of 1961 at Lake Vänern.

CONCLUDING REMARKS

Each system represents a most valuable contribution to the technical resources in modern hydrographic surveying. In spite of the fact that the trials had to be performed rather rapidly and certainly do not cover every phase, we hope that the results will be of interest to other hydrographic offices and organizations interested in accurate positioning over water.

We should also like to state our appreciation of the manufacturers' excellent cooperation, of their sincere desire to carry out suitable trials and of all the information they have given us during the tests.

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In order to make this report as complete as possible we have asked the manufacturers to comment briefly on the results of the trials of their respective systems. These comments are attached as appendices 1 and 2.

APPENDIX 1*a*

COMMENTS ON HYDRODIST MRB2 TRIALS CARRIED OUT BY THE SWEDISH HYDROGRAPHIC DEPARTMENT

(Spring 1960)

by Commander R. BILL,
D.S.O., F.R.I.C.S.
Manager & Director, Tellurometer (U. K.) Ltd.

We offer our thanks and congratulations to Dr. P. O. FAGERHOLM and the members of his organization, for the excellent trials report on Hydrodist MRB2. The detail of the report itself indicates the work and effort which has gone into both the practical trial and the vast number of computations necessary to resolve the observations.

The conditions for the trial were ideal from almost every point of view and the geodetic control carried through the islands in the approaches to Stockolm provided positive accuracy checks at distances beyond the normal line of sight.

Our own contribution to these trials was limited to the loan of the equipment for this purpose and to the loan of two technical assistants to help with any necessary training and maintenance other than this, the trials were carried out entirely by the staff of the Swedish Hydrographic Department.

It should also be pointed out that our own technical assistants had had virtually no operating experience, so that the credit for the results obtained lies with the Swedish Hydrographic Department.

It has been the designers' aim to keep this equipment as simple and versatile as possible; Hydrodist MRB2 is, in fact, a direct reading Tellurometer scaled to read instantaneous ranges between master and remote instruments in metres. It can be used under almost any conditions, on land, at sea or even from a helicopter. One pair of instruments gives one range and in the case of this trial, two pairs were used to give hydrographic positioning.

The suggestions emanating from this trial are under consideration, and remote controlled aerials, semi-automatic cursor and steering indicators are under development. It is intended that these should be supplied as ancillary equipment for hydrographic use, so that the universal nature of the simple system should not be affected.

A more specialized equipment, Hydrodist Duplex, intended for semi-permanent fitting in a surveying vessel, is under development. This system is a parallel development to Aerodist, which is now undergoing trials in the United Kingdom, and is designed to work in conjunction with automatic recording, automatic plotting and other ancillary equipment.

APPENDIX 1*b*

MANUFACTURER'S COMMENTS ON HYDRODIST TRIALS

(Spring 1960)

We have been privileged to receive an advance copy of the report of the Swedish Hydrographic Department on the Electronic Positioning Tests held during the spring of 1960 and have been invited to comment thereon.

In our opinion, the Department is to be congratulated on the excellence of the work carried out during these tests and we consider that the results will prove of considerable value in hydrographic survey.

The development of Hydrodist MRB2 into a form of equipment suitable for hydrography sprang from a suggestion of the Admiralty Hydrographer of the United Kingdom that the well proved principles of accurate line measurement embodied in the tellurometer system could suitably be applied to inshore survey.

The aid of the South African Navy Hydrographer was sought in laying down a specification for equipment to suit the major requirement, and this was considered to be for an accurate, low priced, highly mobile equipment, capable of being used not only in ships, but also in small survey boats or, if necessary, being taken ashore to facilitate extension of the available geodetic control to the shore points required for the survey.

The accuracy requirement was for a system capable of giving a position correct within approximately 15 feet of the true position, this being regarded as the maximum to which plotting accuracy could be effected. It is gratifying to note from the tests that this objective has been more than realized.

Critical conclusions as regards equipment design to be drawn from the tests are : —

1. The number of operators required on the ship with present equipment is two. This partly arises from the design concept of simple, portable units. However, plans exist to improve the method of operation so that the function may be carried out, with less inconvenience, by a single operator.
2. The aerial system supplied for the tests was a mechanically operated mast assembly carrying the aerials. This placed a limitation on the installation inasmuch as the measuring units required to be located adjacent to the aerial mast to permit the operator to have access to the controls. Aerials that will normally be supplied with Hydrodist MRB2 equipment will, however, be motorized and provided with remote controls, enabling the equipment to be installed in, say, the chart room and the aerials to be located in position as convenient to the superstructure of the ship.

APPENDIX 2

COMMENTS BY THE DECCA NAVIGATOR COMPANY ON Dr. FAGERHOLM'S REPORT ON THE HI-FIX TRIALS IN SWEDEN, 1960

The trials carried out in Sweden which form the subject of this report were notable in two respects : —

(1) The area chosen permitted Hi-Fix to be seen under favourable conditions, i.e., with 100 % sea paths between the stations and the ship, and under unfavourable conditions where the transmission paths were over very mixed terrain involving rocks which are well-known for their exceptionally low conductivity.

(2) The close control of the trials which was possible because of the exceptionally high standard of the trigonometric grid in the area and the care with which the geodetic observations were made.

The system performed normally, no lanes being lost and accuracies being in keeping with the Company's predictions. No difficulties were experienced in installing the stations or in equipping the vessels, thanks no doubt to the careful planning undertaken by the Swedish Hydrographic Office.

Dr. FAGERHOLM found errors when using purely sea paths between one and two hundredths (*) of a lane (the Hi-Fix lanewidth for this trial was 76 metres) and that the errors when unfavourable transmission paths were involved were 5 to 10 hundredths *if no correction was applied.*

Had corrections been applied for the mixed transmission paths, the error could have been sensibly reduced — the application of these corrections is quite simple and indeed follows the principles outlined in Dr. FAGERHOLM's report, i.e., that land masses in the master transmission path increase the value of the indication and land masses in the slave transmission path decrease the value of indication. If corrections had been applied, it is considered that the errors would have been reduced to approximately one-third of the value, i.e., about two to three hundredths for each pattern (about 2 metres on the baseline).

Good signals were obtained at ranges of over 40 miles (nautical miles all through these comments) and it was noted that a considerable reserve of power was present under these conditions. From measurements taken at the extreme range it has been calculated that the useful maximum range of the system under these conditions would have been between 100 and 130 miles, this being three or four times the nominal range (20 to 40 miles) for this equipment.

(*) It should be noted that one hundredth on each pattern corresponds to a fixing error of about 3 metres in the useful part of the coverage when using Hi-Fix in the hyperbolic form and 1 ½ metre fixing error in the two-range condition. (For two-range condition one and one half hundredths are assumed following normal practice for this type of operation).

Dr. FAGERHOLM has commented on the Nomogram form of display which was demonstrated during the trials. The display shown involved taking readings from a scale on a strip of film. This unit is still in production but for those who prefer an instrument indicating yards, metres, or feet directly on Veeder type counters a new instrument has now been produced.

Other developments which have taken place since the demonstrations include the Series II*a* Receiver. This receiver differs only in detail from the Series II which was used in the Swedish trials, but does incorporate an improved panel layout and minor circuit changes. However, the main developments in Hi-Fix have taken place with regard to automation, a field of particular importance in view of today's need for data processing and the widespread use of electronic computers. Hi-Fix punched tape equipment permits rapid handling of information and allows results to be transmitted by Telex circuits automatically. Automatic read-outs provide printed records of changes in ships' positions together with time, date and other information. For use on the ship, remote indicators can display numerical values of Hi-Fix readings whilst a refined version of the Decca Navigator Track Plotter and Left-Right Indicator provides assistance to the helmsman.

Although, as stated, no lanes were lost during the trials, we would refer to the new Hi-Fix Duplex, a system giving duplicated patterns providing exceptional reliability and automatic continuous lane identification, facilities thought to be of particular value in areas where few check-points exist.