USE OF THE DECCA NAVIGATOR BY THE ROYAL SWEDISH HYDROGRAPHIC OFFICE

Introduction

A mobile chain of Decca Navigator stations has been regularly used for some years past by the Swedish Hydrographic Office in connection with survey operations in the Baltic and in the Gulf of Bothnia. Much has been learned about the performance of the system, and methods have been evolved for correcting errors of both random and systematic types, to the point that Decca is employed not only for position-fixing when out of sight of land but also as a means of saving time and effort when operating within visual range of shore. Its use is envisaged as an aid to detailed surveying with plotting scales as large as 1 : 2,500.

Deployment of the Decca Navigator

In 1947 the Swedish Hydrographic Office ordered a transportable Decca Navigator chain, to be used as an aid to marine survey. Previously much thought had been given to the introduction of some non-visual aid to position-fixing offshore as a means of increasing the speed and scope of the survey programme to which the Hydrographic Office was committed ; among the methods tested was that of fixing by cross bearings from specially calibrated D/F loops placed ashore used in conjunction with a transmitting station on the survey vessel. The acquisition of a two-range responder system, such as Shoran, was also under active consideration. The long-wave phase-comparison type of system exemplified by the Decca Navigator, however, represented a clear advance on any method that had previously been contemplated, and the commercial introduction of Decca after the war proved to be very timely.

During the spring of 1948 the stations were established on the east coast with a view to use for surveys in the Baltic between the Swedish mainland and Gotland (Fig. 1). The summer of 1948 was spent in rigorous tests with a view to determining the accuracy of the Chain as well as to trying out various methods of using it for hydrographic surveying. A report on these tests was published in the " International Hydrographic Review " for November 1949 (1). In the course of the experiments it was found that the speed of propagation of the radio waves over the badly conducting ground which normally has to be expected in Sweden was considerably lower than that which had hitherto been found in other parts of the world ; for this reason, it was not possible to depend on any single average value for the propagation of speed over both land and water. However, it was found to be relatively easy to apply a correction for the delay in propagation of the wave over the land portion of the transmission path and to prepare a chart

(1) LARSSON H. : « Investigation of the Accuracy obtained with the Decca System for Survey in the Southern Baltic », *I. H. Review,* Vol. XXVI, No. 2, Nov. 1949.

showing the contours of equal correction value superimposed upon a map of the survey area.

A formula was derived for the land-corrections $\Delta\varphi$,

$$\Delta\varphi = k\ \Delta l$$

where Δl is the difference between the overland distances which the wave travels from the Slave and Master stations of a Decca pair. The factor k which for the same frequency is approximately constant for ground having the same conductivity, can be determined experimentally. If values are assigned to the speed of propagation over land C_l and that over water C_w, k can be found by the formula

$$k = \frac{C_w - C_l}{C^2_w} \cdot f$$

where f is the " comparison frequency ."

In the initial tests, an average value of C_l = 297,280 km/sec. was obtained for the red pattern and 297,770 km. for green, compared with C_w = 299,650 km/sec. The corresponding values for the constant k were 0.92 and 0.58 hundredths of a lane per kilometre of difference in the overland receiver-slave and receiver-master distances, for Red and Green respectively. More particularly near the coast and close to the Slave stations, land corrections as large as 0.50 lane were required; here, however, the calculated correction values could in general be checked by the measurement of angles to three or four points having known geodetic co-ordinates, since the coast was in sight enabling accurate correction contours to be constructed.

At greater distances, out of sight of land where no direct check was possible, the theoretical values of the corrections were in general not greater than 0.10 lane. In every place where a check could be made the agreement was very good, the discrepancy being in general not greater than 0.02 lane, so that in consequence the land corrections as calculated could be accepted as sufficiently probable. It was estimated under the general conditions then known that the total error in determining position would not exceed 0.05 lane; this figure made due allowance for the stability of the chain, the calibration of the receivers and the accuracy of construction of the hyperbolic grid. At no place within the survey ares would this give a position error greater than about 100 metres. On the final sea chart at the scale of 1 : 200,000 the corresponding position error is only half a millimetre which is thus the greatest absolute error in the sounding courses when out of sight of land.

The *relative* accuracy — that is to say the accuracy with which the position can be determined in relation to the hyperbolic grid — was considerably greater, especially when the scheme devised by the Hydrographic Office for completely automatic control of the Slave stations through tone-modulated radio signals from the monitor station began to be applied. The relative accuracy of the system, which is in the order of 0.01 lane, is important because it ensures uniformity of separation between sounding lines and thus makes certain that no part of the bottom shall be missed; the absolute accuracy in this connection is less important since a simple check observation can serve to position the whole system of sounding lines correctly. In practice it proved possible for close sounding to be carried out for the purpose of investigating shallow spots on sounding courses separated

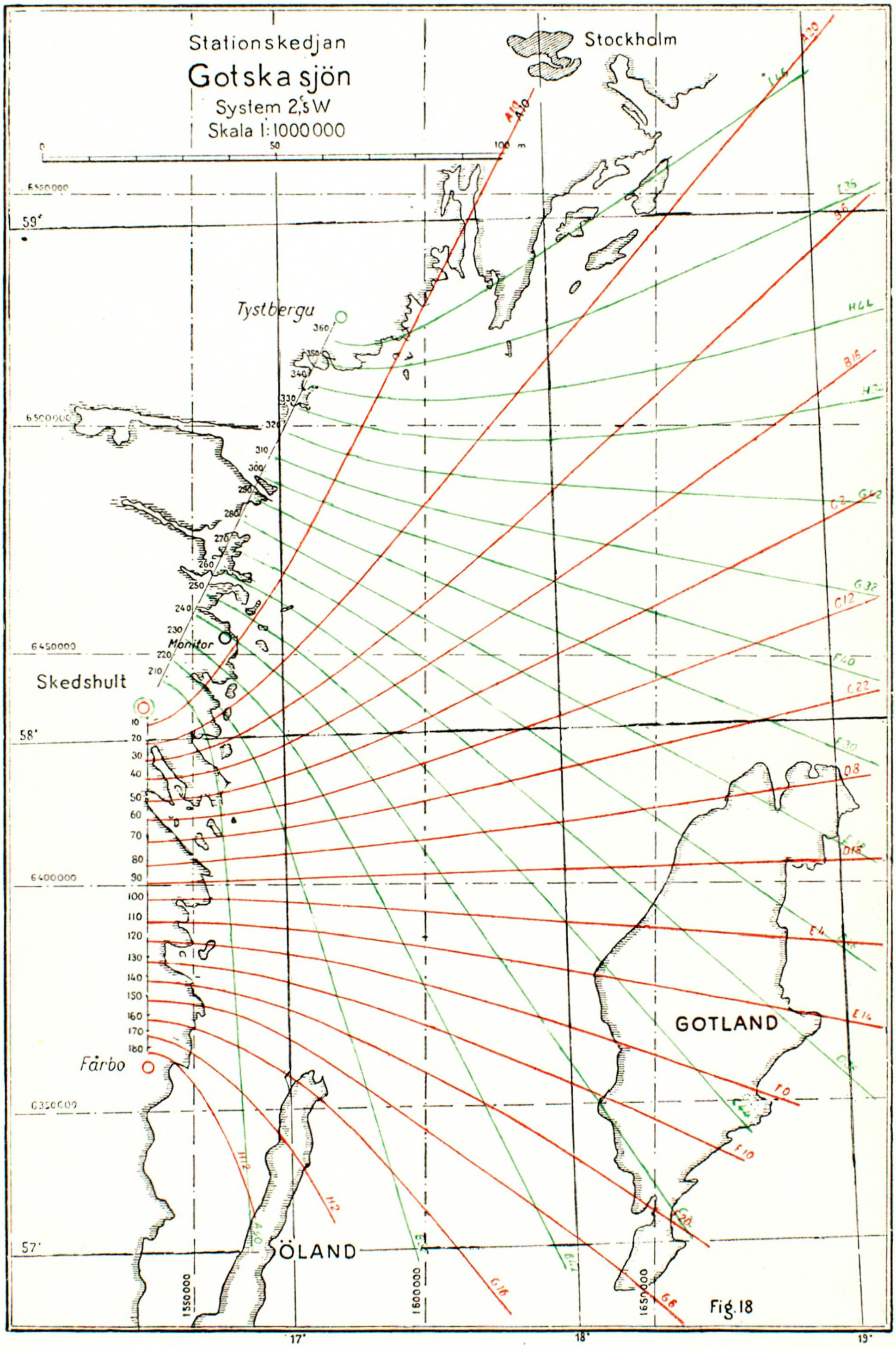


Fig. 1.

Layout of « Baltic » Decca Chain : Farbo - Skedshult - Tystberga.

by only 0.05 lane, this corresponding to a physical separation of between 50 and 100 metres between the courses. The use of Decca even for this relatively high-precision type of survey enabled a substantial saving of time to be achieved by comparison with the older methods entailing the use of buoys, beacons or other marks.

Even within sight of land where the amount of terrain in the transmission paths from the stations necessarily involved large land-correction values, it has been found more convenient to use Decca than to fix by the measurement of angles, in spite of the fact that the latter method would have been feasible. Since, however, the sea chart for which this work is required was at the scale of 1 : 50,000 the requirement of absolute accuracy was greater, so that it was necessary to exert some visual control on the positioning of the hyperbolic grid and the application of land-corrections to the decometer readings. The hyperbolic grid was constructed graphically at a scale of 1 : 30,000 using the method developed by the Hydrographic Office (2) without incorporating any land-correction. The survey vessel carried out comparative measurements within the actual survey area as between the observed Decca co-ordinates and those which were obtained from the hyperbolic chart for the position of the ship found by the measurement of angles to points having known geodetic co-ordinates. This process occupied a few days, in which good visibility prevailed. The results so obtained enabled a correction chart to be constructed and for a further day the corrections were re-checked, especially in locations where the values were unexpectedly great or where unexpectedly abrupt variations had been recorded (Fig. 2).

Once the correction values had been determined and the correct absolute positions thus assigned to points in the survey area, the actual survey operations could proceed with little delay simply by steering the vessel along the hyperbolic position lines so as to secure the required separation between the sounding courses. The use of Decca for running lines in this way enabled the survey to be carried out without the erection of special triangulation points and also without dependence on visibility, the latter factor implying a considerable saving of time in view of the weather that normally prevails.

The Chain remained on the sites described in reference (1) (Tystberga - Skedshult - Farbo) until 1951 when it was re-sited for a survey programme in the southern part of the Gulf of Bothnia. The Chain was then moved to prepared sites with the three stations on islands or peninsulas : the Master on Iggön, the southern Green Slave on Gräsö and the northern Red Slave on Höllicksskär. The Chain layout is shown in Figure 3. The Monitor Station was set up at Axmarby about 20 km. north of the Master. On 27th August, after less than one month, the whole chain was working again and ready for check measurements to be taken at sea.

The new sites for the stations were chosen in the light of the experience gained from the previous locations. In order to reduce the land corrections the stations were sited as far towards the sea as possible. At all three sites the earth mat extends into the water and by this means good earthing conditions were secured in spite of the fact that the Höllicksskär station, for instance, is on a sand spit (Fig. 4 a and b). In order to improve phase stability the earth mats used

---

(2) HILDING S. : « Computation of Lattice Charts for the Decca Navigator System in the Gauss Conformal Projection » ; *I. H. Review*, Vol. XXVI, No. 2, Nov. 1949.

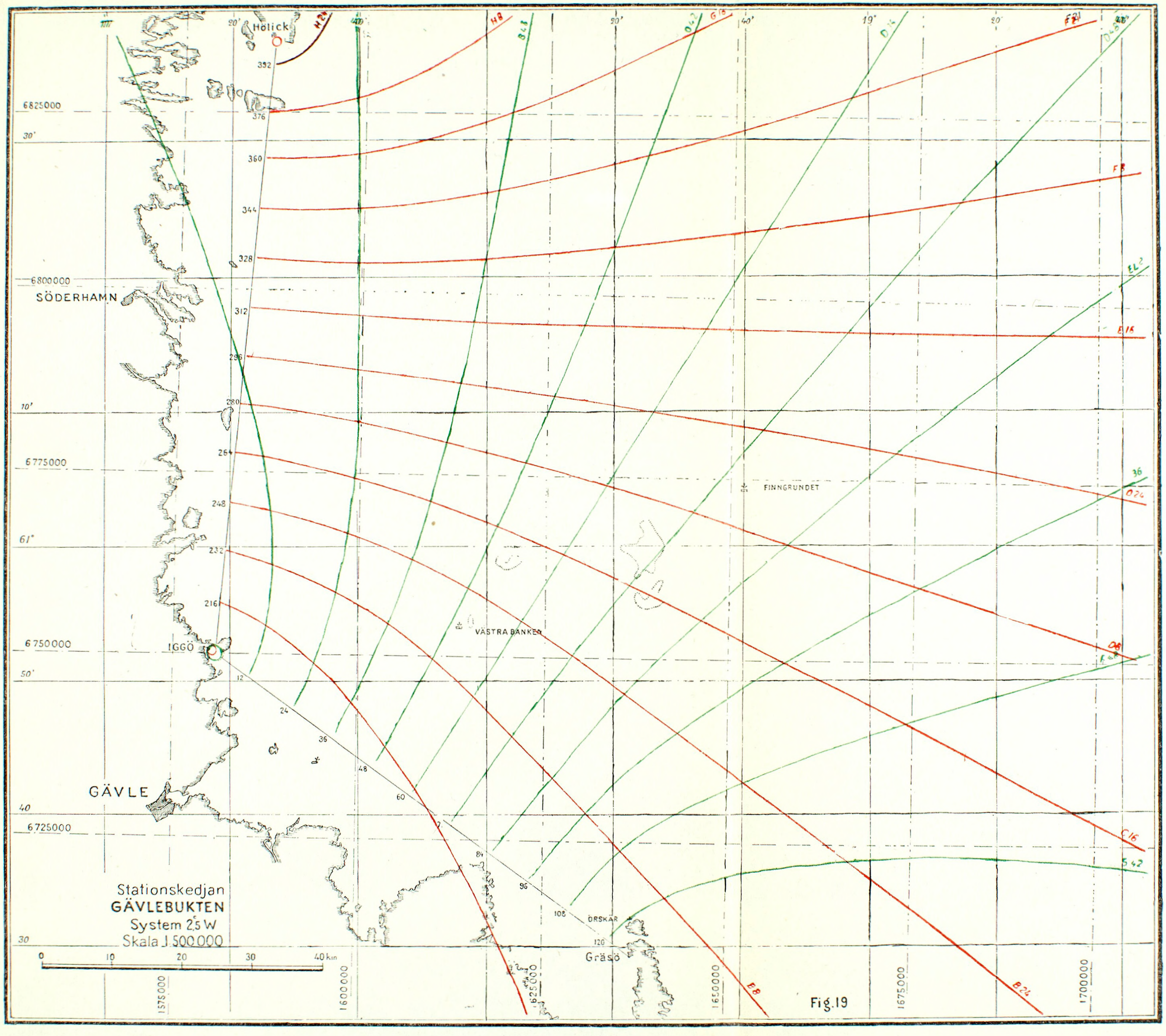


Fig. 3.

Layout of « Gulf of Bothnia » Decca Chain : Gräsö - Iggön - Höllicksskär.

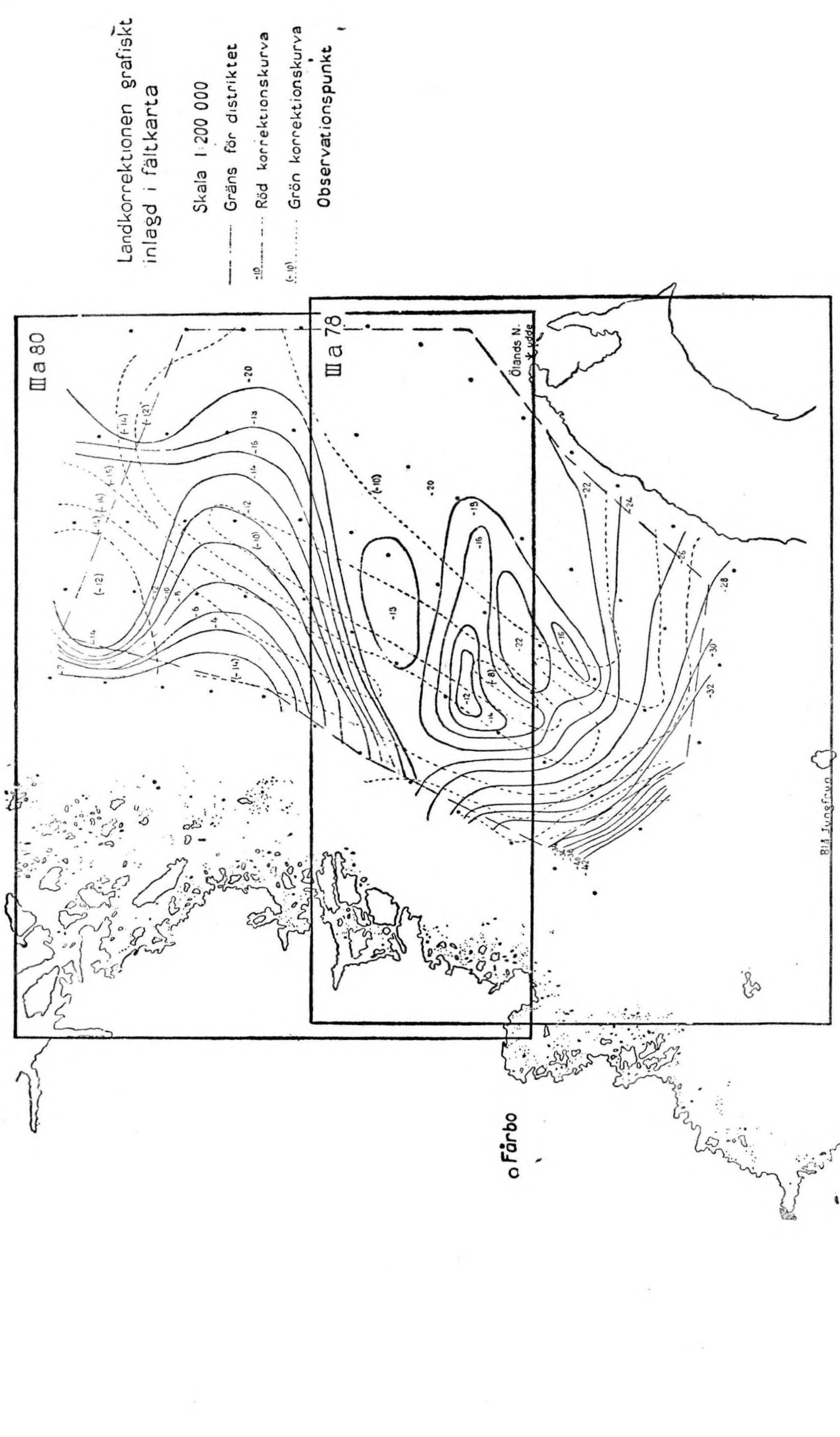


Fig. 2.

Land-Correction Diagram for Farbo - Skedshult - Tystberga Decca Chain
(Swedish Chart No. 330).

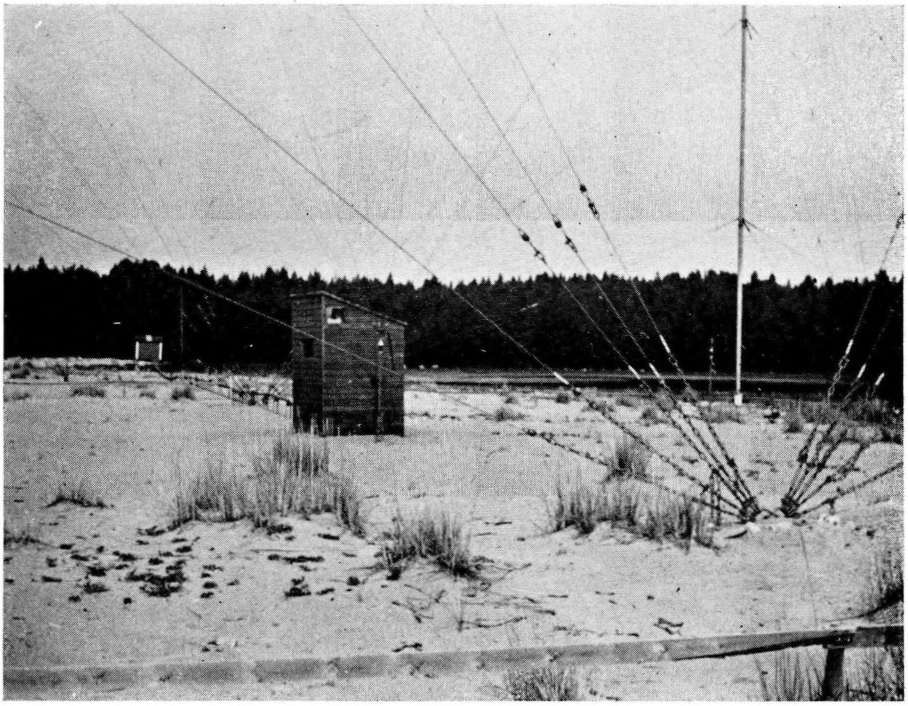


Fig. 4 a.
Red Slave Station at Höllicksskär.

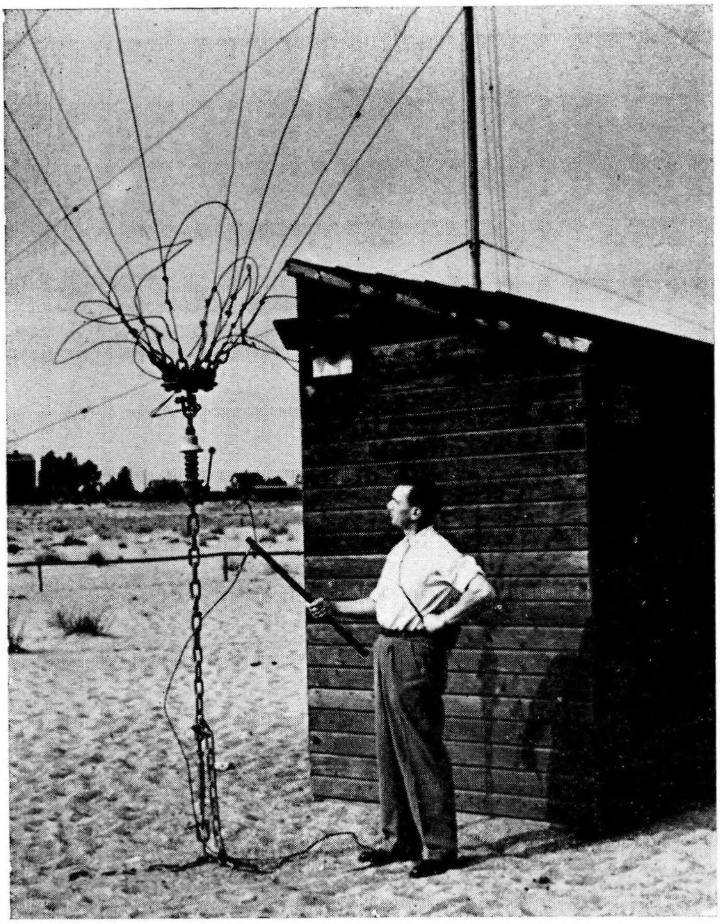


Fig. 4 b.
Red Slave Station at Höllicksskär.

with the receiving aerials at the Slave stations and at the monitor were increased in size. The Monitor was sited in a cultivated area so as to obtain ground of good conductivity. The measures thus taken yielded the expected results ; very good aerial efficiency was obtained and the field strength from the Master station at the Slaves was considerably greater than before owing to the fact that the transmission paths lay wholly over water. The short-term stability of the entire Chain also became appreciably greater than at the previous location.

This time the Chain was also to be used by the Finnish Hydrographic Office which had procured Decca receivers working on the appropriate frequency. This joint survey operation by the two Hydrographic Offices has in fact proved most profitable to both parties and has been carried out in the closest co-operation. The initial control survey was carried out partly by the Swedish Hydrographic Office's vessel " Kompass " on the Swedish side and partly by the Finnish Hydrographic Office's " Nautilus ". The Decca receivers of both ships were checked by a test lasting some six hours, with the ships moored close to the Monitor station. The initial control survey showed a discrepancy of 0.14 lane in the Red pattern between the calibrated and observed co-ordinates at the Monitor station and the pattern was accordingly re-phased.

Thereafter the control survey proceeded with " Kompass " operating on the Swedish side in the area between the Red and Green Slave stations and " Nautilus " from the Green slave up to latitude approximately N62° on the Finnish side of the Gulf of Bothnia. The land-correction values measured were compared with the values calculated for a velocity of propagation c = 299,650 km/sec., the latter figure having been obtained as an approximate average for the survey work in the Baltic ; the errors recorded are considerably smaller than those observed on the previous siting and exceeded 0.05 lane only in exceptional cases. A quite clear effect produced by the lower speed of propagation over land is perceptible, however, and the average errors can be reduced even further if land corrections are applied for the new siting. A graphic investigation similar to that carried out at the previous location shows that the land correction was a somewhat higher value — about 0.01 lane per km. of overland distance — this being due to the even worse ground conductivity in the new area. Since the overland distances are very short, amounting to only a few kilometers, the overall effect of the favourable station siting was that the land corrections were small.

A comparison of the Swedish and Finnish observations shows that the errors on the Swedish side have a greater divergence. This can be accounted for by the error in determination of position, which can amount to 10 or 20 metres given an accuracy of 1 minute of arc in reading the angles. Where the lanes are narrow, as they are in the region of the inter-station baselines (the baseline lane-width is roughly 500 metres), there can accordingly be an error of 2-4 hundredths of a lane. On the Finnish side where the lane-width is many thousands of metres the corresponding error in positioning has no effect worth mentioning in terms of lane values. In the areas where the Decca patterns are fine, therefore, the results indicate that Decca gives *better* accuracy than that of visual position-fixing by the measurement of angles as soon as one is more than a few kilometres distant from the triangulation points, as is in general the case.

A closer scrutiny of the errors remaining after the land correction has been applied shows that a somewhat smaller overall error would obtain if the propagation speed were taken as 299,700 km/sec. instead of 299,650 km/sec. However,

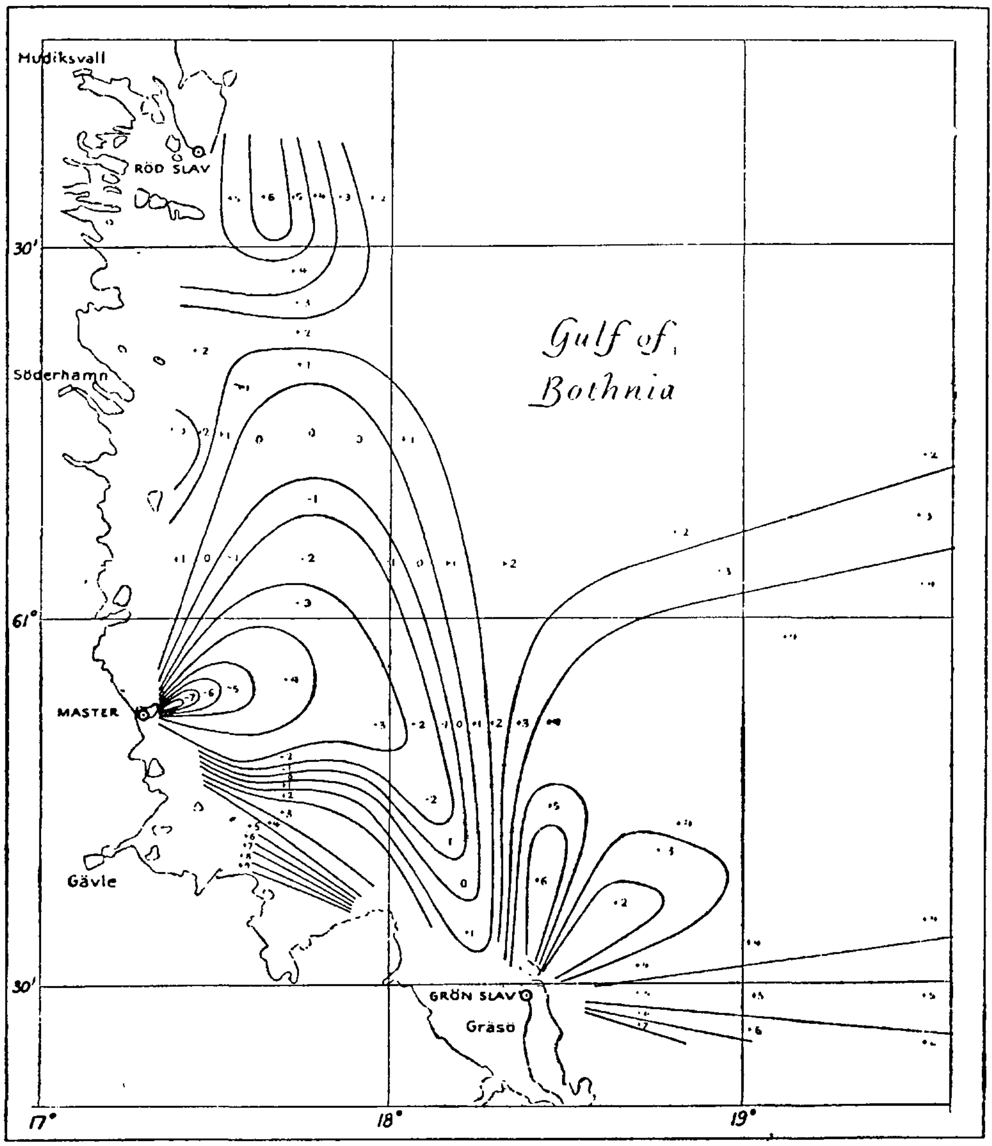


Chart showing the land-correction in hundreds of a lane at the present site of the Swedish surveying chain in the southern part of the Gulf of Bothnia (green lattice)

Fig. 5 a.

Land-Correction Diagram for Chain.

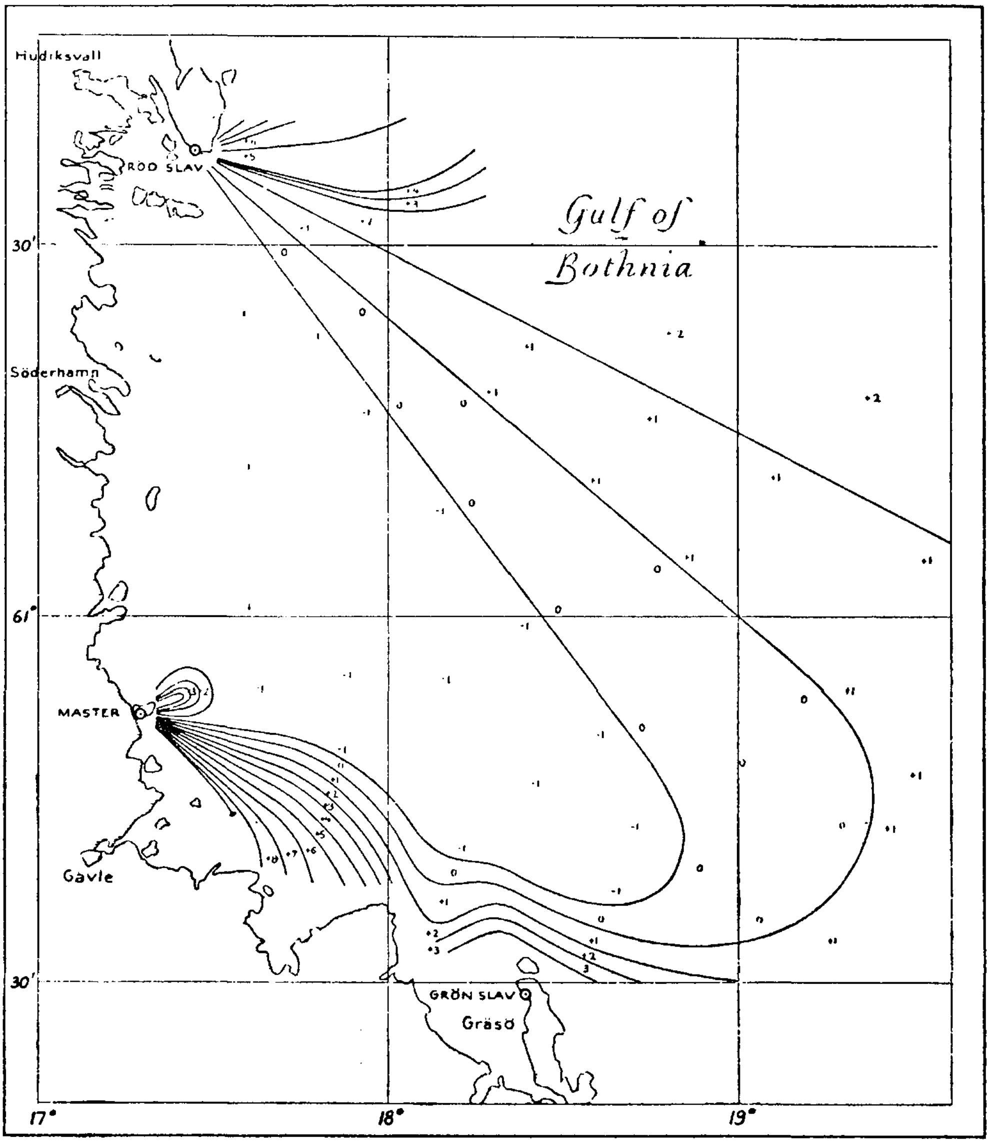


Chart showing the land-correction in hundreds of a lane at the present site of the Swedish surveying chain in the southern part of the Gulf of Bothnia (red lattice)

Fig. 5 b.

Land-Correction Diagram for Chain.

the relative difference between the values calculated with the two propagation speeds amounts to only about 0.02 lane within the area as a whole. Accordingly this correction can be included in the land-correction without the need to carry out fresh computations. When the chain is next moved it may be well to adopt the speed of 299,700 km/sec. which also agrees closely with the values that have been obtained recently in other countries for the speed of propagation over sea water.

After the land correction had been applied, both for Red and Green, a mean error of about 0.05 lane was obtained from a series of about 30 control points. For a single position the error does not exceed 0.02 lane. The calculations on which these figures are based, which included an examination of the precision with which the absolute positions of the control points are known, were carried out by the Geodesist, Mr. S. Hilding, at the Hydrographic Office. This degree of accuracy is sufficient to allow the use of Decca for hydrographic surveys across the entire Gulf of Bothnia, representing a distance of some 150 nautical miles from the Master station. The measurements to the east of a line of demarcation in the centre of the Gulf were carried out as described above, by the Finnish Hydrographic Office. Since on the Swedish side it was found possible to use the Chain for position finding even near land with an accuracy which was if anything greater than that which could be obtained by the measurement of angles, and since freedom was acquired from visibility restrictions, thus enabling positions to be determined over a much wider area, it was decided to determine accurately the land-correction values within the whole area covered by the Chain as far out from the coast as the available triangulation points permitted.

For this the method described in connection with the earlier siting was employed and the results are shown in Figures 5 a and b. It will be seen that a piece of land of small extent covering a few wavelengths has only local influence. Even at a distance as small as a few tenths of a nautical mile from such pieces of land the correction has already become considerably smaller. Around the two peninsulas on which the Master and the Green Slave stations stand this gave rise to the loop-shaped correction curves shown in the diagram. South of the Master Station the loop-shaped correction is positive, which would seem to indicate a higher speed of propagation; the explanation is, however, that the electrical centre of the aerial does not coincide with its physical centre. Although the aerial is itself symmetrical, having the shape of an inverted pyramid suspended between four masts at the corners of a square, the earth mat had been extended southward so as to reach into the water. The north side of the earth mat lies on fairly dry sand. The values of the correction correspond to what they would be if the station where located a few metres further to the south, i.e. closer to the centre of the earth system. Since the correction was found by measurement, it does not affect the accuracy of the surveys, but to avoid this effect the stations will in future be sited in places where the ground conductivity is as uniform as possible and care will be taken to ensure symmetry of the earth- as well as the aerial system.

By using, on the Swedish coast as well as the Finnish, the land corrections obtained by observation instead of the calculated values, greater accuracy will be obtained. With a sufficient number of control points, therefore, accuracy of 0.01 lane may be expected for practical purposes in the survey area. Corresponding errors in metres are shown in Figure 6.

Now that the Decca Chain was starting to be used near the coast, where the demand for accuracy is greater, there also arose the need to secure the maximum

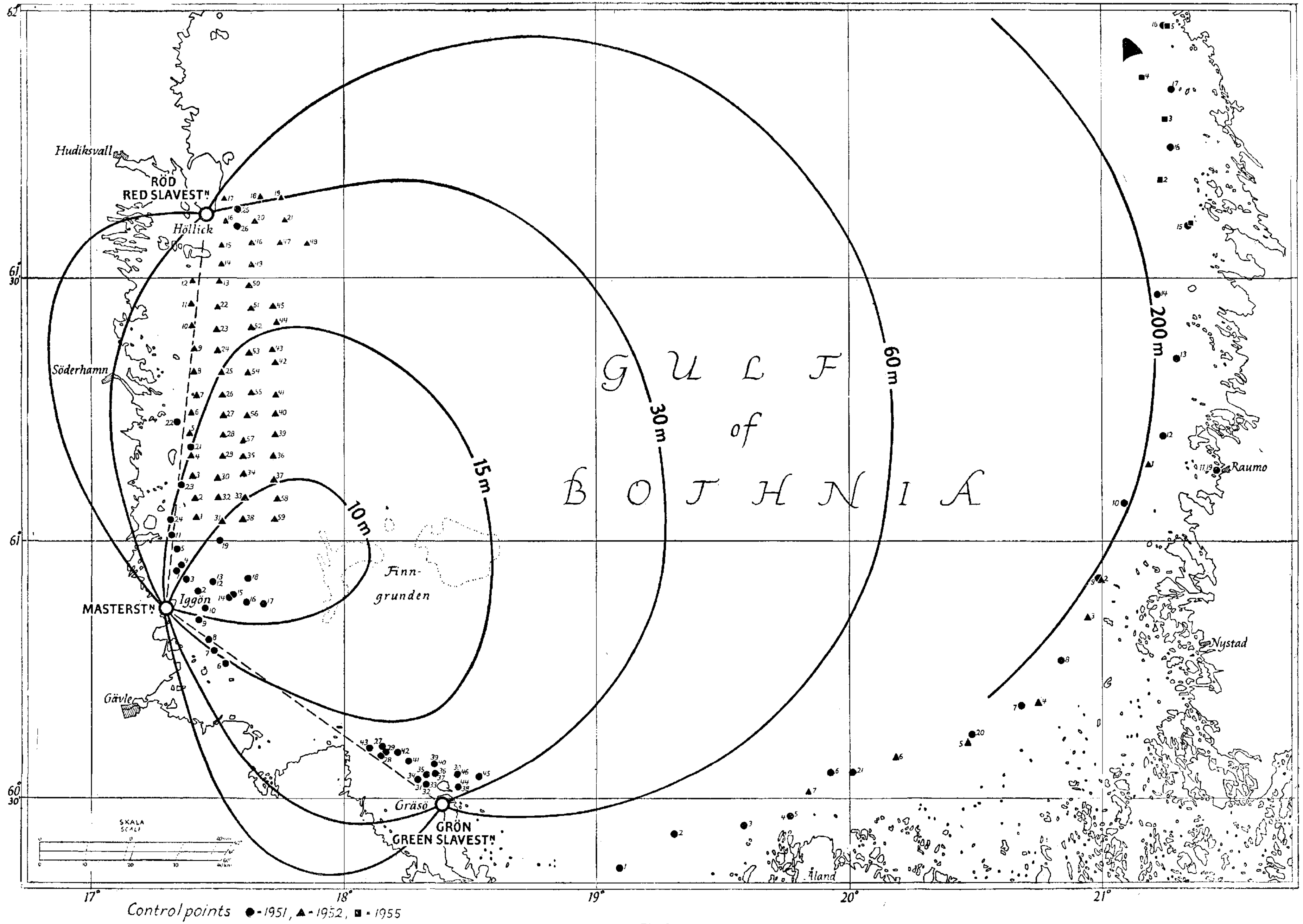


Fig. 6.

Contours showing predicted accuracy in metres.

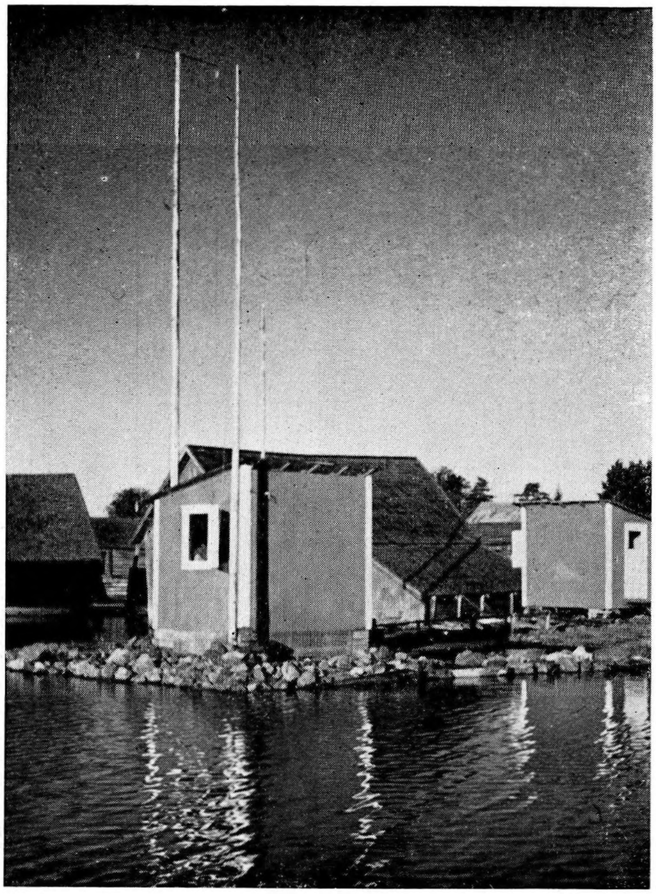


Fig. 7.
Monitor Station placed on pier.

Fig. 8.
Motor Boat for sounding under Decca control.

possible phase stability. Modifications were accordingly made to the automatic remote monitoring system already referred to, which enabled fully automatic adjustment to within 0.005 lane to be made. To secure even greater accuracy it is possible to over-ride the transmission of the correction signals manually, by which means phase adjustments of 0.001 lane can be made.

In order that an accuracy of this order, which corresponds to variations of about plus/minus 0.5 metre on the inter-station baselines, shall have any practical value it is essential that the Monitor station shall be electrically stable within itself ; otherwise the entire hyperbolic grid will fluctuate in sympathy with variations at the Monitor. Careful tests with ships firmly moored at various spots showed that the site first selected for the monitor was not ideal, variations of about 0.02 lane having been observed during rain. It was found that the thickness of the layer of soil in which the earth mat was laid out was only a few decimeters. while the ground beneath consisted of sand of which the conductivity varied very greatly according to the degree of moisture. Accordingly the Monitor station was moved down to the water and placed on a pier so that the whole earth mat could be lowered below the surface (Fig. 7). The effect of this was notably to improve stability, which should now be of the same order as on board ship.

Following the realization of this high degree of pattern stability at the Monitor station, amounting to a few thousandths of a lane, it was decided to carry out experiments in due course with a view to determining how the pattern stability within the area is affected by rainfall or by seasonal changes. Furthermore, it was decided to examine the use of Decca for detailed hydrographic surveys in the inner belt of islets, for which purpose a stability of a few metres over several hours is essential. Preliminary tests show promise that the latter condition can be obtained and that in consequence it will be possible to make further savings in time, personnel and equipment and to eliminate the use of buoys or marks that are required when following precise sounding lines by visual methods. A special motor boat for taking soundings within the belt of islets by means of Decca navigation has been built by the Hydrographic Office and is illustrated in Figure 8.

To improve the accuracy of tracking along hyperbolic position lines, which is normally done by steering the ship so as to maintain a constant Decometer reading of the appropriate value, a special course indicator has been developed by the Decca Navigator Company for use in conjunction with the latest type of hydrographic survey receiver which has calibrated goniometer phase controls. By setting the appropriate control to a reading corresponding to the desired lane value, the course indicator reads zero when the ship is located precisely on the desired hyperbola. The helmsman, who has in front of him the compass and the course indicator, steers the compass course of the hyperbolic line and corrects the steering by reference to the course indicator which functions as a left/right meter. It is remarkable how quickly a helmsman learns to keep a small boat on the precise course, checked by comparison with visual observations on buoys, even in a fairly rough sea.

NOTES ON OPERATING TECHNIQUE

Procedure for Decca Fixing

When surveying by course sounding, i.e. steering the vessel along pre-selected compass courses as opposed to Decca position lines, the ship's position and hence the location of the observations can be determined by Decca when the scale is in the region of 1 : 50,000. This enables the survey team to be reduced by one assistant surveyor, since the leader will be able to plot both the position of the vessel on the chart and also to keep the necessary record. His place will be taken by a radio operator who maintains contact with the Monitor station and operates the Decca receiver (e.g. checking reference at the prescribed interval of half an hour and immediately before starting a series of fixes).

Every 5 minutes a signal is given to read the Decometers. The Monitor operator also receives this signal by R/T and passes back any necessary correction to the nearest 0.001 lane with the appropriate plus or minus sign so that it can be immediately applied to the Decometer values as read. Great care is taken to ensure perfect time synchronisation between the readings at the ship and Monitor. On board, one Decometer is read by the leader of the survey team and the other by the helmsman, reading to the nearest 0.01 lane. The ship's log and the magnetic and gyro compass are recorded concurrently together with the time at which the receiver was last referenced and the voltage of the power supply. A typical record is shown in Figure 9. The echo-sounder record is carefully timed to ensure accurate co-ordination with the Decca fixes.

Sounding by the Hyperbola Method

When surveying at a scale of 1 :30,000 the small but inevitable uncertainty in the Decometer values coupled in some cases with insufficient angle of cut between the lanes may greatly complicate the process of position fixing when the soundings are run along compass courses. In such cases the ship is tracked along selected hyperbolic position lines by the method already described. The choice between the two hyperbolic patterns is settled by their direction and lane-width, first choice being given to the pattern whose lanes run most directly across the channel and shoals and for which a lane-width of 0.10 - 0.05 most nearly corresponds to the prescribed separation between sounding lines . 0.05 lane represents the smallest separation on which the larger vessels may be run when sounding by this method. Position-fixing is carried out as described above at intervals of 3-5 minutes. Where the lane-width is suitable it is often expedient to carry out the sounding of the channel at the scale of 1 : 50,00 using the hyperbola method.

The Survey of Shoals

Where the shallower parts are isolated, of small extent and clearly defined their examination can be carried out direct at the appropriate scale. If, however, they are numerous and widely spread over a clearly-defined area, that area must first be closely sounded before the actual detailed examination can be carried out. In regard to these conditions the process of examination can be either direct or indirect. In the former the scale of 1 : 2,500 is used where the depth is less than 18 metres and 1 : 5,000 where it is greater. The technique evolved by the Swedish Hydrographic Office for close sounding and examination by means of echo sounding boats was described in detail in an earlier issue of the Review (3). Using visual methods, a network of carefully positioned buoys has to be set up for the control of the finely-spaced sounding lines required. The lines are run at a spacing corresponding to 5 mm. at the plotting scale (e.g. 12.5 m. apart at 1 : 2,500) with interlines 2.5 mm. apart in shallow water. The proposed introduction of Decca for this type of operation, taking advantage of the high relative accuracy now achieved and making the essential corrections for systematic error already referred to, will clearly enable very great savings in survey effort to be made by dispensing with the buoy-laying boat and will virtually allow one survey launch to do the work of two.

Sjökarteverkets kopparttryckeri 1950 · 121

SV. Bl. nr. 67 2000 3 1950

KSV Sjömätningsfartyget G. Kl.	Lägesbestämningsprotokoll Normalvärde: Röd 960 Grön 430 Vind W Sjöhävning 0 Lodat av L.O.	Tis dag 22/8 1950 Kurs nr ______ Distrikt IIIa 77

Tid	Nr	Röd	Land-korr.	Slav-korr.	Kart-korr.	Rättad Röd	Grön	Land-korr.	Slav-korr.	Kart-korr.	Rättad Grön	Logg	Gyro-komp.	Magn-komp.	Anmärkningar
0915	272	19 09	-2	-2	+3	19 08	31 81	-8	-5	+6	31 74	00.3	92	91	Kurs 128 O
20	73	10	-2	-1	+3	10	32 74	-8	-6	+6	32 66	01.1	90	90	
25	74	17	-2	-5	+2	12	33 60	-7	-6	+5	33 52	01.8	89	88	
30	75	14	-2	-3	+2	11	34 39	-6	-6	+5	34 32	02.6	89	88	Reff. 230 v
35	76	17	-2	-3	+2	14	35 40	-6	-5	+5	35 34	03.4	90	88	
40	277	16	-2	-2	+2	14	36 30	-6	-5	+5	36 24	04.1	91	90	
0945	278	18 41	-2	-1	+2	18 40	36 36	-6	-5	+5	36 30	04.9	268	271	Kurs 130 W
50	79	43	-2	-4	+2	39	35 43	-6	-4	+5	35 38	05.7	269	271	
55	80	32	-2	0	+2	32	34 50	-6	-4	+5	34 45	06.4	271	273	
1000	81	28	-2	-2	+2	26	33 59	-7	-5	+5	33 52	07.2	271	274	Reff. 229 v
05	82	18	-2	-1	+3	18	32 65	-7	-5	+6	32 59	07.9	268	272	
10	283	15	-2	-2	+3	14	31 73	-8	-5	+6	31 66	08.7	269	272	
1015	284	17 18	-2	0	+3	17 19	32 01	-7	-5	+6	31 95	09.4	93	92	Kurs 132 O
20	85	30	-2	-2	+2	28	92	-7	-5	+5	32 85	10.2	90	90	
25	86	35	-2	-1	+2	34	33 82	-6	-4	+5	33 77	11.0	90	89	
30	87	42	-2	-1	+2	41	34 74	-6	-6	+5	34 67	11.8	88	87	Reff. 230 v
35	88	53	-2	-2	+2	51	35 64	-6	-5	+5	35 58	12.6	90	88	
10 40	289	58	-1	-3	+2	56	36 58	-5	-5	+5	36 53	13.4	90	89	
1045	290	17 08	-1	-3	+1	17 05	36 40	-5	-5	+5	36 35	13.9	270	273	Kurs 134 W
50	91	66	-1	-2	+1	17 64	35 55	-5	-4	+5	35 51	14.7	271	273	
55	92	65	-1	-2	+2	64	34 62	-6	-5	+5	34 56	15.5	270	273	
1100	293	58	-1	-3	+2	56	33 67	-6	-4	+5	33 62	16.3	268	271	Reff. 230 v

Fig. 9.

Record of observations in offshore surveying.

Indirect Examination

In the case of indirect examination, an intermediate sounding of the area containing shoals is carried out using either the compass-course or hyperbola method of tracking. Plotting is generally carried out at the scale of 1 : 10,000 where the mean depth is less than 40 metres and at 1 : 20,000 for greater depths. Shoals at depths less than 18 metres thus revealed are then directly examined. When the hyperbola method is to be used, the lines delimited the area to be examined indirectly are first transferred from the fair chart to the field board hyperbolic chart, using the basic grid. Decometer values observed while position fixing during the previous course or hyperbolic sounding are subjected to the necessary land correction so that the corresponding positions plotted in terms of the hyperbolic co-ordinates, and hence the depth figures inserted on the basis of these, are located with geographical accuracy on the fair chart. In order to secure agreement between the examination area as transferred to the hyperbolic chart and the hyperbolic grid, the land correction must also be applied to the hyperbolae. The correction is derived direct from the hyperbolic chart and the corrected hyperbolae drawn in with faint pencil lines. These lines will thus represent hyperbolae located with geographical accuracy across the examination area. In general it is sufficient to mark with thin lines the positions of the geographically-correct hyperbolic lines forming the outer boundaries of the examination area and to draw the hyperbolae across it as straight lines ; in the case of a large examination area or of rapidly changing land corrections or sharply curving hyperbolae, however, it is necessary to mark a number of points along all the hyperbolae in order to represent them with the maximum accuracy. Once agreement has been thus established between the hyperbolic patterns and the examination area, the plan which has been drawn on the chart in pencil is transferred to the examination record at the scale laid down ; by virtue of the land correction, the decometer values subsequently recorded thereon will now be geographically accurate (see Figure 10).

In the examination record the whole-lane values are entered with the appropriate colours and are designated by letter and number. According to the scale and lane width there are also entered hyperbolic values for tenths or hundredths of a lane. 0.03 lane is the smallest difference between courses on which the vessel should be run in the examination quadrilateral. The extent of the area and the lane-widths will determine whether sounding should be carried out along Red or Green. To secure maximum accuracy the Monitor station is informed whenever a vessel is carrying out examination, and it in turn notifies the vessel if any deviation occurs. The closely sounded area is called the " close quadrilateral " and is designated by the letter T (*Tätlodning* = close sounding) (Fig. 11).

Direct Examination

If the close sounding shows indications of shoals requiring fresh examination (denoted by the letter U for *Undersökning*) at the scale of 1 : 2,500, the area is marked by buoys placed according to the observed decometer values and the sounding is then carried out by a motor boat by reference to the buoys according to the rules laid down for examination in coastal surveying (3). The position of

(3) « Description of Boat Echo-Sounding Methods Employed by the Swedish Hydrographic Office » ; *I. H. Review*, Vol. XXVI, No. 2, Nov. 1949.

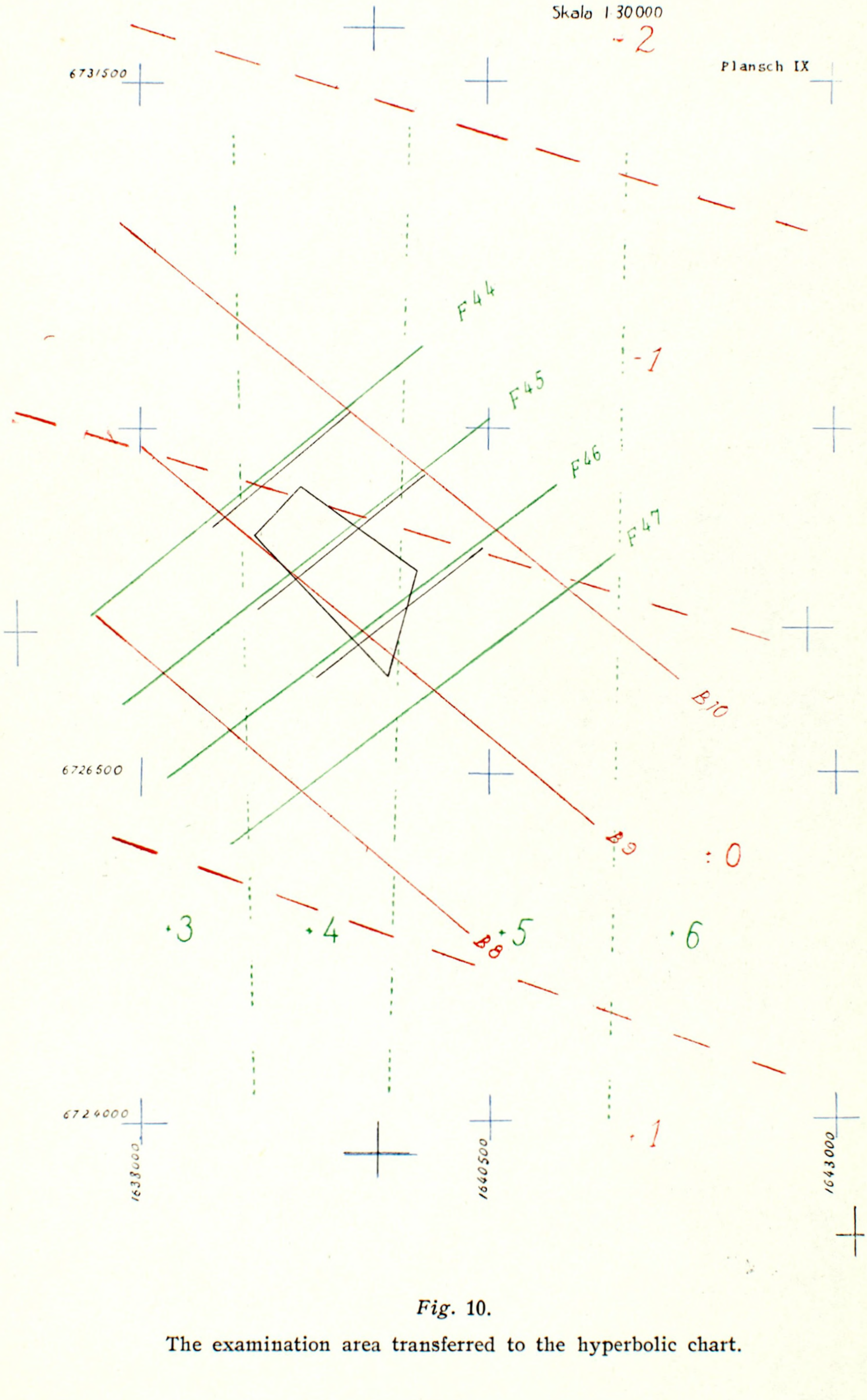


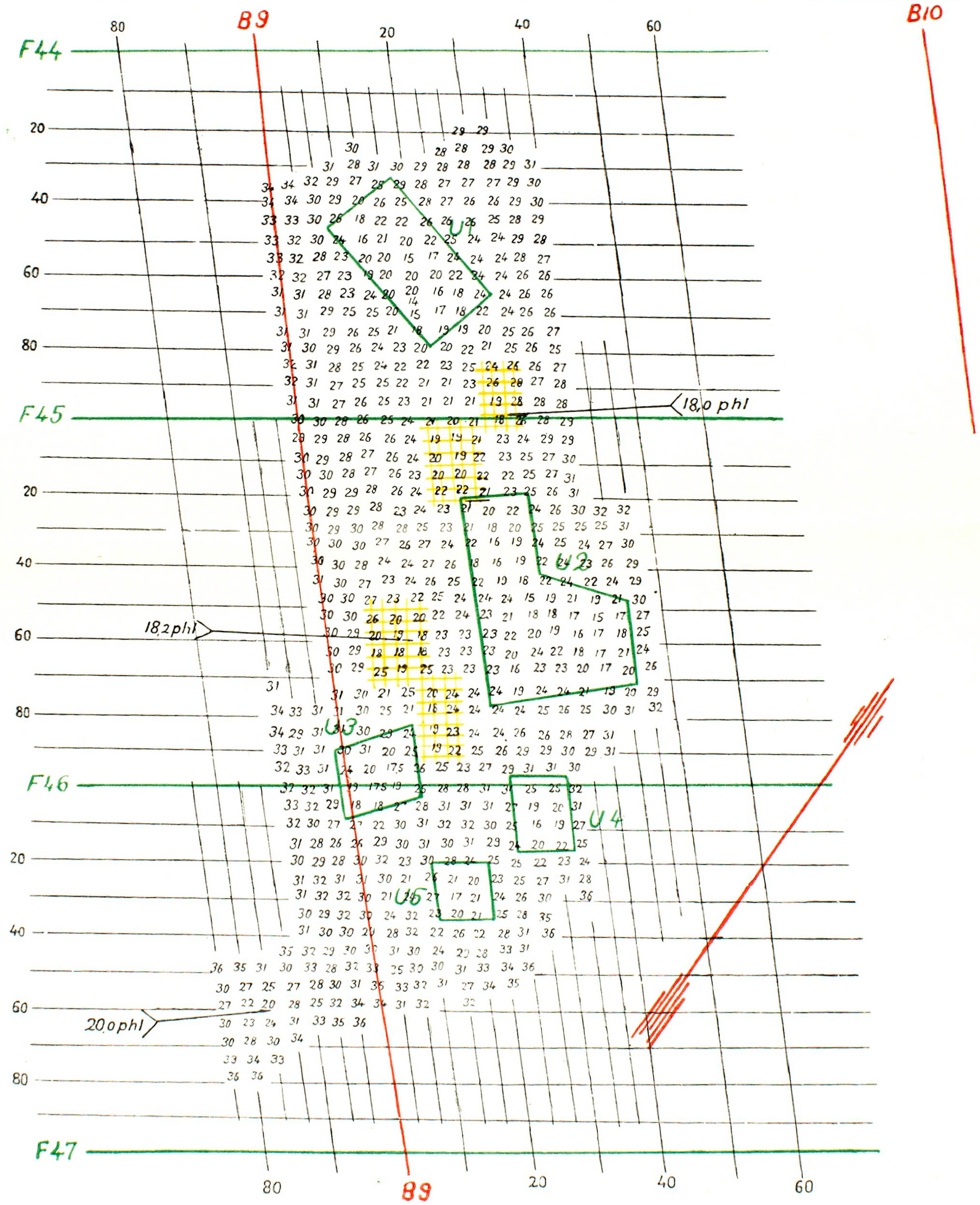
Fig. 10.

The examination area transferred to the hyperbolic chart.

Sjömätningsfartyget Ejdern den 20/8 1952 kl. 0545-1110 Distr. II a 60

Tätlodat område. T4 (U1. U2. U3. U4. U5)

Skala: 1: 10000	Lage för grund		djup		Bott lag	Konstr. av: N. N	Anm
	Kart röd	Kart grön	p lod	red			
Vattenst 3dm ö	B 09 19	F 44 70	14.0	14.0	st	Lodad av N. N	
	B09, 29	F45 51	15,0	15,0	st		
Vind: NV 3	B09, 02	F46 02	17,5	17,5	st.	Införd av N. N	
	B 09 26	F46, 13	16.0	16.0	st		
Sjöhävn.: 3	B09, 12	F46, 34	17,0	17,0	st	Normalvarde Röd: 370 Gron. 0040	



Utdrag ur protokoll över tätlodat område

Fig. 11.

Close quadrilateral at scale of 1:10,000.

Sjömätningsfartyget Mb 23 den 20/5 1955 kl. 0850-1020 Distr. II a 60

Rekognoscerat område: R 17 (U 19)

Skala: 1: 2500	Läge för grund		djup		Bott lag		
	Kart röd	Kart grön	p lod	red.		Konstr. av: N. N	
Vattenst MV	B 08,355	G 47,770	2,0	2,0	K	Lodad av: N. N	
Vind: S 2						Införd av: N. N	
	B 08,160	G 30,165					
Sjöhävn.: 1	B 08,175	G 30,040				Normalvärde Röd: 370 Grön: 0040	
	B 08,400	F 47,590					

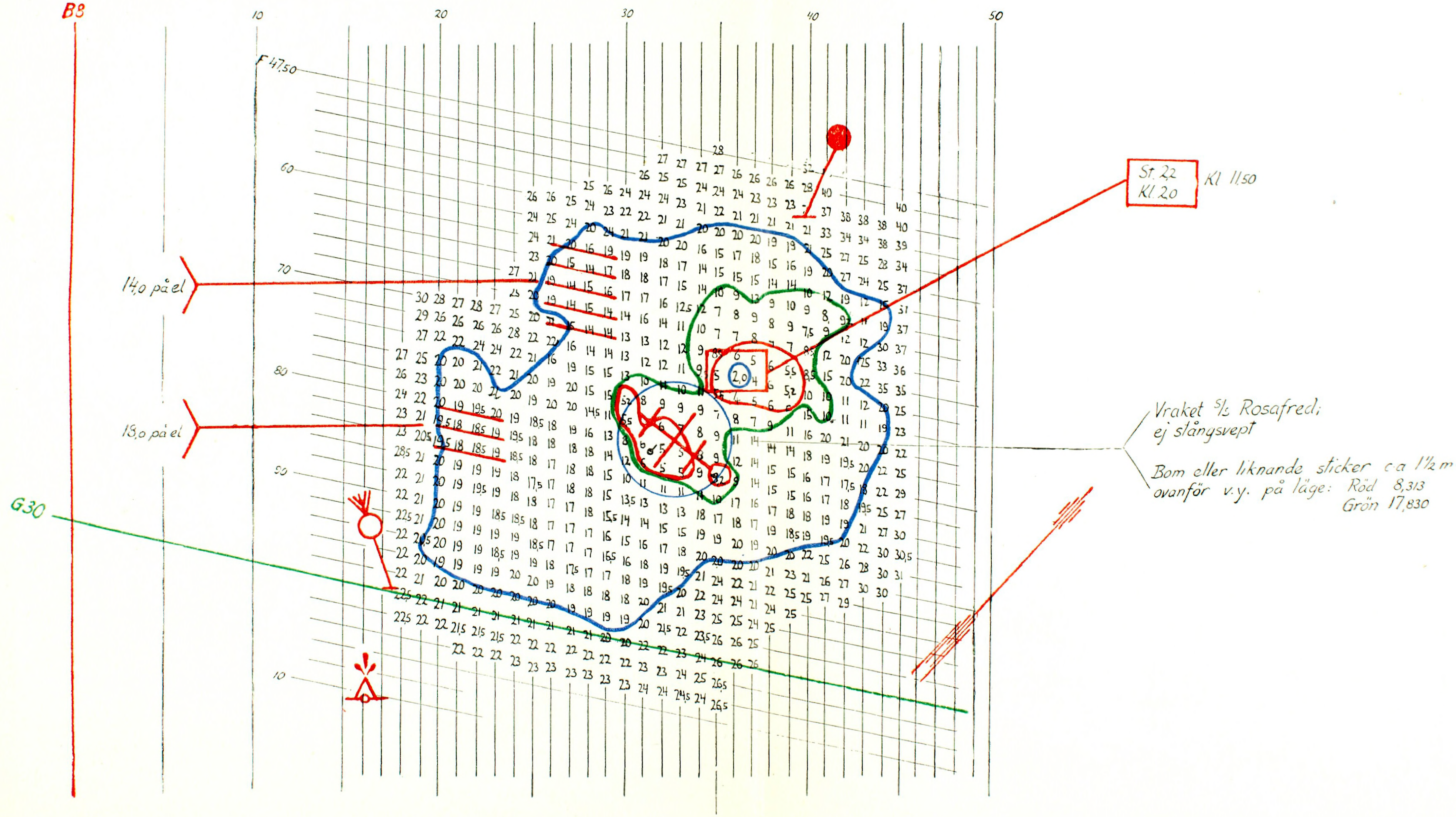


Fig. 12.

Examination record by boat at scale of 1:2,500 with use of Decca.

the point of verified least depth is established by the vessel, by taking decometer readings alongside a buoy previously laid over the shallow spot by a motor boat. In the column for bearings in the examination record, the corrected Decometer values for the buoys placed by the vessel are recorded together with the corrected value observed with the vessel positioned over the point of least depth. The position of the shoal will also be marked in the close quadrilateral. The successful use of the Decca system for guidance along the sounding lines, given a degree of instrumental accuracy which can be achieved by the methods already described, will obviously lead to notable savings in effort and equipment. Figure 12 shows the examination of the shoal of Argos (Swedish Chart No. 113) at the scale of 1 :2,500, which was carried out last summer (1955) by a new method with the use of Decca without buoy-laying.

Conclusion

By dint of successive improvements in the equipment and as a result of the experience gained in regard to the propagation of radio waves, the use of Decca for position-fixing out of sight of land has been developed to cover coastal surveys and to include detailed survey work in the inner channels. The Decca Navigator system has given, and more than given, the degree of accuracy which was desirable for survey work out at sea and which could not be achieved before the Decca chain was procured. For examination work Decca ensures above all else a great saving in time and greater reliability.

Through the use of Decca, coastal survey work within sight of land has become completely independent of visibility. Furthermore, greater accuracy is obtained than by visual fixing from cross-bearing, at least within those areas where the lanes are sufficiently narrow and the angle of cut is not too acute. In addition the building of special triangulation points and marks is saved.

For detailed hydrographic survey work in the inner channels, which are a special feature of the Swedish belt of coastal islets, it may be said that the introduction of Decca will again ensure considerable savings of time and equipment and personnel without the accuracy becoming any less than with the methods now in use, at least in those areas where the lane-width and angle of cut are favourable. It should not be out of the question to obtain savings of up to 50 % and the object of forthcoming comparative trials is to prove this.