THE METHOD AND USE OF TWO-RANGE DECCA

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INTRODUCTION

Two-range Decca is a variant of the Decca navigator system. It was developed specifically for surveying and, unlike conventional Decca, which utilizes permanently based transmitters ashore, the master is carried in a ship and the shore-based equipment is designed for portability, as well as for the essential accuracy.

The first Two-range chain used in Canada was established aboard the C.G.S. *Kapuskasing* in 1955 and work was started in the Gulf of St. Lawrence. This work was extended in 1956 and a second chain was set up in Cabot Strait, using the C.G.S. *Fort Frances* as the master ship. In 1957, our latest survey vessel, C.G.S. *Baffin,* used the system off the coast of Nova Scotia, and the C.G.S. *Wm. J. Stewart* started Two-range Decca work in Hecate Strait, British Columbia. Both these projects were continued in 1958 and, during that summer, the *Baffin* transferred the Nova Scotia chain to the southwest coast of Baffin Island, where it was used to survey a previously uncharted region.

In the following, the method of Two-range Decca is briefly outlined and its use as an aid to offshore hydrography is discussed. The calibration trials and other tests described are from the experience gained during two seasons' work on the Pacific coast, for which the equipment provided was a Two-range system of the 6*f*, 300-watt type, using Green and Purple slaves.

THE METHOD OF TWO-RANGE DECCA

In a Two-range Decca chain, the master transmitter and a Decca receiver of conventional type are carried in the ship whose position, relative to two slaves ashore, is to be established. The decometers, associated with

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the receiver, indicate the phase difference between the master signal and that received from either slave. This phase reading bears a linear relation to the length of the transmission path, hence it is a measure of the distance. The position lines are circles concentric about the slaves and only the ship carrying the master station can utilize the chain.

Considering a Two-range chain, with Purple and Green slaves of the $6f$ type, the basic frequency may be called f. The master aboard ship radiates frequency $6f$ and this is received by the Green slave, whose drive is phase locked at $6f$, and then radiated from Green at frequency $9f$. In the ship's Decca receiver, this received frequency is raised to $18f$ and compared with the master frequency, also multiplied to $18f$. The phase comparison is accomplished within the phase discriminators, and the phase difference is displayed on the Green decometer.

In like manner, the Purple slave receives frequency $6f$ from the master and returns it at frequency $5f$. This frequency is raised to $30f$, phase compared with the master frequency and the phase difference appears on the Purple decometer.

The Decca measurements of any chain are governed by the assigned frequencies and the speed of wave propagation. The half wavelength, called lane width, is half the wave velocity divided by the comparison frequency.

The velocity of radio waves at Decca frequencies over sea water, as presently accepted for our purpose, is 299 650 Km/s. However, since they travel as surface waves, their speed is influenced by the electrical properties of the surface medium. Conditions over sea water are fairly uniform, but this is not so over land. In general, the speed over land is less than over sea water.

For hydrographic work it is evident that slave stations should be located so that, insofar as possible, a wave path over land is avoided. The Decca Company recommend that the slaves should be located within 300 metres of the shore whenever possible.

Since the comparison frequency of Green is $18f$ and that of Purple is $30f$, it follows that 18 Green lanes are equal to 30 Purple lanes and this is called a zone. The Green decometer is numbered in lanes from 30 to 48 and the zones indicated by the letters A to J. The Purple decometer is numbered 50 to 80 lanes and the zones are also lettered A to J. In this way, confusion between Green and Purple decometer readings is avoided.

No lane identification is provided in our Two-range systems. At the start of work, the proper number of whole lanes must be set on the decometers at a point where the Decca coordinates are known. After that, the decometers keep the lane count automatically.

For practical surveying, the following approximate equation may be used :

$$R = D + a + b$$

where R = distance (lanes) between effective electrical centres of master and slave.

D = decometer reading (lanes) to which the mean goniometer correction has been applied.

a = locking constant (lanes).

b = correction due to proximity of slave's induction field (lanes) from Norton and Bremner curves.

The small error which may occur due to goniometer change with variation of decometer readings can be neglected. It may also be assumed that the wave speed remains constant if care is taken to ensure that the wave path is largely over sea water and free from significant electrical interference.

The effective electrical centre at slaves may be taken as the mid-point between transmitting and receiving aerials if there is no significant electrical interference and the separation of aerials is about 200 feet.

At the master aboard ship, the aerial separation will often be much less than 200 feet and the effective electrical centre cannot be closely defined as the mid-point between them. It can be found by trial, however. Its position may also vary a small amount about a central point, depending on the bearing of the ship relative to the slave, but this effect is small and need not be considered.

The locking constant is a significant correction introduced by the ship's induction field. Its magnitude may vary but, for a given set of conditions, can be considered as constant for practical purposes. This effect increases the decometer readings. It must be determined by trial and then subtracted from the decometer readings by offsetting the goniometers.

The correction due to the slave's induction field is a function of distance. If the master aboard ship approaches within about six miles (11 kilometres) of the slave, it must be considered. Like the locking constant, its sign is negative, that is, the amount must be subtracted from decometer readings. This correction has been computed from theory and is determined by the use of Norton and Bremner curves (figure 4).

The best possible positions of the slave electrical centres must be obtained by surveying as all subsequent Decca measurements depend upon them.

The non-directional, unmodulated, continuous-wave signals used in Decca chains are in the frequency band 70 to 130 Kc/s. At these frequencies the waves tend to follow the earth's surface, and so the range of a Decca system is not limited to the optical horizon.

The Decca frequencies assigned for use on the Pacific coast and the resulting lane widths and comparison frequencies are :

Master	85.046	Kc/s
Purple slave	70.872	Kc/s
Green slave	127.569	Kc/s
Purple comparison frequency	425.230	Kc/s
Green	255.138	Kc/s
Purple lane	352.3387	m
Green lane	587.2312	m

For plotting the Decca results, a special method was developed by the Nautical Geodesy Section of the Hydrographic Service. This is described in the Appendix.

SUMMARY OF OPERATIONS

The assignment was in Hecate Strait (figure 1) where an area exceeding 6 000 square miles, within Capes Scott and St. James, had not been adequately surveyed.

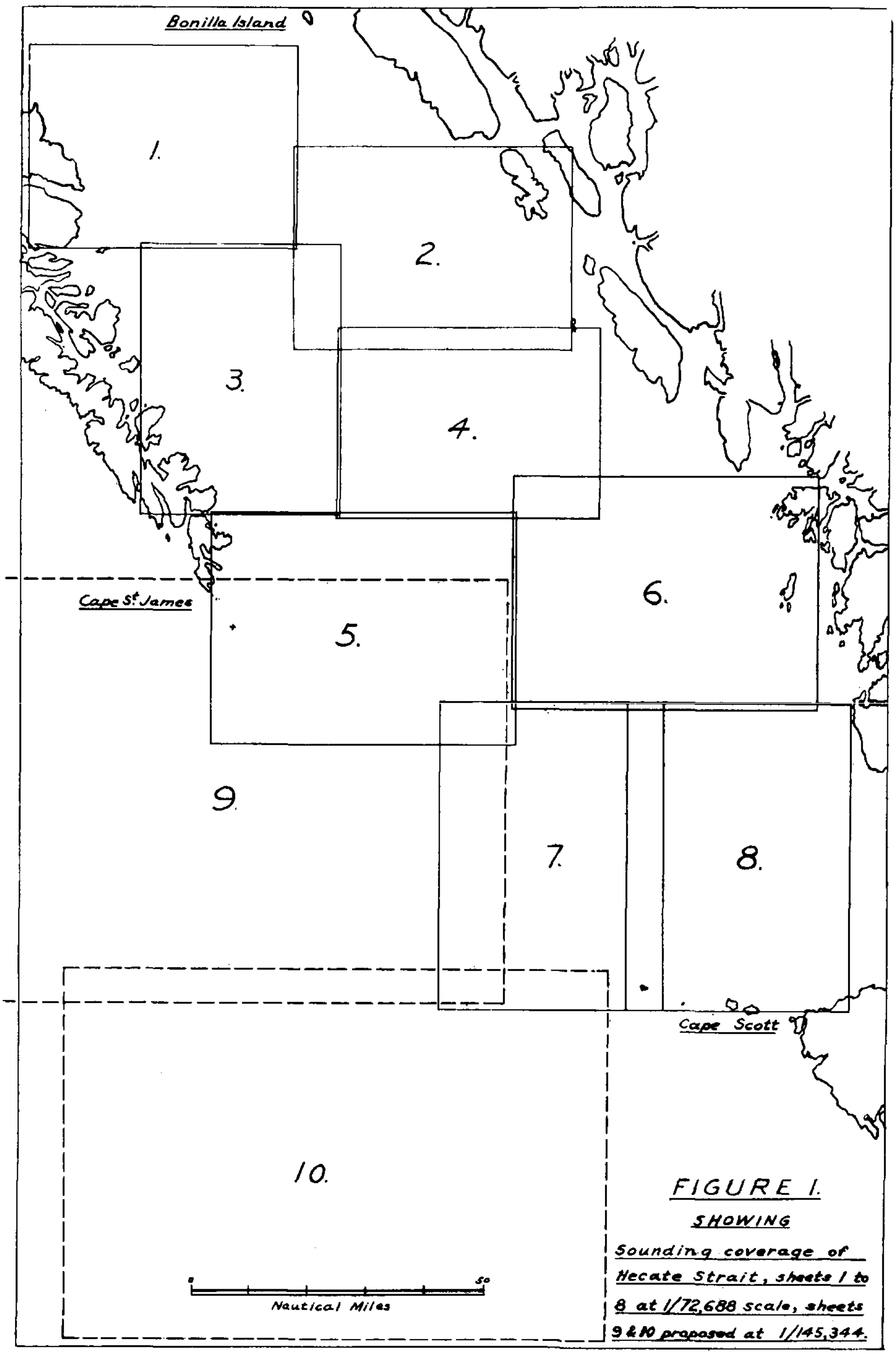

Bonilla Island
1.
2.
3.
4.
Cape St James
5.
6.
9.
7.
8.
Cape Scott
10.
0
50
Nautical Miles
FIGURE 1.
SHOWING
Sounding coverage of
Hecate Strait, sheets 1 to
8 at 1/72,688 scale, sheets
9 & 10 proposed at 1/145,344.

FIG. 1

The shores of this strait are rocky and broken and the softwood forest, almost without exception, grows to the water's edge. This, together with the tangle of fallen trees and underbrush, caused the siting of the slaves to be rather a severe problem. It was only overcome after several weeks' work at each place and these locations are by no means ideal. However, they were the best available.

The Purple slave was placed on a small islet in the region west of Aristazabal Island and the Green slave on Copper Island, at the entrance to Skincuttle Inlet, Queen Charlotte Islands (figure 2). The locations provided wave paths over the sea without intervening land masses of any consequence and these slaves were used for all the subsequent work in 1957 and 1958.

Prefabricated houses were used for the slave equipment and personnel and the generators were placed under cover in separate shacks.

The nature of the country and the problem of establishing the slaves are illustrated by photographs.

When the slaves were ready for operation, the first step was to determine the geographical positions of their electrical centres. This was done by surveying from previously established triangulation points ashore.

From trial observations, the ship's electrical centre was found and the locking constants determined. The decometers were corrected accordingly and the system was then, presumably, ready for use. However, it appeared essential to make sure that the new equipment would fully satisfy the standard of accuracy required and, for this reason, additional trials were made before sounding was commenced.

First, the distance between the slaves, as derived from the geographical positions, was compared with the distance as determined by Decca. Then a final test was conducted near the northern limit of the proposed work where a position determined from a shore base was compared with the Decca result. The close coincidence which was obtained by these tests indicated the very good results that could be expected from the Decca system and it was then considered safe to proceed with the work.

The correct lane numbers were set into the decometers either by visual fixing, from range marks to natural objects ashore, or by the use of buoys for which the Decca coordinates had been previously established. Offshore, the use of buoys proved to be essential. These were moved to strategic locations from time to time as the work progressed.

C.G.S. *Wm. J. Stewart*, the survey vessel used for the work, was built in 1932. Her length is 228 feet, breadth 35 feet, mean draft 13 ½ feet, gross tonnage 1295 and normal cruising speed 10 knots.

As a result of the two seasons' work, 10 252 nautical miles were sounded in Hecate Strait using the Decca Two-range system. The area which is now completed, as well as that still remaining to be done, is shown in figure 2.

BASE POSITIONS AND DECCA CALIBRATION

Base positions

The position of Green electrical centre was obtained from a nearby geodetic base through two independent nets. Four triangles at most were involved and the results checked closely. It is considered that the accepted

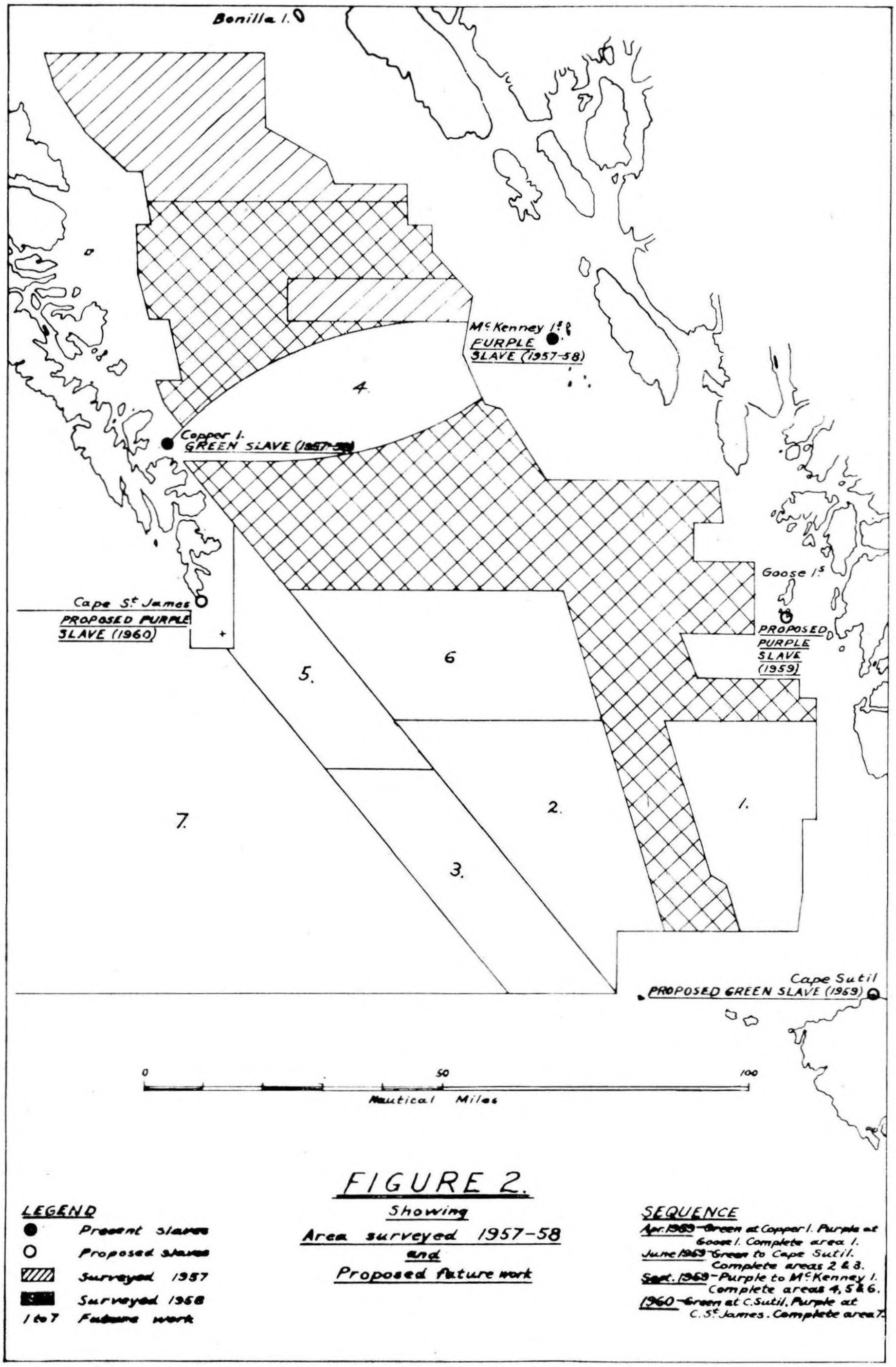
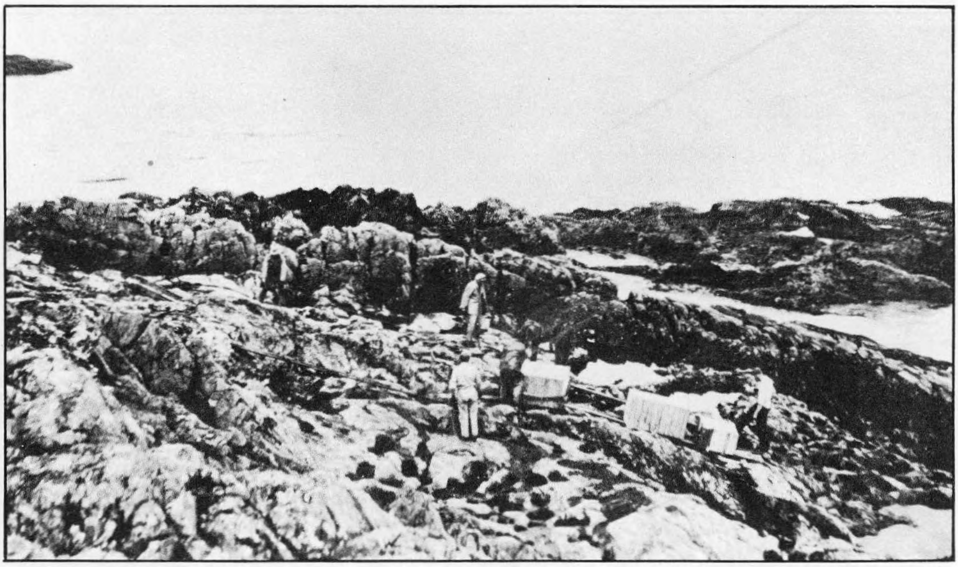
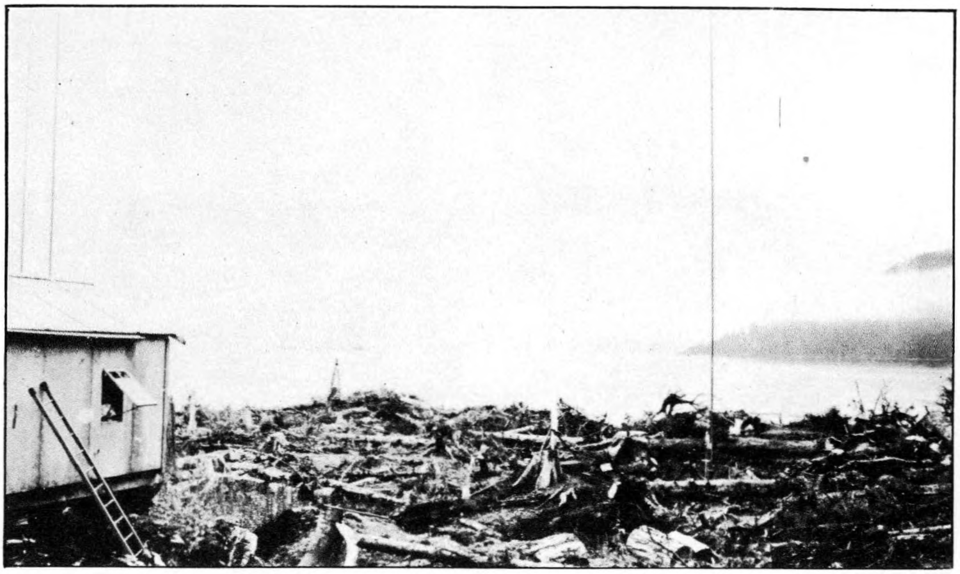

Bonilla I.
Mc Kenney Is
PURPLE SLAVE (1957-58)
Copper I.
GREEN SLAVE (1957-58)
4
Cape St James
PROPOSED PURPLE SLAVE (1960)
Goose Is
PROPOSED PURPLE SLAVE (1959)
5.
6
1.
2.
3.
7.
Cape Sutil
PROPOSED GREEN SLAVE (1959)
0
50
100
Nautical Miles
FIGURE 2.
Showing
Area surveyed 1957-58
and
Proposed future work
LEGEND
Present slaves
Proposed slaves
Surveyed 1957
Surveyed 1958
1 to 7 Future work
SEQUENCE
Apr. 1959 - Green at Copper I. Purple at Goose I. Complete area 1.
June 1959 - Green to Cape Sutil. Complete areas 2 & 3.
Sept. 1959 - Purple to Mc Kenney I. Complete areas 4, 5 & 6.
1960 - Green at C. Sutil. Purple at C. St James. Complete area 7.

Fig. 2

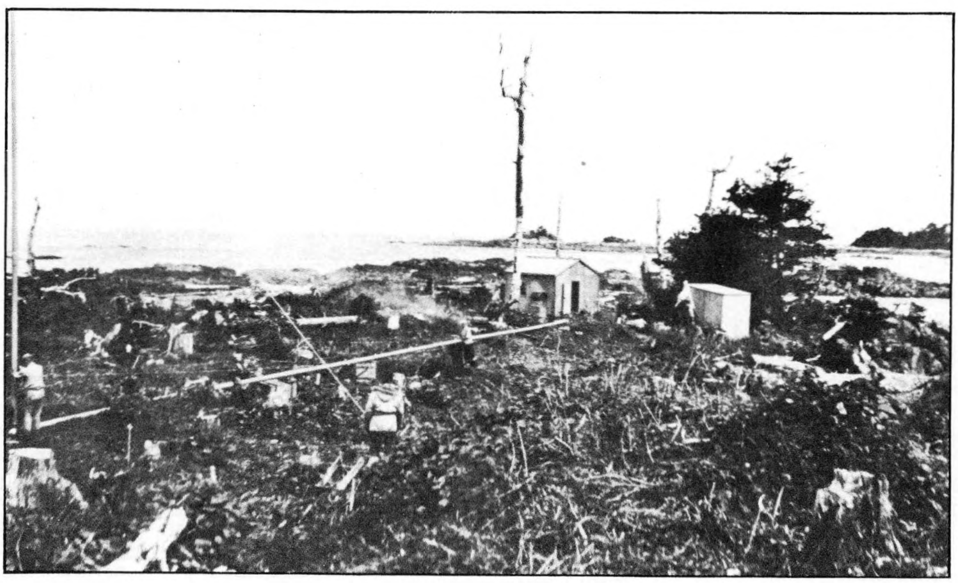


Pl. 1. — Copper Island
Landing Equipment at Green Slave

Pl. 2. — Purple Slave — McKenney Island
Landing Place and Ramp over the Rocks



Pl. 3. — Green Slave — Copper Island
Decca Installation Completed



Pl. 4. — Purple Slave — McKenney Island
Erecting Decca Mast

position is of a high order, probably coinciding with a primary geodetic value within two feet.

The position of Purple electrical centre is less certain. It was derived from a base established by the Hydrographic Service in 1922. Two values were obtained by different routes which showed a negligible difference, and it was evident that the accepted position is just as valid as the survey of 1922 on which the charts are based.

It would have been preferable to start from the geodetic base but this could not be managed without unduly delaying operations. The side used was only six triangles distant from the geodetic base of the original survey, however, and the position error of Purple is unlikely to be great. Nevertheless, it is recognized that residual error probably does exist in this third-order triangulation.

Ship's electrical centre

As no wharf was available, a location near Purple was chosen where the ship could safely steam toward the slave, and in a reverse direction. The line of sight of a theodolite placed ashore at right angles to this course provided the fix. Radio-telephone communications were maintained from ship to shore and the decometers read at the moment the observer indicated the foremast to be on his line of sight. A slow ship's speed was maintained and calm weather prevailed.

The results, listed below, did not agree too well. However, the mean value is likely to be quite close to the true value and it was accepted.

Results — Ship-Electrical-Centre Observations

Purple decometers

Ship's head (gyro)	Standard	Reference	Half-diffs. (lanes)	Equivalent feet
322 142	.267 .354	— —	.0435	50
322 142	.255 .373	.288 .400	.0575	66
322 142	.300 .370	.339 .400	.0325	37
Mean distance, foremast to ship's electrical centre			.044	51 feet

(This value was used in all subsequent computations).

Locking constants

To determine the locking constants, *ship stations* were conducted in which observers positioned the ship's foremast from a shore base with theodolites. The observations were synchronized by dipping a flag aboard ship at prearranged intervals and simultaneously reading the decometers and the ship's bearing. Ten repetitions were made in each case and the results averaged.

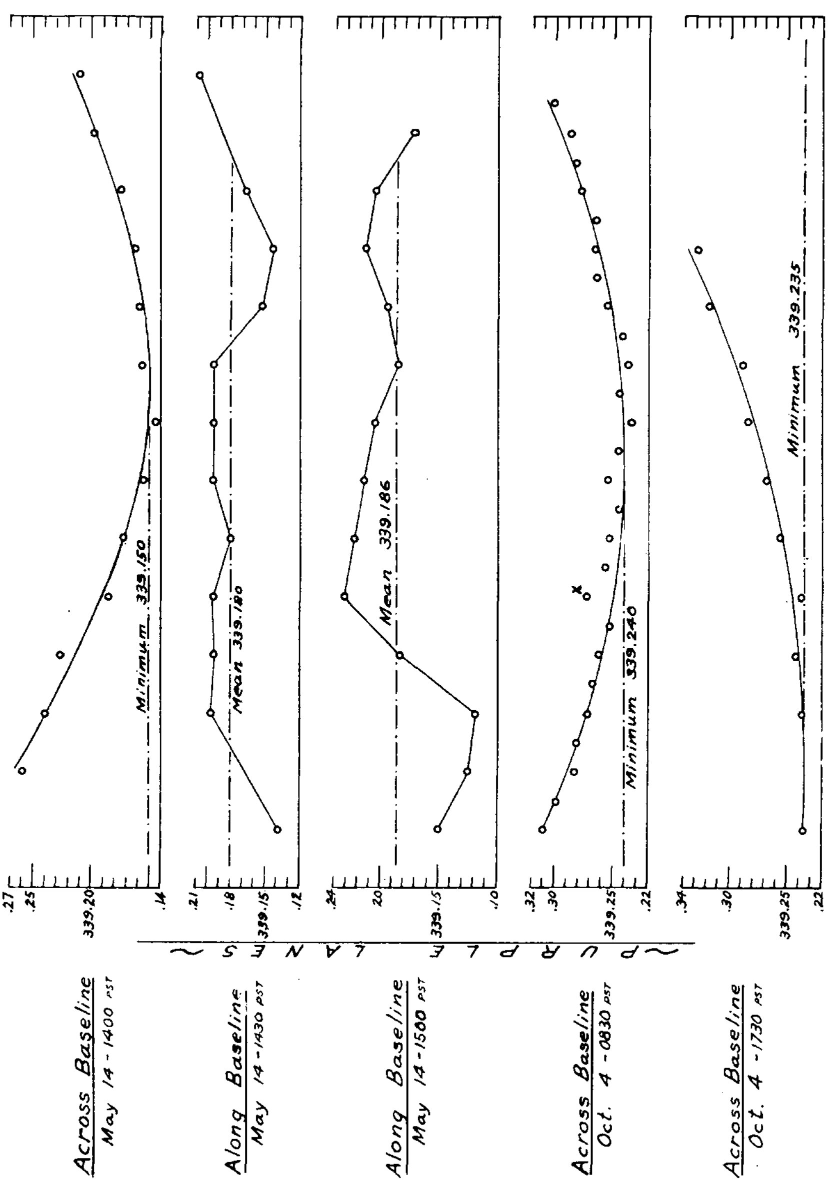


FIG. 3. — Baseline Tests 1958

The locking constants were then computed from the approximate equation already given.

$$R = D + a + b$$

Since R is the distance between the electrical centres of master and slave, whereas the distance resulting from the shore-based observations and subsequent computations is that between the slave's electrical centre and the ship's foremast, the latter was corrected as follows :

$$R = R_1 + X \cos \theta$$

where R_1 = surveyed distance from slave electrical centre to foremast.
X = distance, previously determined, foremast to ship's electrical centre.
θ = angle between the bearing of ship's head (observed) and the bearing of the slave from the ship (computed).

Thus,

$$R_1 + X \cos \theta = D + a + b$$

in which $X \cos \theta$ takes the sign of the angle and a and b are always negative. The b correction was taken from Norton and Bremner curves (figure 4) and the locking constant (a) could then be computed.

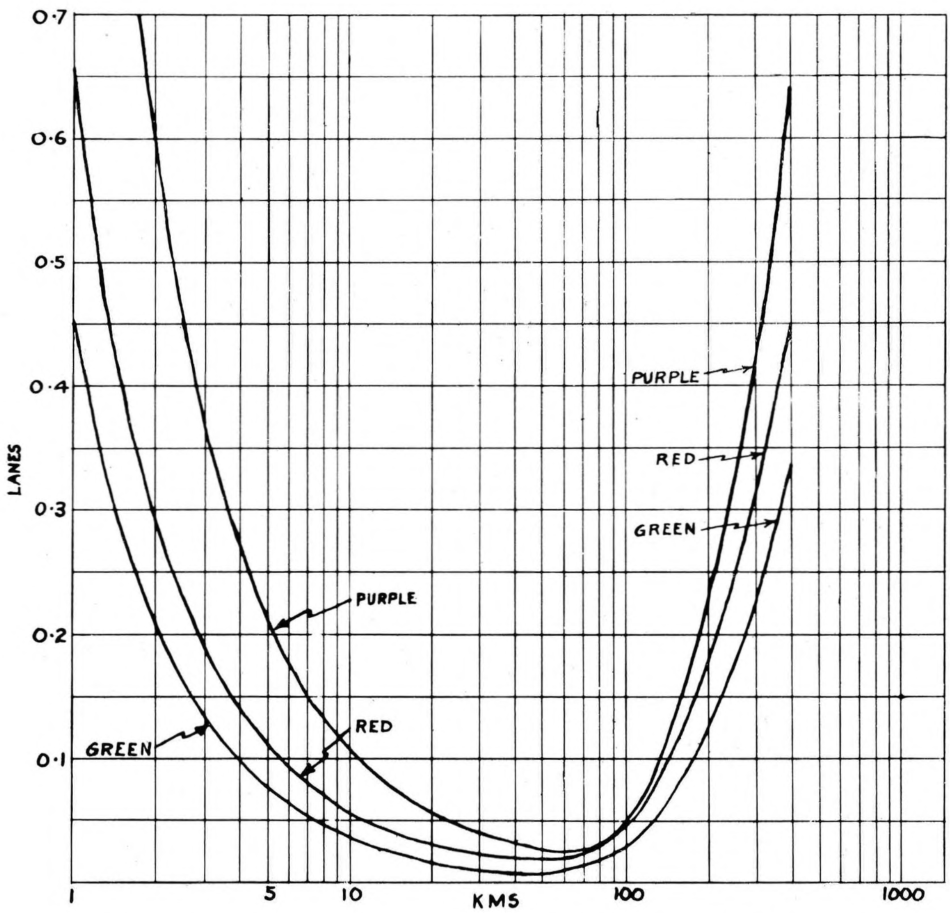


Fig. 4. — Phase Correction over a Sea-Water Transmission Path (Conductivity $\sigma = 5 \times 10^{-11}$ *e.m.u.*)

Example cf. locking-constant computation

R_1	=12.812 Green lanes	12.812
D	=13.286 Green lanes	.003
b	= .047 Green lane	.047
X	= .026 Green lane	
θ	= 84 Degrees	12.862
		— 13.286
a	The Green locking constant	— .424

Locking-constant Results, 1957

Standard decometers

Trial	Purple	Green
1	—.763	—.424
2	—.794	—.443
3	—.556	—.409
4	—.600	—.545
5	—.592	—.439
Means accepted	—.661	—.452

Locking-constant Results, 1958

Trial	Standard decometers		Reference decometers	
	Purple	Green	Purple	Green
1	—.577	—.407	—.578	—.421
2	—.602	—.495	—.654	—.514
3	—.572	—.377	—.574	—.387
4	—.588	—.372	—.612	—.389
5	—.582	—.506	—.592	—.524
6	—.626	—.436	—.629	—.443
7	—.684	—.387	—.704	—.402
Means accepted ..	—.604	—.426 lane	—.620	—.440 lanes

Baseline distance

The distance between the slave electrical centres, as computed from surveys by the inverse method, was 64.42 nautical miles. This is equivalent to 339.107 Purple lanes.

To test the total lane count, a trial run was made from Green to Purple, starting and ending with sextant fixes. This showed the integral lane count of both decometers to be in accord with the above measurement.

A further baseline measurement was made as follows : Starting near Purple, lane identification was accomplished and the ship's course made good on the baseline toward Green. When beyond the influence of the slave's induction field, the total Decca distance, Green plus Purple, was recorded at quarter-hour intervals over a two-hour period. The ship would not have wandered far from the baseline during this time and the observations were discontinued before the onset of the skywave. The mean baseline value thus obtained was 339.117 Purple lanes which is 12 feet greater than the computed value. It is to be noted, however, that the 1957 locking constants were used in this trial.

Further Decca measurements of the baseline were made in 1958, the results of which appear in figure 3, and this matter is discussed later.

Final position check

This trial, made in 1957, was considered to be the most valuable check on the performance of the new equipment. The place chosen for the test was approximately sixty nautical miles from Green and ninety from Purple. It was felt that if a good check could be obtained here it would, in large measure, confirm the reliability of the Decca system for the work in hand.

A ship station, consisting of the usual ten repetitions, was conducted and the 1957 locking constants used to determine the Decca distances.

As before, a geographical position of the ship's foremast was derived from a triangulation base ashore and the position of the ship's electrical centre computed.

Using the Decca values, another position of this electrical centre was found as follows : Given the side Green to Purple as computed by inverse and the observed Decca distances from the ship to the slaves, the angles of this large triangle were found and the ship position solved using the Green and Purple positions which had been accepted from the surveys.

The resulting difference was 82 feet (25 metres), which is equivalent to .013 inches on the 1/72 688-scale plotting sheets. This trial is further discussed below.

ADDITIONAL OBSERVATIONS, COMPUTATIONS AND CONCLUSIONS

The 1957 locking-constant results were none too consistent and these trials were repeated in 1958.

Having in mind the previous experience, every precaution was taken to try and obtain more uniform results. The number of trials was increased, all observers were requested to be as precise as possible and both the Standard and the Reference decometers were read in order to establish locking constants for each pair. The 1958 results were considerably better than those of 1957 and are considered satisfactory for all practical purposes. However, quite a spread still appeared in the individual results and the reason for this is obscure.

The differences between the 1957 and 1958 locking constants amounted to .057 Purple lanes (66 feet) and .026 Green lanes (50 feet). If it is assumed that the 1958 values are correct for both years then the 1957 Decca results would be in error by the above amounts. However, no consideration was given to replotting this work as any changes would scarcely exceed .015 inches on the plotting scale which was used.

The results serve to indicate the necessity of careful evaluation of the locking constants, since any error introduced into the system during calibration will be carried into all the work which follows.

Recomputation of 1957 position check

As before stated, the 1958 locking constants are believed to be better than those of 1957. Also, it appeared reasonable to suppose that the true values could not have changed materially since the same slaves were used in both years and no alterations were made to the equipment. It was reasoned that insertion of the 1958 locking constants into the Decca values of the position check made in 1957 should result in a closer coincidence between the geographical coordinates obtained by Decca and by the survey. This proved to be the case.

When recomputed, the difference in position was reduced from 82 feet (25 metres) to 18 feet (5 ½ metres).

Baseline

Referring to the 1958 Decca measurements of the baseline (figure 3), it was evident that these results were not very consistent, varying from 339.150 to 339.240 Purple lanes. It was estimated that the May 14 trial was probably the best and a Decca baseline value of 339.160 Purple lanes was used for the computation of wave velocity.

As a result of the baseline trials, it seems evident that the best way to measure a Decca base is to steam the ship slowly across it, reading the decometers at short intervals. A smooth curve drawn through the plotted points then serves to remove the scatter inherent in the individual Decca readings and the minimum value is, of course, the desired measurement. This method will be used in future.

Variation of decometer readings

A difference in the locking constants derived for the two Green decometers, and also for the Purple pair, was noted in the results and to investigate this a further trial was made.

By means of a signal generator, the same signal was impressed on both Decca receivers and the decometer differences noted at various points around the dial. This showed that the Decca receivers are not perfectly linear, that is, the decometers do not read exactly the same at all times. The Decca Company states in their manual that this difference may amount to as much as .02 lanes which is largely confirmed by the above results as shown in figure 5.

It is evident that small errors, in the order of .02 lanes are inherent to the equipment and may be expected to occur at any time.

The variation of individual Decca readings from all sources was demonstrated by the trial made along the baseline in 1957 where the extreme variation of nine readings from their mean was plus or minus 85 feet (.074 Purple lanes). The pattern of such variations is also illustrated in figure 3 where the readings, made at 30-second intervals crossing the baseline, are plotted.

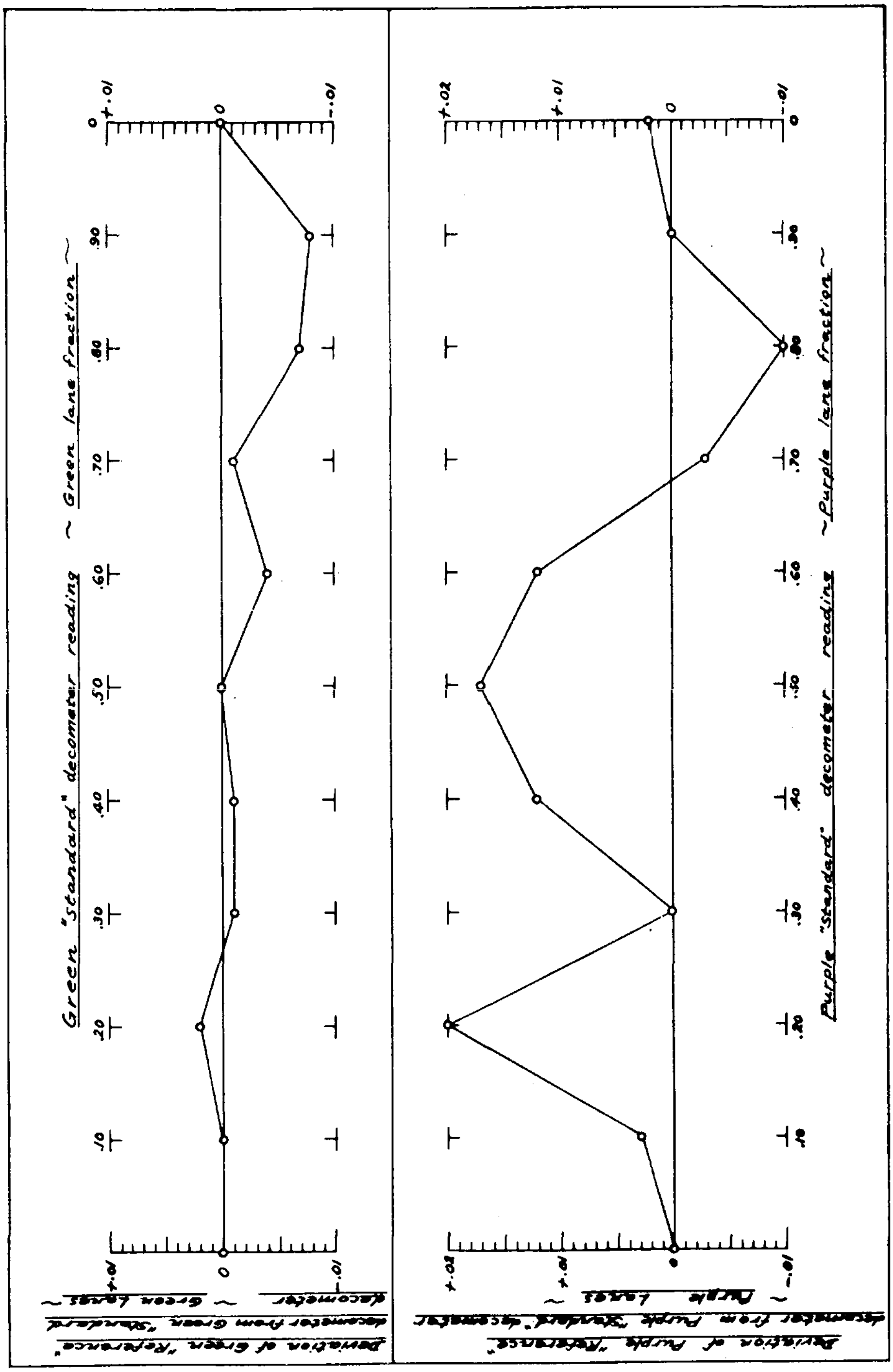


FIG. 5. — Nonlinearity of Decca Receivers

Repeatability of Decca readings

Having made the appropriate tests and started work, it was desired to know just how well the new system would remain in adjustment under operating conditions which varied a great deal from time to time. A conclusion as to this was not immediately available but, within a short time, an impressive array of evidence was gathered from the daily position checks which were made. Some typical examples of these are listed below. They are the differences obtained when the ship checked back at marker buoys placed in relatively shallow water for which the Decca coordinates had been previously established, and fairly represent the degree of coincidence which was almost always obtained.

Differences in Repeated Readings at Check Points
Buoys Anchored in Depths up to 25 Fathoms

Purple	Green	Purple	Green
.03	.03 (lane)	.13	.09 (lane)
.16	.10	.08	.0
.06	.0	.08	.07
.11	.10	.18	.01
.11	.02	.01	.02
.13	.01	.06	.06
.06	.03	.09	.08

The excellent repeatability of the Decca system was also demonstrated many times by the ease with which the ship could return to the buoys. On one occasion when it was nearly dark the ship almost ran down the buoy before it was sighted from the bridge.

Extreme range

To test the Decca result at an extreme range, a ship station was conducted in 1958 near Cape Sutil (figure 2) at a mean distance of 125 miles from the slaves, with an intersection angle of 27 degrees. The result showed a difference between the Decca and surveyed positions of 367 feet, or .06 inches on the 1/72 668-scale plotting sheet.

At the extreme southern limit of soundings (figure 2), where the mean distance from the slaves was around 105 miles and the intersection angles varied from 31 to 35 degrees, it is fair to assume that this difference would be somewhat less, probably about .05 inches as plotted, according to the ratio of distances.

During this ship station the Purple signal was noted to be very weak and this, together with the magnification of residual error existing in the surveys, may account for the rather disappointing result. The test served to indicate that extreme distances and poor intersection angles are to be avoided whenever possible.

With regard to the sounding that had been done at the southern end of the area, it was decided that the probable positioning error could be tolerated under the circumstances, since the soundings all indicated a very flat bottom with depths of 30 fathoms or more throughout.

Effect of land masses on the Decca wave

This effect was so clearly shown on one occasion that it is of interest to record the event.

On August 26, 1958, at the close of the day's work, it was convenient to anchor for the night in ship position 1 (figure 6). Visual fixes showed that the Green decometer was reading too high by almost exactly half a lane. The next morning, in the same position, the fixes again showed this discrepancy. However, the decometer was set as before on the assumption that it was due to the decrease in speed of the wave caused by the intervening land which would increase the decometer reading. This proved to be the case. When the ship reached ship position 2 (figure 6) which was well clear of the land, additional fixes showed clearly that the Green decometer had returned to normal and close checks were obtained.

As shown in figure 6, the Green wave path was about 38 per cent over land, and this land is mountainous and believed to be rather highly mineralized. It is of interest to note that the error introduced to the Decca reading on this occasion was nearly 1 000 feet and it is doubtful if skywave effect could have accounted for more than a small fraction of it.

Velocity of radio waves at Decca frequencies

Throughout the work, both in 1957 and 1958, a Decca wave speed of 299 650 Km/s was used and the position-circle templates and plotting diagrams are made up on this basis (Appendix).

Several different values of Decca wave velocity have been used by different authorities, and it was of interest to attempt evaluation of the wave speed from the 1957 and 1958 data.

The distances used were those determined from the surveys. The computations, some of which involved very long sides, were well checked and are substantially correct. The 1958 locking constants were applied to the Decca readings in all cases.

The values were computed on the following basis. Assuming that there are no survey errors and that the Decca constants of 1958 are correct for both years, then the total distance measurement by Decca is half the wave speed divided by the comparison frequency multiplied by the total lanes as read on the decometer. This should equal the distance obtained by the survey. Knowing the other values of the equation the wave speed was solved.

Result of Computations

Side	Length *(Km)*	Wave Velocity *(Km/s)*
Baseline	119.2	299 602
Purple to Ship 6, 1957 ..	163.0	299 660
Green to Ship 6, 1957 ..	105.1	299 660
Green to Ship 9, 1958 ..	259.4	299 531
Purple to Ship 9, 1958 ..	217.4	299 496

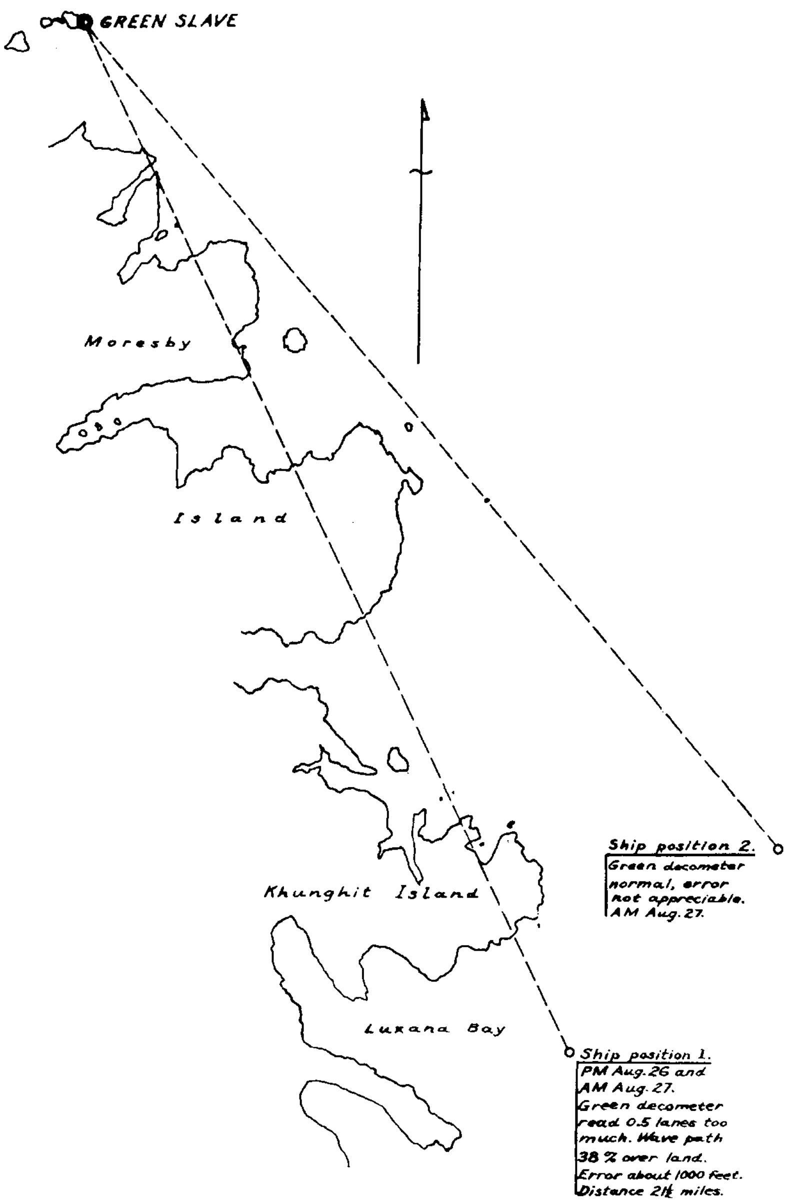


FIG. 6. — The Effect of a Land Mass on the Decca Wave Velocity

It is not clear why the values determined from Ship 9 should fall so low. Possibly it is due to magnification of small survey errors by the very long distances and the small intersection angle or to phase changes occurring over the Decca wave path. At any rate it appears evident that these values are not to be trusted. Less uncertainty exists in the other three values, as the Decca signals were strong, the Decca base measurement is at least close, and Ship 6 was in a well-conditioned triangle so that residual survey errors could not have been greatly magnified. They should agree fairly well with the true Decca wave speed, and it is noted that their average is 299 641 Km/s as compared with 299 650 Km/s which is the value being used.

Adequacy of the Two-range Decca system

Although much of the Decca equipment is duplicated, a few breakdowns occured from time to time during the Hecate Strait survey. These were the type of faults which are, no doubt, common to all complex electronic equipment, such as tube failures, blown fuses, failure of other components, moisture collecting on aerial tuning coil, etc. In every case, the technicians repaired the trouble without delay and they deserve much credit for the success of the operation. Only a very small part of the time was lost due to Decca operational faults.

The lack of any means of lane identification within the system was inconvenient. Each day, after this was accomplished, a constant watch had to be kept on the decometers to make sure that no lanes were lost, particularly when atmospheric conditions created a poor signal-to-noise ratio. However, the lane count was only in error twice in Hecate Strait when the ship arrived back at a check point in the evening, and very little of the work had to be discarded. On a few days, faults developed and lane integration was lost when the ship was many miles offshore. Then it was necessary to return to the nearest check point and time was lost accordingly.

The chief problem experienced with the system used aboard the *Wm. J. Stewart* was the relative inadequacy of the Purple frequency as compared to that of Green. While it usually functioned well up to 70 or 80 miles from the slave, the Purple signal invariably became weak at greater distances. On a few occasions it was totally unreliable and the work was interrupted. When atmospheric conditions were poor, Purple occasionally weakened even at distances less than 70 miles, causing a disconcerting oscillation of the decometer needle and even skipping of lanes.

At no time, nor at any distance worked, was trouble of this nature experienced with the Green frequency. Both slaves use exactly similar equipment and it is certain that, under these conditions, Purple is less reliable than Green. It was concluded that the range from Purple slave should be restricted to about 75 miles until some way is found to improve the signal strength. Possibly this can be done by raising the slave transmitter aerial.

The most prevalent difficulties encountered during the east coast surveys included thunderstorms, interference from other radio transmission, weak signals and grounding of the Decca mast on board ship.

It was found that radio interference could usually be overcome by lengthening the slave transmitter mast or increasing the top dressing of the master transmitting aerial, thus increasing signal strength. On certain occasions, interference was traced to reradiation from other shipborne aerials and overcome by relocation of the offenders.

Grounding of the master transmitter mast was overcome by fitting cowlings of copper or fibreglass to shield the base insulator from salt-water spray, heavy rain and snow.

Exceptional, and as yet unsolved, interference from radio transmissions last year on the *Baffin's* northern survey caused a change from Purple - Green to Red - Green slaves for the future operations.

The Two-range system is not affected seriously by fog, rain, snow or rough weather and, on the North Pacific coast, electrical storms are rare. It has functioned quite well even in weather so bad that the echo sounders failed to deliver depth readings and, despite the imperfections mentioned above, it is fair to say that the equipment remained in satisfactory working order about 95 per cent of the time.

The need for constant vigilance and daily checks when using this electronic system is self-evident. The value of careful calibration before use and the danger of overextending the range, have been indicated. With due allowance for these matters, it is concluded that Two-range Decca is a powerful aid for offshore hydrography.

The Two-range chains operated by the Canadian Hydrographic Service have proven dependable to ranges beyond 100 miles. When using the Decca Navigator chains of Nova Scotia and Newfoundland, the range could be extended out to 250 miles, and one ship completed 17 000 miles of sounding in a season. During the four years the Decca systems have been used for Canadian surveys, almost 40 000 miles of sounding have been accomplished. Great savings of time have been effected and ranges never before possible have been employed.

APPENDIX

PLOTTING METHOD FOR TWO-RANGE DECCA

The sheets designed for the Hecate Strait project were plotted on the polyconic projection and the layout is shown in figure 1. All of the sheets used to date are at 1/72 688 natural scale.

Consideration of polyconic projections shows that the maximum distortion due to the projection is less than two metres or, .001 inches on the sheets.

The problem of mechanical distortion of the plotting sheets, due to changes of temperature, humidity, etc. was overcome by using metal-backed paper. Tests made during the work showed no significant change in lengths.

Position circles were drawn directly on the field sheets whenever the slaves could be plotted. In most cases this could not be done and the method used was that devised by the Nautical Geodesy Section of the Canadian Hydrographic Service, Ottawa, as follows :

Based on a wave velocity of 299 650 Km/s and the Decca frequencies assigned to the C.G.S. *Baffin,* it was computed that 1.90837 inches is equivalent to 3, 6, 9 or 12 Green lanes at natural scales 1/36 000, 1/72 000,

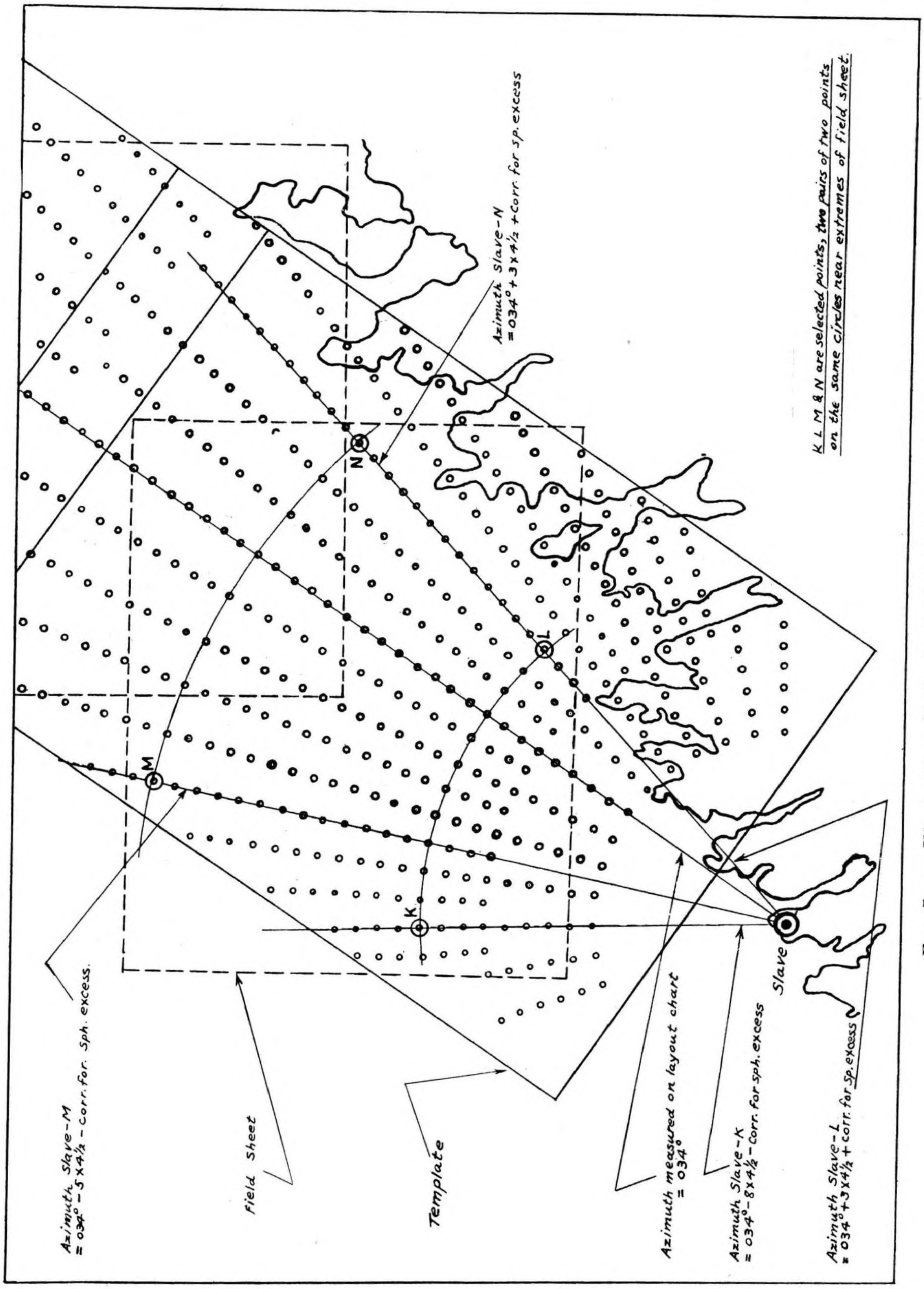


FIG. 7. — Illustrating Method of Fitting Plastic Templates to Field Sheet

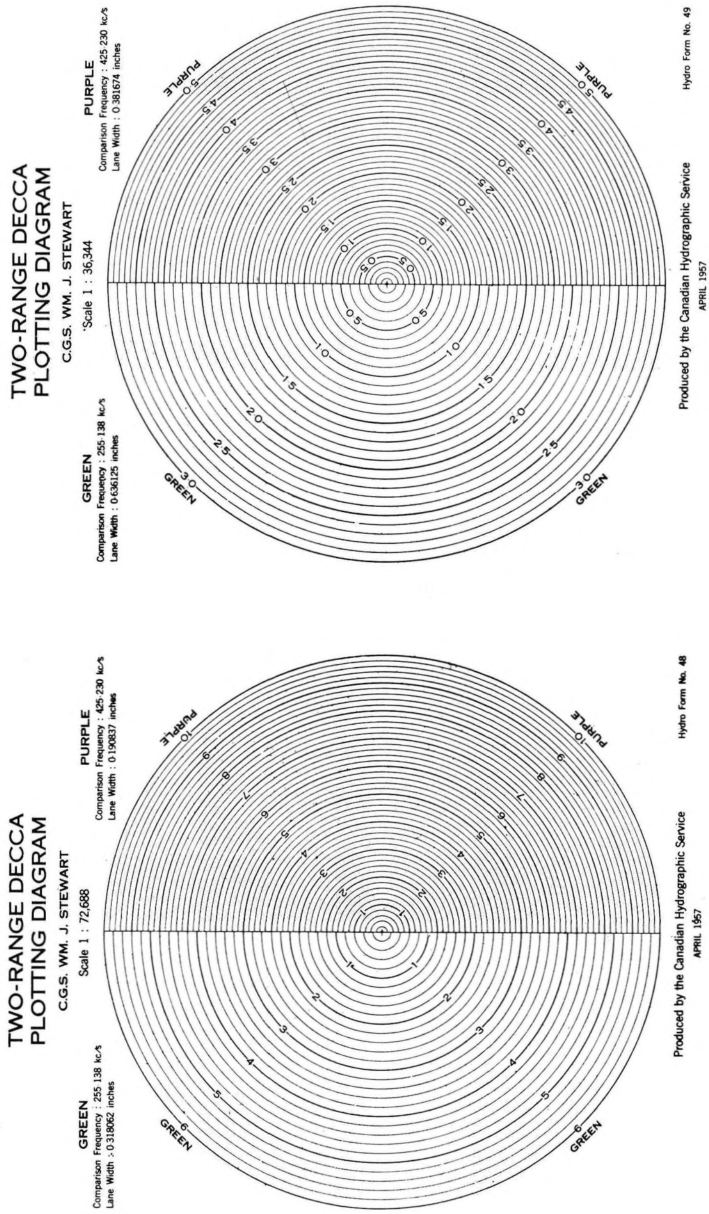


FIG. 8. — Plotting Diagrams

1/108 000 and 1/144 000, respectively. This distance is also equal to an integral number of Purple (or Red) lanes at these scales. Templates were made on heavy plastic by plotting points from the calculated values, each series representing a circle of known radius and each pair in the series having a given intersection angle at the origin. The distance between circles developed by these points is 1.90837 inches, as nearly as may be plotted, and the same templates are used regardless of which scale is adopted. These templates are also used for other assigned frequencies. In such cases a slight change is made in the scale of the field sheets to conform with the templates. Thus the natural scales used by C.G.S. *Wm. J. Stewart* are 1/36 344, 1/72 688, 1/109 032 and 145 376.

The template must be oriented to the field sheet by plotting a few control points on the latter. From the known position of the slave, an approximate bearing to a central point in the survey area is found graphically. This bearing may be assumed to coincide with the central line of template points. The positions of any pair of template points lying on the same circle can then be computed and plotted as their distance from the slave and the angle of separation from each other are known. Relative to each other, the computed positions will be correct and they lie on the required circle. The template is fitted to this control and all its points pricked through to the sheet. Using a set of railway curves, the position circles are then drawn and numbered to conform with the decometer readings for convenience. Figure 7 illustrates the use of these templates.

For plotting the Decca fixes, which normally fall between position circles on the sheet, plotting diagrams were provided. They consist of concentric semicircles drawn on transparent plastic and are subdivided in accord with the lane widths of each slave. The outer circle is equal in diameter to twice the distance between adjacent position circles. As the number of lanes depends on the scale, a diagram is provided for each scale to be used and all are suitably subdivided to facilitate plotting. These plotting diagrams are illustrated in figure 8.