THE DECCA NAVIGATOR IN HYDROGRAPHIC SURVEYING

(Extract from Hydrographic Department, British Admiralty, Professional Paper No. 17).

Preface.

The object of this paper is to give guidance on the great use which can be made of Decca Navigational Chains for surveying purposes in certain circumstances.

If the surveyor is to assess the value of the Decca system which may cover the area in which he is working, he needs a knowledge of the errors likely to be encountered, and to obtain this knowledge, he has to have some idea of how the system works.

A brief and non-technical description of the Decca system is therefore given first*, followed by information on the inherent errors and expected accuracy. This leads to the surveying application of Decca, and some methods which have recently been employed.

The advent of the Decca Navigator must not mean the acceptance of standards of accuracy lower than those obtained by conventional methods of position fixing. Its use independently of or in conjuction with the latter methods will depend on various factors and be either at the C.O.'s discretion or the result of instructions given or discussions with the Hydrographic Department.

Finally, a reference is made to the use of special Decca equipment for surveying, because its function can best be explained in conjunction with the general description.

Decca Errors.

It is common to divide errors into two kinds, random and systematic.

Random errors vary from moment to moment, and the greater the number of observations taken, the more closely with the average value agree with the true figure. With Decca, if we neglect the human errors due to inaccurate reading of the dials or bad plotting, there are only three other sources of random error which need be considered : Radio Interference, Instrumental, and Natural. Interference from other radio transmissions will cause deflections of the meter pointers, but usually in the form of fairly rapid flickering which will be noticeable. A rather similar effect takes place during the short duration of the Lane Identification transmissions, which occur at fixed intervals in a sixty second cycle. Instrumental errors may cause a change in transmitted frequency or wave form, or perhaps a phase shift at the slaves. With modern equipment these will be very small unless a major breakdown occurs. Defects in the Receiver or Decometers will generally be obvious. The major natural source of random error is the effect of Skywave. Some of the transmitted signals will inevitably be reflected from the ionosphere and, on reaching the observer, will have followed a longer path than the groundwave. These skywave signals will therefore have an error in their phase when received and, if sufficiently strong, will affect the reading of the Decometers. At night and in Winter the

---

* Not reproduced herewith.

Skywave effect is large and increases with range from the stations. During Summer daylight, that is from about one hour after sunrise to one hour before sunset, it will not be serious, and the figure of 0.01 Mean Lanes for the total deviation due to random error is likely to be reasonable.

Systematic errors are those which remain constant in time but which vary according to the position of the observer. Any errors in fixing the stations or calculating the lattice grid caused by projection approximations etc., will create systematic errors as will also an erroneous assessment of the speed of propagation of the radio waves. The former type of error is inherent in any position fixing system, so it is only the latter which will be considered here. The conductivity of the material over which the waves travel affects their speed and thus the phase angle at which they reach the observer. The ideal is for all the paths to lie over material of uniform conductivity, for example the sea, but this can seldom be achieved when large coverage is also required. If part of the path of the waves between the stations and the observer lies over land systematic errors of considerable magnitude may be introduced which will change as he moves from place to place. How serious this is to the surveyor will depend on the rapidity of the variation of this error with position, which he must ascertain in each area. It will be noted that systematic errors are defined as being invariable in time, and it might be thought that the drying of sand-banks due to the tide or the flooding of land by rain would invalidate this. It is unlikely, however, that any variation in error will result from these changes, as the water content of a drying bank will remain high, and only deep and prolonged flooding could cause any change in the conductivity of the earth underneath.

Decca Accuracy.

If the transmitting stations can be sited ideally, the accuracy of position fixing obtainable from he Decca System is of a very high order. Usually, however, some accuracy has to be sacrificed in order to provide a wide area of coverage, and because the siting of the stations has to conform to terrestrial factors.

The angle of cut of the hyperbolae and the width of the lanes are, of course, the major considerations when assessing the effect of errors on position accuracy at a particular place. Any random or uncorrected systematic errors will have a greater effect as the angle decreases and the lane width increases. The angle between the base-lines and their length are thus the two critical factors when considering both the total usable, and the maximum high accuracy, coverage.

Figs. 4-6 show accuracy contours based on a standard deviation of 0.01 Mean Lanes (about 5 metres on the base-lines). In the areas enclosed by these contours Root Mean Square Errors of the value shown may be expected as the result of random factors only. The effect of systematic errors cannot be shown, and this must be borne in mind when studying the diagrams if an over-optimistic picture is to be avoided. The r.m.s. error can be described as the radius of a circle which, symmetrically drawn on the distribution of a number of fixes at a particular point, will nclude about 65% of them. A circle with radius of twice the r.m.s. error would enclose 95% of the plots. The longer the base-lines the larger will be the coverage, up to a maximum depending on the strength of the transmitted signals. The length of Navigational Chain base-lines is usually of the order of 100 miles.

Fig. 4 shows a three station chain with base-lines at sixty degrees. The area enclosed by the 35-ft accuracy contour is the maximum possible and this ideal

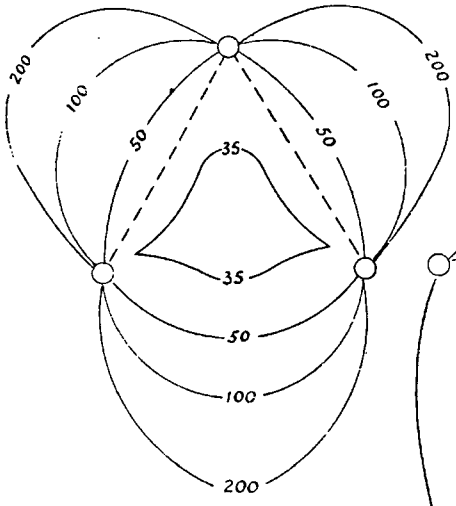


Fig. 4

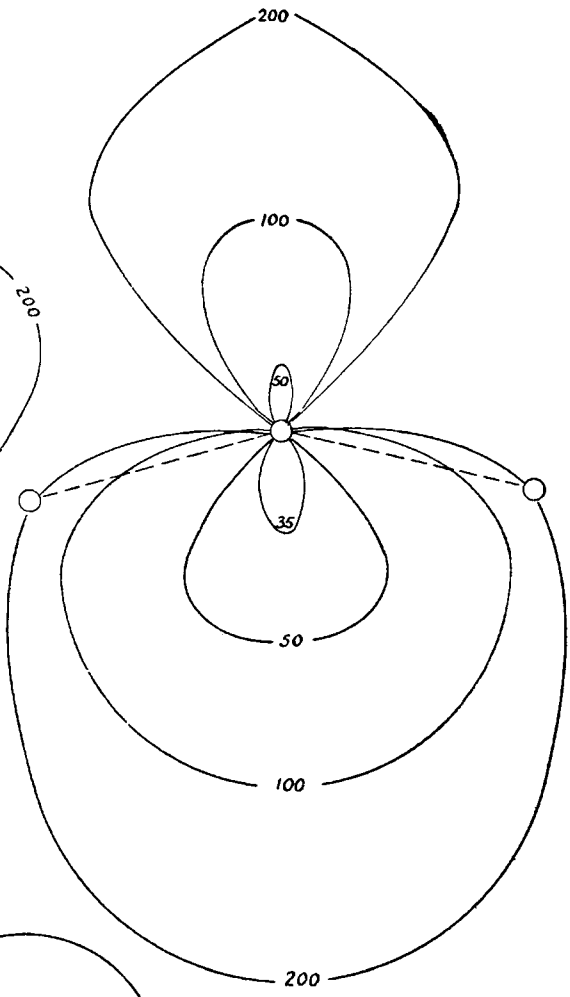


Fig. 5

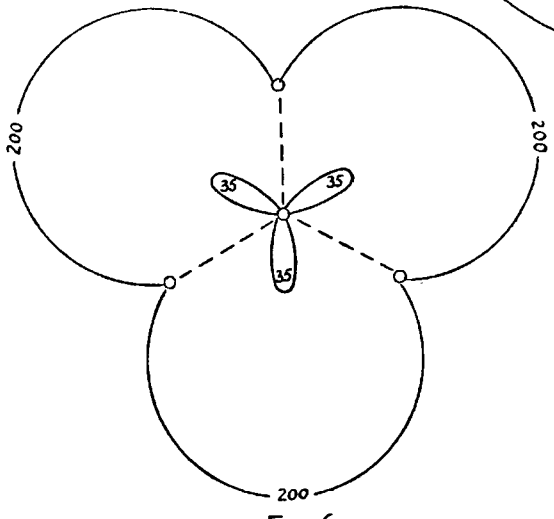


Fig. 6

Accuracy Contours in Feet.
(for a standard deviation of 0.01 Mean Lanes.)

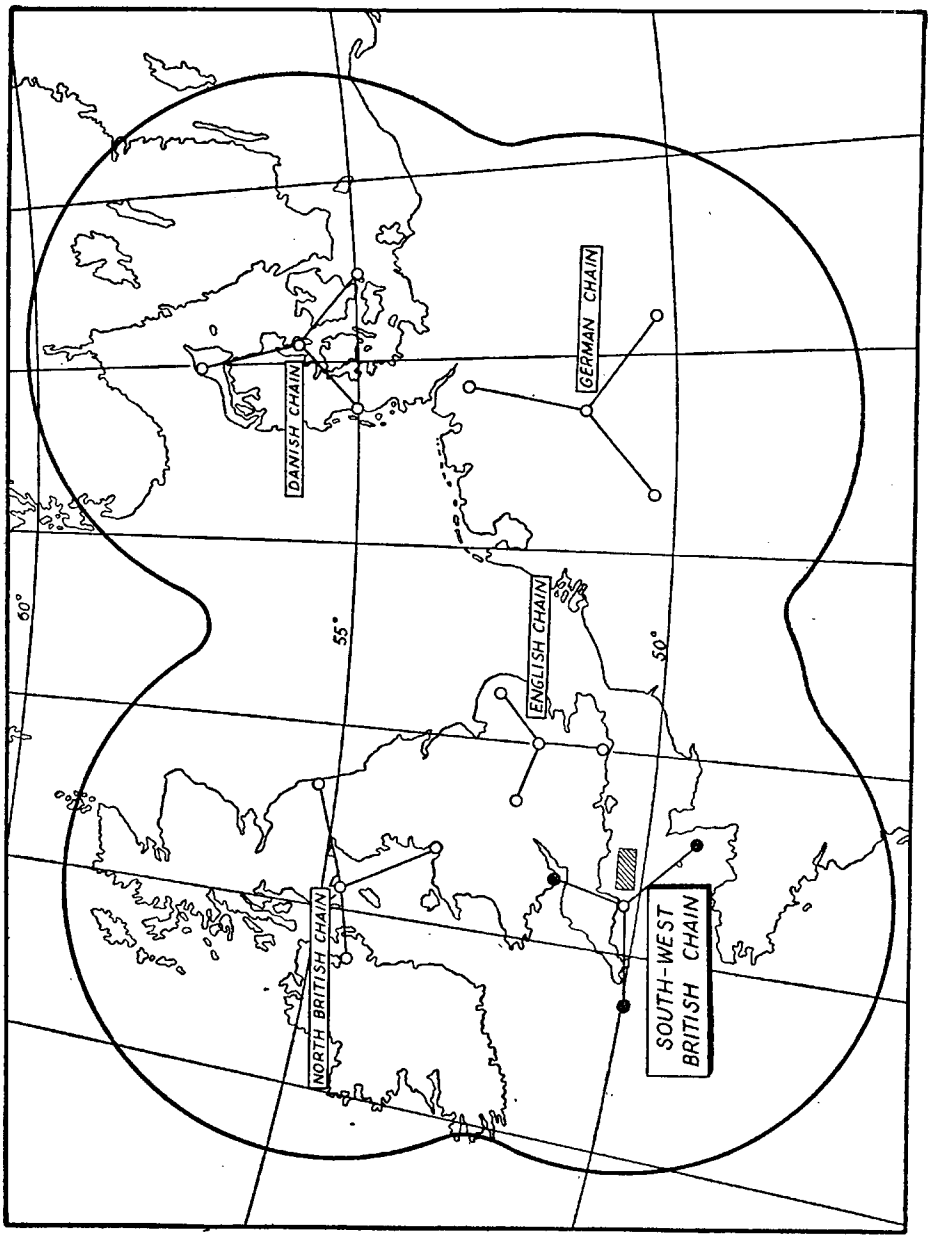
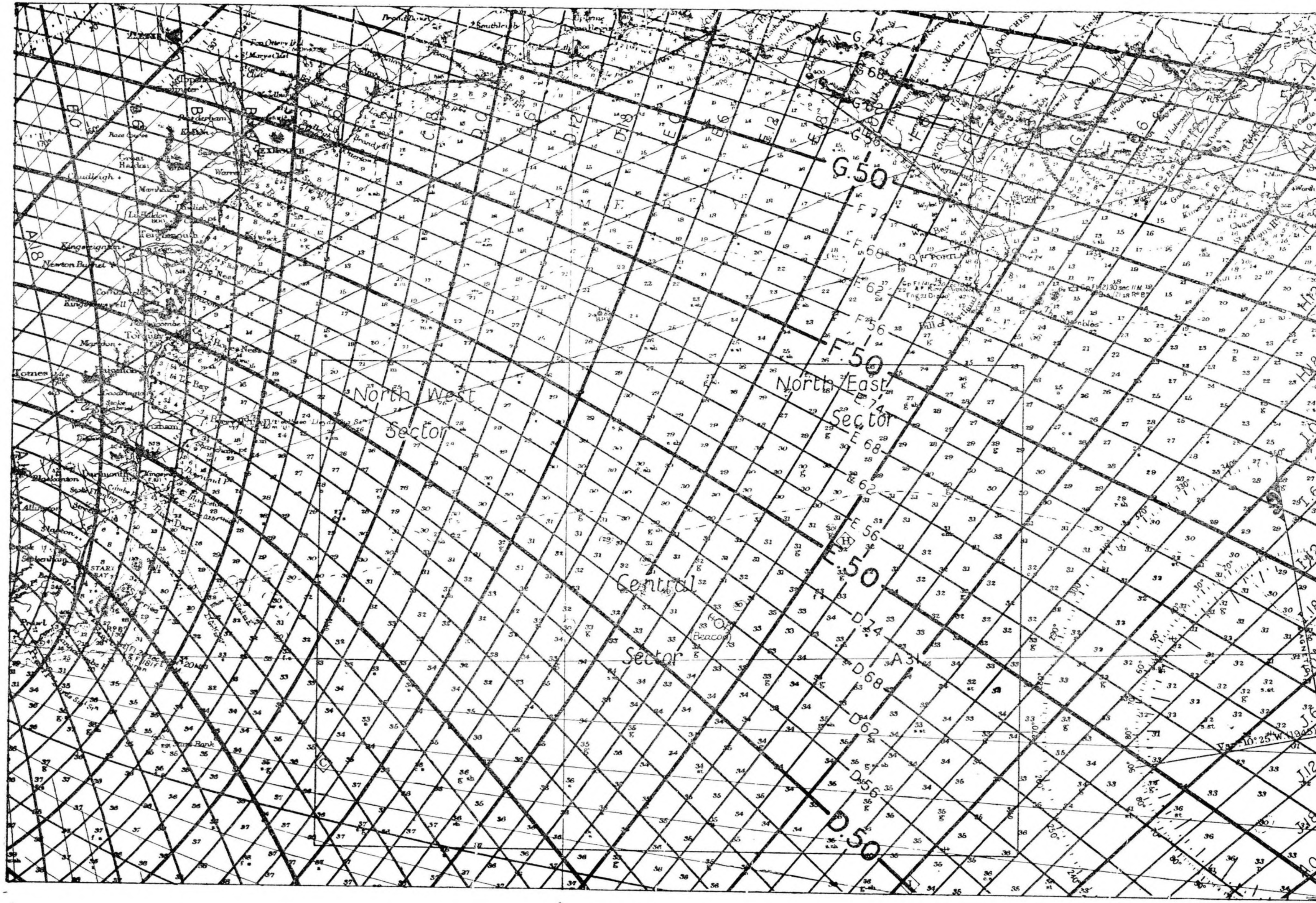

DANISH CHAIN
GERMAN CHAIN
ENGLISH CHAIN
NORTH BRITISH CHAIN
SOUTH-WEST BRITISH CHAIN
60°
55°
50°

Fig. 7


North West
Sector
North East
Sector
Central
Sector
G.50
F.50
E.50
D.50
Beacon

arrangement may be achieved when survey work is among islands. It will be seen, however, that the 200-ft coverage in Fig. 4 is very much smaller than that in Fig. 5 where the base-lines are at 150°. 120° base-lines provide a good compromise between the two, and have the additional advantage that a fourth station can be symmetrically placed to give all-round coverage (Fig. 6).

The arrangement shown in Fig. 6 is that generally adopted for navigational chains, where total coverage is the main factor, and the stations are often of necessity placed well inland. This inevitably introduces systematic errors which may reduce the accuracy of the system to too low a level for surveying purposes.

Fig. 7 shows the lay-out of the Northern European Decca Chains, and, the principle causes of systematic error having been understood, it will immediately be apparent how ideally placed for the surveyor are the three southern stations of the South-West Chain. With the transmission paths between Master and Red and Green stations passing almost entirely over the sea, the likelihood of systematic error on these patterns is greatly reduced, and accuracy of the order of that shown in Fig. 6 may be expected.

The Use of the Decca Navigational Chains for Survey Purposes.

As has been shown, the surveyor will often find that Navigational Decca is not sufficiently accurate for fixing purposes except, perhaps, on very small scales. However, the small effect of random errors in Summer daylight gives a good repeatibility to the system and the resulting high accuracy in relative positions can be utilised in work of a very localised nature such as wreck sweeping. In this case the wreck is first located by Asdic and the ship steered to pass over it, the Decometer readings being taken when the wreck's outline appears on the echo-sounder. A very large scale Decca grid can then be drawn with the small portions of the hyperbolae shown as straight lines, and the area of the wreck very thoroughly examined either by sweeping or with close lines of soundings. The ship or boat is usually steered along the most convenient Decca Lane, keeping the appropriate Decometer pointer on a constant reading for each run.

If one system of Decca lines cuts the fathom lines at a suitable angle, it can be used as an aid to steering though fixing is still carried out by visual methods. The Thames Estuary is a particularly suitable area for this, and much time has been saved due to the ease with which straight lines can be run and the speed of getting on to them despite violent tidal stream conditions.

There may, however, be occasions when the surveyor's work lies in an area where the accuracy of the Navigational Decca is sufficiently high to warrant its use, with safeguards, for the fixing of soundings. A recent survey in Lyme Bay using the South-West British Chain is a good example of this, and a brief description of the methods used is given below.

The area to be surveyed is shown in Fig. 8. Unfortunately, it lies on the Green base-line extension, which necessitated the use of the Red and Purple lattices only, thus introducing some systematic error from the Purple over-land paths. Nevertheless, reference to Figs 6 and 7 shows that the area lies within the highest accuracy coverage from the point of view of random error, which fully justifies the use of the system on a scale of 1 : 72,000.

A plotting sheet on which the red and purple lattices were drawn was supplied by the Hydrographic Department, and it was decided to run the lines of soundings along the red lanes, using the purple as a « cut-off » at each fix. The average width of the red lanes was about 1800 feet and the purple slightly more.

Before sounding was commenced, check fixes were taken in the North-East and North-West sectors by means of sextant angles to shore objects. These showed that the red errors were negligible as might be expected, but that there was a systematic error on the purple varying from 0.16 lanes in the North-East to 0.26 in the North-West. A floating beacon was then moored in the central sector and fixed as accurately as possible by means of taut wire runs from visual fixes in-shore. The position thus found was compared with that given by the Decca readings, and, although the accuracy of the taut wire did not allow a precise Decca error to be arrived at by this means, the result did not contradict those found from the shore fixes. A series of Decca readings at the beacon during the course of the survey showed that the repeatability of the system was good, i.e., the effect of random error was small. Slight differences in the readings were almost certainly due to the uncorrected swing of the beacon.

As the result of the checks described above, a correction of 0.20 lanes was applied to the purple readings throughout the survey area, and it is considered that any residual Decca errors were unlikely to be plottable quantities.

The surveyor must be constantly alive to the possible use of the Decca Navigator for absolute position fixing when, as in the Lyme Bay survey, checks confirm the expected accuracy and reliability throughout the area; or for relative position fixing when, for example, lines of soundings can be run out and back to fixes by classical methods. Thereby will endless time on beacon work or waiting for visibility be saved. In other areas its use for conning along sounding lines or large scale examination work is unlikely to be overlooked.

Special Decca Equipment for Survey Purposes.

Using Transportable or Lightweight Decca chains, the hydrographic surveyor may be able to provide fairly accurate coverage for his work by placing the stations in the best possible positions. A glance at the accuracy diagrams, however, shows how difficult it is to provide this coverage on a convex shaped coastline without siting the stations inland and introducing systematic error. The computing and plotting of the hyperbolic lattices is also a major problem when the chain has to be periodically moved as the survey progresses.

To eliminate these two major disadvantages, the « Two Range » Decca System has been developed. This system utilises a conventional lightweight chain, but the master station is fitted in a surveying ship with the two slaves sited on the coast. The drawback that only one ship can operate is acceptable in surveying practice, and some method of time sharing so that two, or even up to six, ships could use it simultaneously is a possibility of the future.

It was stated when discussing the principle of Decca that the reading of a receiver on the base-line extensions will either be zero or the difference between the length of the base-line and whole number of lanes. In a normal system the phase locking is so arranged at the slaves that the zero line is at the master. In « Two Range » Decca, however, this is reversed, and as the master travels about

in the ship, so a receiver also situated in the ship will always indicate the residual fraction of a lane. Thus the Decometers will give a direct indication of range from the slaves, position lines becoming circles and lane expansion being eliminated. It is of course necessary to set the Decometers at a fixed point before using the system, as lane identification is not incorporated due to its extra bulk and complication. This is not a problem in surveying, however, as some sort of visual check on the system will always be required. Great accuracy is excepted from « Two Range » Decca, ± 30 ft. at 75 miles is anticipated. Trials have yet to be completed in 1955.

Finally, it may be of interest to note that the principle of « Two Range » Decca can be used with pairs of stations ashore for measuring distances over water. For instance, an island could be « tied in » to the mainland control by measuring ranges on the base-line extensions, the master being sited on the island and the two slaves on the mainland sufficiently dispersed to provide a satisfactory cut for the two ranges. A large number of such readings should give a highly accurate mean. The ranges must, of course, already be known to the nearest whole number of lanes.