DEVELOPMENTS IN DECCA

Recent Refinements in a Radio Aid to Surveying

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By way of introduction it is appropriate to look first of all at the present extent and coverage of the Decca Navigator radio position fixing system as an aid to general navigation. The permanent transmitting installations providing this service, and the complementary receivers installed on ships and aircraft, are basically similar to the Decca equipment used for surveying; the principles of operation are identical, carrier frequencies are virtually so and much of the circuit technique is common to both classes of apparatus. For these reasons the progress made in improving or refining the navigational equipment concerns the navigator and surveyor alike and, no less important, the extent of the system's utilization interests both types of user since it points to the volume of field experience and observed data gathered in the course of day-to-day operation.

There are now six navigational Decca chains in Europe, each providing three hyperbolic patterns (from a Master and three outlying Slave stations) together with the Lane Identification system: the English, or Thames Chain, (opened in 1947), the Danish (1948), the North British (1951), the German (1952), the South West British (1952) and the French (1953). The six chains combine to produce the coverage shown in Figure 1. In the diagram the line forming the boundary of the coverage is a contour within which the accuracy of the system at night, at the 95 % probability level for random error, does not exceed 5 nautical miles; closer to the stations the accuracy increases in accordance with the well-known laws governing hyperbolic systems and by day there is again an improvement due to the reduction, or virtual absence at short distances, of the downcoming « skywave » signal. For summer daylight conditions the 5 nautical miles contour of the diagram can be labelled 1 nautical mile and in the inner coverage of each chain, say within the circles including the three slave stations as shown, the accuracy of « repeatability » which the contours represent rises to an order approaching that which is given by the specially-sited Decca chains used in various parts of the world as an aid to survey. Within these circles the daytime 95 % random error does not exceed about 100 yards, and in the relatively small areas close to the Master station where the combination of angle of cut and narrowness of lane is at its most favourable, the accuracy rises to about 15 yards at the 70 % level generally assumed in predictions for survey work as opposed to general navigation. The foregoing accuracy figures do not, of course, take account of systematic or fixed shifts in the position line patterns but where these exist they can be largely or entirely corrected by prior observation.

Over 2,000 vessels of every size and class now use the European Decca Navigator service, as well as about 100 aircraft of similarly varied type and function.

The great majority of the ships carry the Mark V type of receiver, the most recent version of which has provision for switching to nine different chains compared

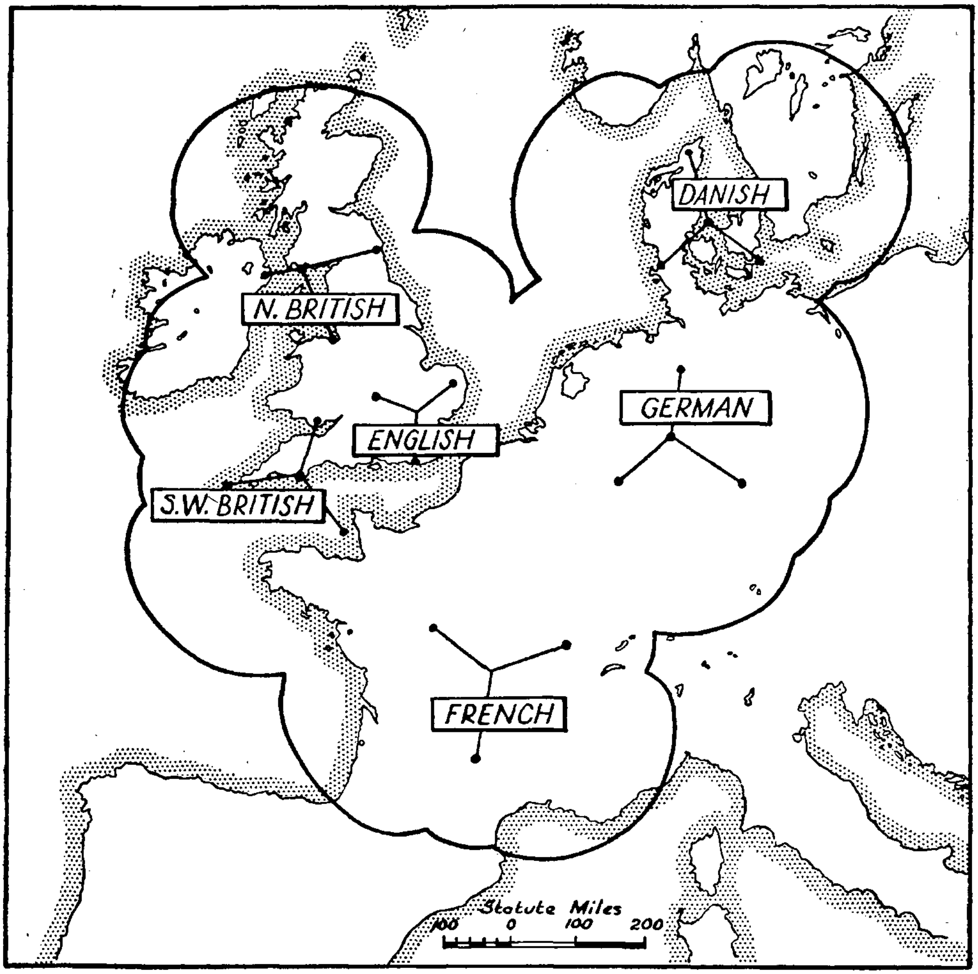

Fig. 1.
EUROPEAN DECCA COVERAGE
Six chains form the present Decca coverage in North-west Europe.
Within the contour, accuracy is better than 1 nautical mile by day and 5 n.m. by night 95 % of the time.

to the five-chain and later six-chain capacity of the earlier model. Figure 2 shows a Mark V in transportable form, self-contained with Decometer unit, rotary converter and plotting shelf for temporary installation on board ships operating for limited periods within Decca cover. Many of these « short-term hirings » are concerned with special projects such as underwater salvage, which benefit greatly from the ability to fix position without the cost and delays involved in dependence on visual fixes. The navigational Decca coverage is used for many other specialized tasks including cable-laying and maintenance, buoying, fishery research, various types of marine and air survey and, on the air side in particular, the calibration of other radio aids to navigation.

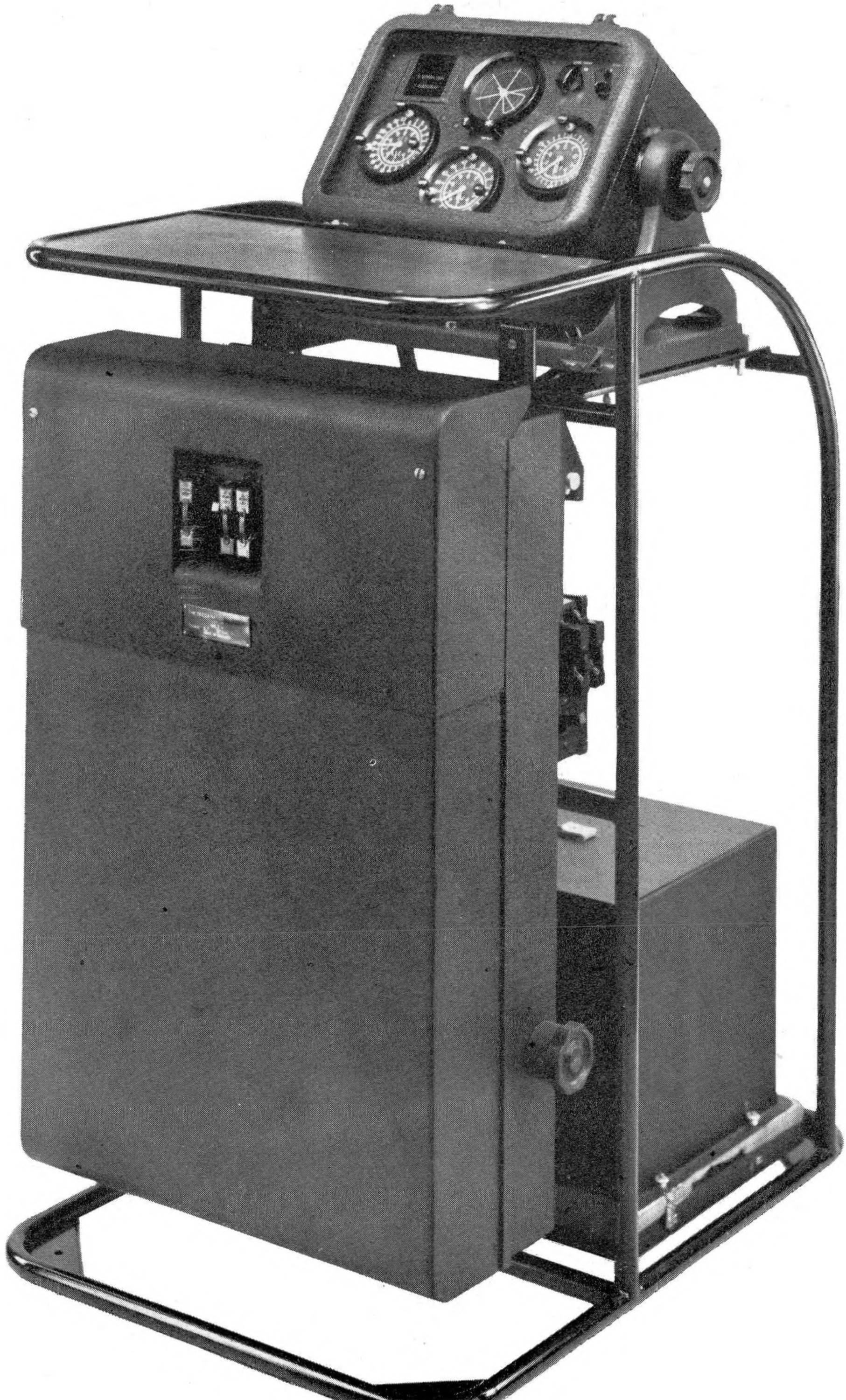

Fig. 2.

TRANSPORTABLE MARINE RECEIVER

The standard Mark V Decca receiver, with three Decometers and Lane Identification meter, is here shown in the form of a single transportable unit complete with rotary converter.

It is interesting to note that some 400 ships continue to use the Mark IV type of receiver, an early design which has no Lane Identification facility. That this instrument continues to prove a thoroughly successful navigational aid is no doubt largely due to the stringent precautions taken at the transmitting stations to avoid interruption of the service. For the whole of the year 1953, for example, the total time that the English Chain was « off the air » without prior warning to users, was 236 *seconds*. Of this time the complete chain was affected for only 55 seconds, due to an unusual succession of events at the Master station which originated in the sudden collapse of the glass envelope of a valve. The rest of the time is accounted for by incidents at one or other of the three Slave stations, mainly in the shape of momentary interruptions of the power supply.

Since the inception of the system during the last war the equipment has been subjected to a gradual process of development and refinement. In particular, the process of phase locking, whereby the Slave stations are automatically held in an exact phase relationship with the Master transmission, has been brought to a high pitch of efficiency and has for some time ceased to present any special problem in field deployment. In the past the criticism has been levelled at the Decca system that the phase-locking process inherent in it is a source of random error, and various subterfuges have been adopted in other systems to achieve effective synchronism as between two focal stations of a hyperbolic pair without recourse to direct locking ; there is now, however, plenty of evidence to show that phase locking in its present state of development is in fact a negligible source of error. The stability recorded on the navigational chains for daylight operation in the summer months, when there is no « skywave » effect to mask possible instrumental variations, has been higher during the past few years than that assigned in 1949 to high-accuracy survey equipment. At the monitor station of the Danish chain, for example, the mean stability of all three patterns was about 0.009 lanes for the summer months of the years 1951-1953, compared with the figure of 0.02 lanes assumed for the early types of survey chain.

Figure 3 typifies the performance available from the present Decca survey-type equipment under the ideal conditions of coastal operation. By setting the stations on or near the coastline, the small systematic errors that may result from differences in effective velocity over sea and ground are avoided, and all other variations — propagational, instrumental or interpretive — appear as random fluctuations about the mean (true) position and can be treated statistically. The error figures in the diagram are based on the 70 % probability level. The inter-station baselines are assumed in the case illustrated to be 25 miles long, but could be extended to nearly twice this distance without affecting the daytime figures; by night, the relatively short baseline-length reduces skywave errors to a low order but beyond about 60 miles path-distance these start to increase markedly.

The Survey Equipment.

The development of the transportable Decca stations designed for survey and kindred projects has proceeded hand in hand with that of the « navigational » apparatus. Equipment of this type has been deployed in Greenland, Sweden, the Persian Gulf, North Africa and — a recent addition — the Sahara Desert. The latter chain is used by the *Compagnie des Pétroles d'Algérie* for fixing the position of vehicles engaged in an oil-exploration project. The phase-locking units at the slave stations now employ the same circuit techniques as on the permanent chains, whereby the slave signal is derived from an oscillator which is in turn held in phase

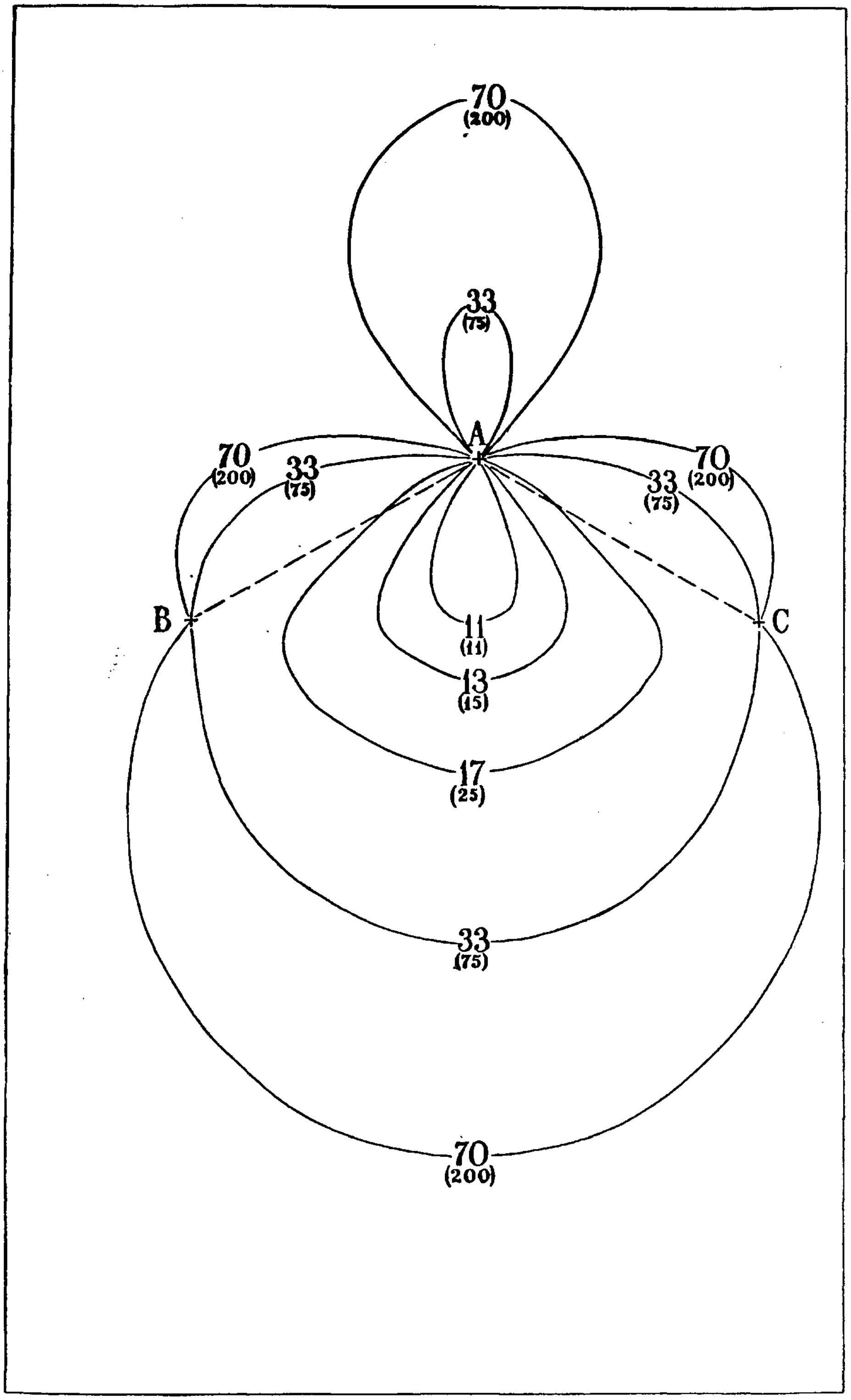

Fig. 3.

ACCURACY OF A SHORT-BASELINE CHAIN

Predicted standard-error contours in feet, based on observed results, for a coastal Decca chain having baselines 25 miles long at an angle of 120°. The top figures refer to daytime operation, the figures in brackets to winter night.

with the incoming master signal. This arrangement gives a considerably higher overall stability than the original scheme in which the master signal itself, after appropriate frequency change, was used to drive the slave transmitters. The stability of the transmissions from the present survey-type stations is now such that the function of the monitor is mainly a supervisory one; pattern fluctuations are in general so small that it is questionable whether the overall stability is not slightly reduced rather than enhanced by attempting to pass phase corrections from the monitor to the slaves. It has further been established that the monitor may be set up at the master transmitting station site without loss of sensitivity to pattern variations, with obvious savings in administration and manning. The master transmitter runs for long periods without attention and the station operator can readily divide his time between the transmitting equipment and the monitor receiver with its associated communication gear.

The transportable transmitting stations have been considerably lightened and simplified, and a range of different aerial heights and transmitter powers is available to meet widely varying requirements. Each station, irrespective of power, comprises four basic elements: the drive unit, the transmitter unit, the aerial/earth system and the generators (if used). The *drive unit* is the name given to the rack containing, at the master station, two master oscillator units, one of which is a stand-by, and at the slaves a single phase control unit. The slave drive unit rack may be duplicated if required. The *transmitter unit* houses an input voltage amplifier, two or more 150 watt power amplifier units, the tank circuit, the dummy aerial load and the power supply circuits; a typical transmitter unit contains two power amplifiers and power supply circuits for 230 volts A.C. input and consumes about 1 kilowatt at this voltage. The total take-in consumption for such a station, neglecting communication equipment etc., is about 1,5 kw. The drive and transmitter units, each in a standard vertical rack 21 inches wide, are housed in a tent, hut or vehicle appropriate to the working conditions. Figure 4 shows how the basic items are disposed on a lightweight station.

A feeder cable takes the transmitter output to the aerial coil, which forms part of the aerial/earth system and is housed in a weatherproof box at the base of the aerial mast. The latter is a sectioned tube 70 or 100 feet high, or, when maximum radiated power is required, 150-foot light welded steel mast of triangular section. In each case the mast is base-insulated and supports a pyramidal assembly of wires forming a capacity top. The 150-foot mast breaks down into 10-foot sections and can be erected either by the familiar derrick technique in which the mast is assembled on the ground and pulled up bodily by means of a member attached at right angles to the base, or it can be assembled vertically by riggers using a simple crane of light alloy with which to haul up the sections. The whole mast packed for shipment weighs less than 3,000 lbs and successfully solves the problem of combining good mobility with relatively high power. A chain of survey stations using this aerial has a range of over 200 miles even in high-noise areas. The shorter tubular masts are used in close and medium-range operations, the smaller 70-foot mast enabling a chain of small stations each weighing about 1 ton to cover distances ranging from 30 to 150 miles depending on regional noise level and soil conductivity.

The Receiver.

The shipborne survey-type Decca receiver operates on the same general principle as its navigational counterpart but is in three-channel form, for use with a three-station chain giving two hyperbolic patterns. Figure 5 shows the front panel

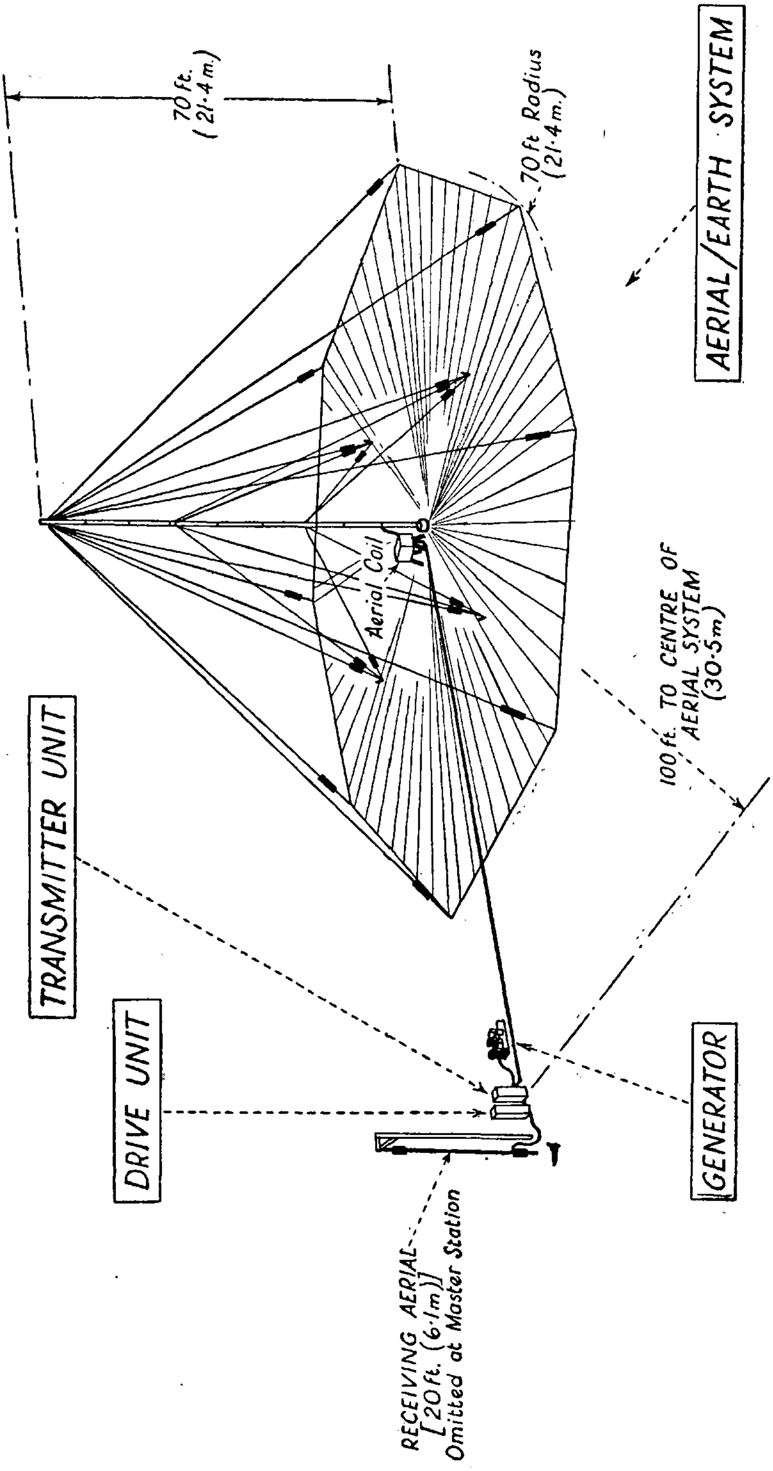

Fig. 4.

DECCA LIGHTWEIGHT STATION

A chain of stations each weighing one ton and consuming 1.5 kilowatts can give a working range of 30 to 150 miles depending on regional noise level and soil conductivity. The drawing shows disposition of the principal units.

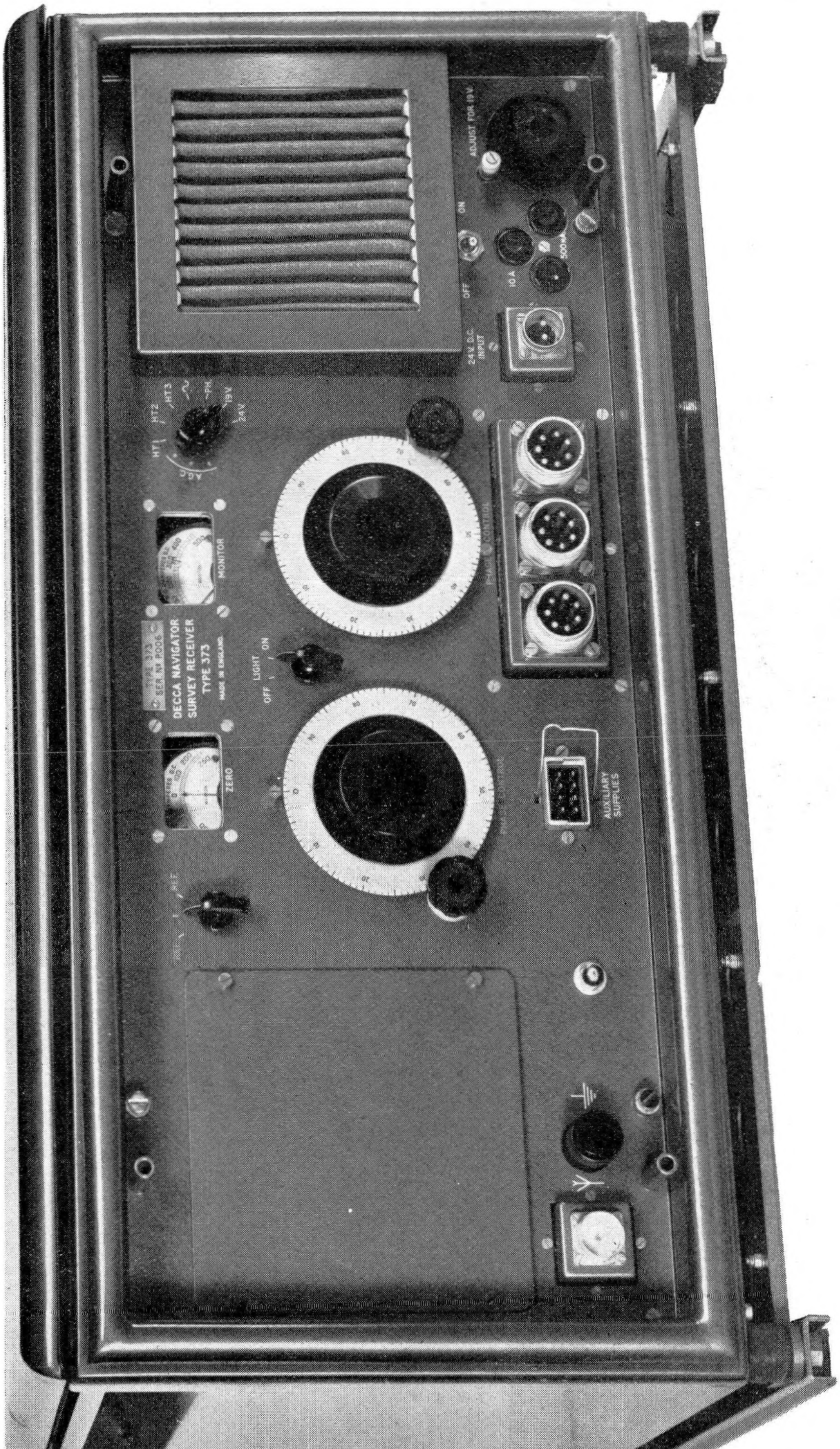

Fig. 5.

THE SURVEY RECEIVER TYPE 373

The 24-volt version of the Survey receiver, shown here, is used in small craft having no mains supply. The large dials are phase-controls, a recent innovation enabling the Decometers to be checked for linearity at every point on the scale. The receiver has an overall accuracy of about three thousandths of a lane.

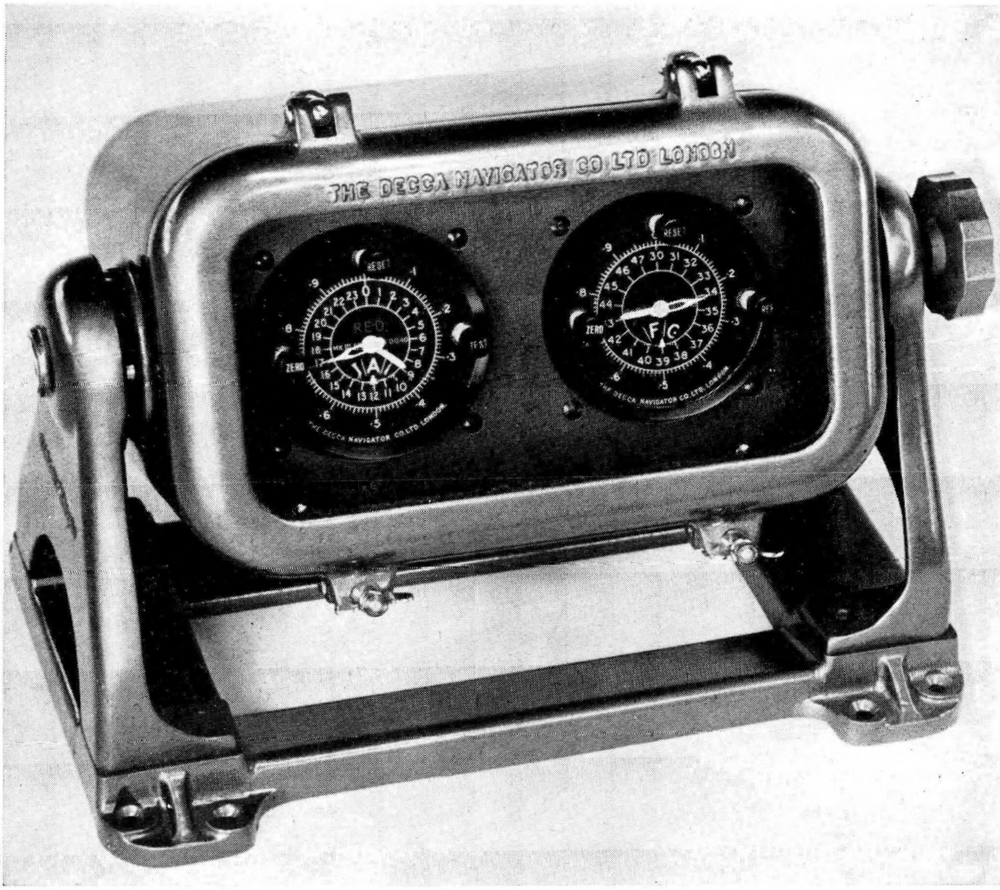

Fig. 6.

THE SURVEY DECOMETERS

These instruments differ from the « navigational » type in having the fractional lane scale on the outer periphery of the dial for maximum accuracy of reading.

of the survey receiver Type 373 designed for operation from a 24 volt DC supply. The power consumption is approximately 9 amperes at this voltage. The overall dimensions of the receiver are 27″ × 17 1/2″ × 15″ and the total weight is approximately 80 lbs; it can supply two Decometer units of the type illustrated (Figure 6) and, simultaneously, the Track Plotter described below.

The survey receiver and associated Decometers are designed to give the highest practicable degree of instrumental accuracy. Stringent precautions are taken to minimise and check phase-drift in the various channels and the final result yielded by the receiver corresponds to a standard deviation of only one or two thousandths of a lane. Prominent on the front panel of the receiver are the two phase controls: these operate goniometers in the red and green slave channels and enable any desired phase shift to be set-in by reference to the 1/100 scales on the control dials. This in turn allows any non-linearity in the Decometer-discriminator combination to be measured and corrected so that each Decometer can be precisely calibrated. The phase controls are also used for « referencing », a standard feature of all Decca equipment which ensures repeatability as between different receivers and which serves as a built-in standard of measurement for the whole system. A secondary function of the phase controls is to enable one of the Decometers to be off-set to indicate zero when the vessel is being « homed » along a selected fractional hyperbola. The Type 373 receiver can be operated from AC mains by means of a separate power pack. Alternatively the Type 371 receiver has a built-in power supply for AC operation over a wide range of input voltages.

The Track Plotter.

A well-know element in the airborne Decca receiving equipment is the Flight Log, an automatic plotter which records the progress of the aircraft on a map in response to the output of the receiver. This « pictorial presentation » facility has obvious advantages in the air, particularly in fast aircraft. For navigation at sea, however, the process of plotting a Decca fix manually is generally fast and simple enough for all practical purposes, but for hydrographic surveying, marine oil exploration and similar applications the use of a continuously-recording automatic plotter can bring very real benefits. The marine derivative of the Flight Log is known as the Track Plotter type 350 and the « display head » of the instrument is illustrated in Figure 7. Essentially the Track Plotter is closely similar to the Flight Log; the Decometer information is translated into related movements of a roller-mounted chart and a plotting pen along axes lying at right-angles. The hyperbolic Decca position-line patterns are presented upon the chart in a rectilinear « inverse lattice », form; the pen indicates the position of the ship upon that lattice at any instant, tracing a continuous record of the track made good as the ship moves across the Decca pattern. A range of five switch-selected scales from 1/4″ to 4″ per Decca lane is available for both the pen and paper, giving chart scales between 1 : 5,000 and 1 : 80,000 in the central coverage of a Decca Chain, these limits falling to some 1 : 30,000 and 1 : 500,000 at the extremes of the coverage area. Further switching gives four possible orientations of the display, each displaced 90° from the next, enabling a rough approximation to a North or heading-upward display to be obtained in all parts of the coverage area, while other controls provide facilities for using the Plotter as a drafting machine to produce latticed charts upon a blank chart sheet. This last operation permits the production of track records in areas for which no prepared charts are held; with the addition of the control settings and the Decometer readings for any one point on the track, a complete chart record is obtained.

The complete Track Plotter Type 350 comprises a Display Unit and a Servo-Amplifier/Power Supply Unit. The first embodies the actual display head, in which an area of chart approximately ten inches square is visible at all times, and all the operating controls. The unit is equipped with a glazed spray-proof cover, a quick-release catch permitting easy access to chart and controls. The Amplifier/Power supply unit takes the form of a bulkhead-mounting case; this may be fitted in any convenient position as access to it is not required during normal service. The equipment is designed for operation from an AC power source and will normally draw its supply from the converter associated with the Decca receiver.

Figure 8 shows a typical track record made in a vessel on the river Thames. The receiver driving the plotter was a standard Mark V instrument working from the English Chain. The mean scale of the inverse lattice chart is 4 inches per mile for the example shown. The Track Plotter is of particular value when it is required to make good a tortuous track or one that is not coincident with a Decca position-line. The only alternative method of following such a track with a comparable degree of accuracy is to plot the Decometer readings every few seconds and to con the ship by reference to the plots in relation to the wanted track. The Track Plotter is rather more accurate than the most proficient and tireless plotting team since it records continuously, but apart from this it does not add to (nor detract from) the accuracy of the system. The record of the track made good that the instrument provides can be of considerable value and can be annotated with marks indicating soundings, seismic observations, etc., as the operation proceeds. For this purpose a button is provided which when pressed causes the pen to make a distinctive mark on the track.

The production of charts is no problem since the instrument operates always on rectilinear co-ordinates and with known scale values given by the different gear ratios provided; the grid can be marked on the paper beforehand, using the instrument itself for this as already indicated, although in many cases a blank sheet of paper with one or two co-ordinating points is all that is required. For example if the plotter were to be used for some repeated function such as the control of a ferry service, the chart would be drawn simply by first making good the desired track under visual control with the plotter running: the record thus made would serve as the « master copy » for subsequent issue and use by the ships concerned.

The conversion of the hyperbolic grid into the rectilinear one required by the plotter is bound to introduce considerable distortion but this can generally be kept to a tolerable level. The provision of several different scales for each co-ordinate is of value for this, suitable values being chosen to correspond with the relative lanewidths of the two patterns. The distortion increases as the angle of cut gets more acute, but the type of operation that benefits from automatic plotting generally takes place in areas where the angle of cut is large. In the region shown in Figure 8, for example, the angle of cut is 70° but the result of converting this to 90° in the plotter is seen to produce an acceptable approximation for most purposes. For conning a ship by means of the plotter it is useful to draw, quite roughly, the distorted compass rose for the area of the chart, but even without this refinement it is possible to follow a wanted track with remarkable accuracy. The helmsman should use the compass as the basic heading indicator and monitor his course with the information from the plotter; Decca is responsive to small changes in position but not to heading, so that the plotter and the compass are complementary.

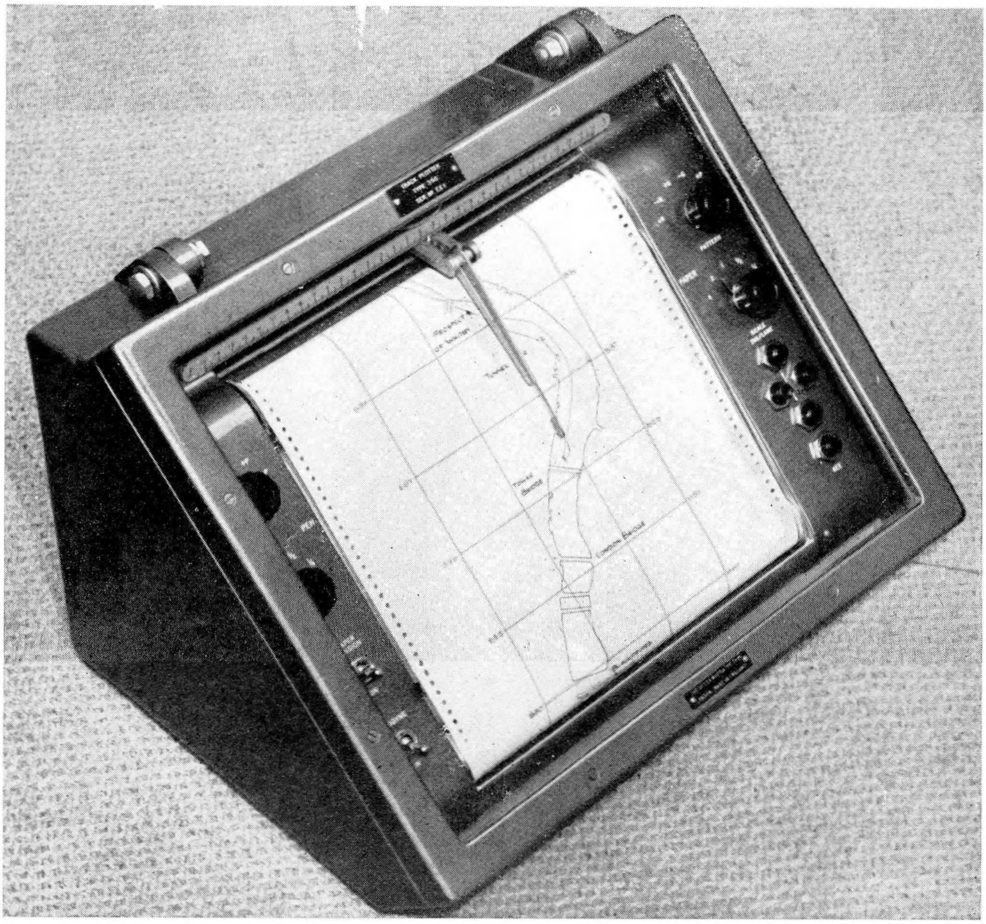

Fig. 7.

THE TRACK PLOTTER TYPE 350

The display head exposes a 10 inch square section of the chart roll, which is moved in response to one Decca co-ordinate by the sprocketed drive roller. The other co-ordinate actuates a lead screw and translates the pen laterally. Controls for scale-selection, etc. are mounted alongside the chart.

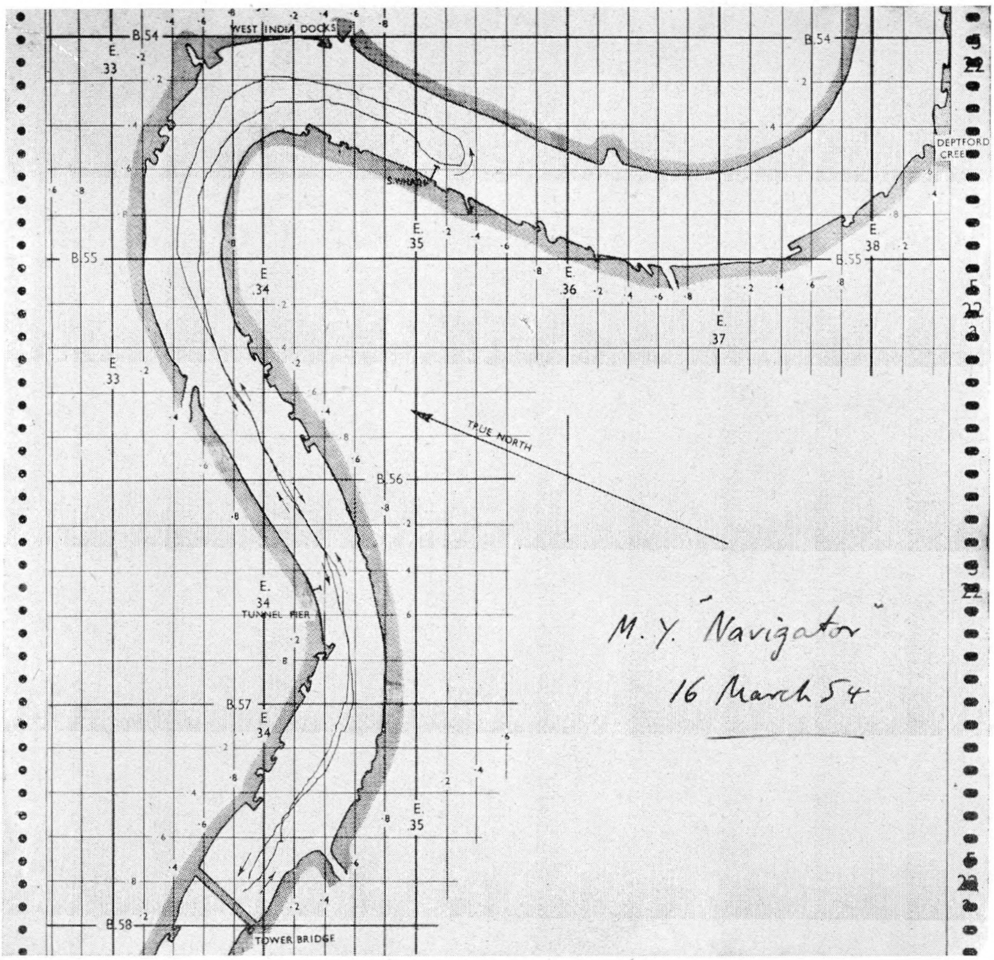

Fig. 8.

THE TRACK RECORD

This photograph, untouched except for the addition of arrows to indicate direction, shows a chart used on the Thames in M.Y. « Navigator ».

To show the accuracy of the instrument and of the system as a whole, the vessel was taken as close to South Wharf as the presence of another craft alongside allowed. The small gap between the track and the wharf can be clearly seen The English chain of stations was used.

Characteristics of the System.

In conclusion the characteristics of the Decca Navigator as an aid to hydrographic surveying may be briefly summarised as follows.

Frequency.

The use of low carrier frequencies (70—130 Kc/s) gives working ranges far beyond horizon distance and minimises the effects of skywave interference, transmission-path variations and local re-radiation.

Lanewidth.

The Decca « lanes » (the areas bounded by two adjacent in-phase hyperbolic position-lines) average 500 yards in width on the master-slave baselines. This lanewidth is the optimum for sensitivity and ambiguity: wider lanes would make excessive demands on the precision of phase-measurement, whereas narrower lanes would introduce the danger of lane-slipping and render re-setting increasingly difficult.

Lane Identification.

The Decca lanewidth is such that ambiguity is a negligible problem in most Decca-aided survey operations. In general navigation, however, some means of resolving the residual ambiguity is desirable and this is provided by the Lane Identification facility which is unique to the Decca Navigator and which is built into all permanent Decca chains and associated receivers.

Sensitivity and Accuracy.

The shipborne receiver indicates a movement of 3 feet on the inter-station baselines, and a fix accuracy of 11 feet can be obtained in the best geometrical region of the coverage. The latter figure refers to repeatability under all siting conditions and to absolute accuracy when the three transmission paths lie over water. The systematic (transmission-path) errors which create the gap between repeatability and absolute accuracy can be corrected by observation and do not change with time. At longer ranges the accuracy is reduced by the geometry of the system and by propagational variations which, very small as they are by day at the low carrier frequencies used, become increasingly greater than the overall instrumental error as range is extended.

The Reference System.

The Decca slave stations and all receivers are furnished with the « Reference » facility (not to be confused with the similarly-named transmitting stations used in certain hyperbolic systems). This provides, electronically, a standard of measurement against which every shipborne receiver may be checked at will.

Shore Stations.

The Decca system uses three stations, a master (which may also include the monitor receiving station) and two slave stations. The stations are identical except for the carrier frequency and the drive circuits; each contains four basic units - drive rack, transmitter unit, aerial/earth system and power supply. The station use single-mast aerials and have a total weight and consumption of 1 ton and 1.5 Kw upwards, depending on the service required. Each station less aerial can be housed in a vehicle.

Personnel.

The shore stations do not call for continuous attention and only one man is required for each. The chain as a whole should be supervised by a qualified radio engineer. The shipborne receivers are operated by non-technical personnel.

Ship Installations.

Any number of ships can use the system simultaneously. The shipborne equipment comprises essentially a receiver about the size of a large suitcase, a Decometer unit and a simple wire aerial. The set can work from ships' mains or a 24-volt supply. A second Decometer unit and a Track Plotter can be added.

Two-Range Decca.

The foregoing paper refers exclusively to the conventional Decca Navigator system, in which two pairs of stations — one the common Master — generate two families of hyperbolic position-lines. If it is not required to use more than one surveying ship throughout a given operation, the stations of a Decca chain can be re-disposed in such a way as to introduce certain valuable features not given by the normal layout, together with a very large increase in the area within which accurate position-fixing is possible. In this system, which has recently been the subject of trials by the British Admiralty, the master station is installed on the survey ship together with a receiver; the Red and Green Decometer readings are then a direct function of the distance to the respective slave stations ashore, hence the system's designation « Two-Range Decca ».

When the single-ship limitation can be accepted, the two-range system offers the following advantages:

(a) chart computation simplified.

(b) The use of only two shore stations simplifies the problems of station survey and maintenance in undeveloped areas.

(c) The area covered by the high-accuracy contours can be some hundreds of times larger than for the corresponding conventional Decca layout.

(d) The two-range layout lends itself to siting on a convex coastline, always a problem with normal Decca.

A paper on the Two-Range Decca system will appear in a future issue of the *International Hydrographic Review.*