RADAR IN SURVEYING

(communicated by the Hydrographic Department of British Admiralty)

1. (a) *Introduction.*

Very considerable use was made of radar (type 972 M) by H.M.S. « Dalrymple » whilst carrying out a survey on a scale of 1/150,000 between Malta and Sicily and another of 1/60,000 to the eastward of Malta.

The experience gained seems well worth recording, more especially as the methods adopted differed from those discussed in other papers.

(b) The problem was closely studied when planning the surveys and it was soon appreciated that the Constant Range method of sounding would be uneconomical since over most of the areas the only targets available would be floating beacons. There was only one islet off the coast of Sicily and one radar beacon on the coast of Malta which could be used to a greater range than the ten miles of the floating beacon reflector.

(c) The Constant Range method was thought to have other disadvantages in the restraint it exercises over the direction of the lines of soundings ; and in the difficulties vis-a-vis passing shipping to which the continuous alterations of course must give rise. No doubt it has its application in certain circumstances, being akin to the constant angle method of carrying out examinations.

(d) Another factor of no little importance is that radar may break down or require maintainance over considerable periods ; in addition to routine breaks in continuous operation for cooling down the set. This means that the best method in the present stage of radar development may be one which permits a switch to the ordinary visual methods and accordingly there were developed the plotting methods herein described to permit orthodox straight lines of soundings to be run.

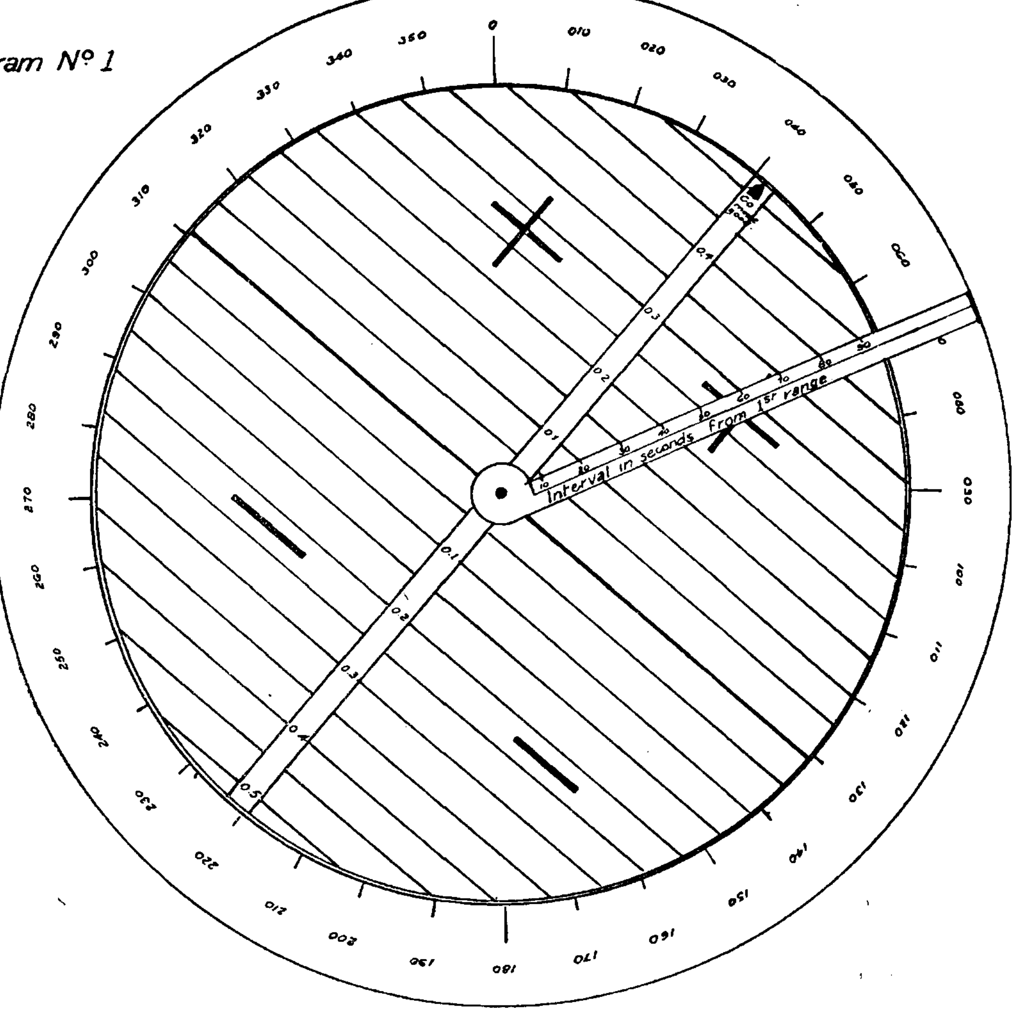
2. (a) *Plotting by two ranges.*

The problem to be solved was the rapid plotting of a fix by radar ranges of two objects which cannot be taken simultaneously. It was achieved by connecting the second range to the position at which the first was taken by a corrector made in the ship initially of bristol board and later of brass plate. - See diagram 1.

(b) A 360° circle surrounds a central disc. The central disc carries lines across it at suitable intervals of range and an arm is graduated at intervals of time in seconds for a given speed of advance and using the same scale of distance as on the disc. The figures 0.1, 0.2, etc. on the face of the disc denote 100, 200 etc. yards, the cross lines being at 50 yard intervals

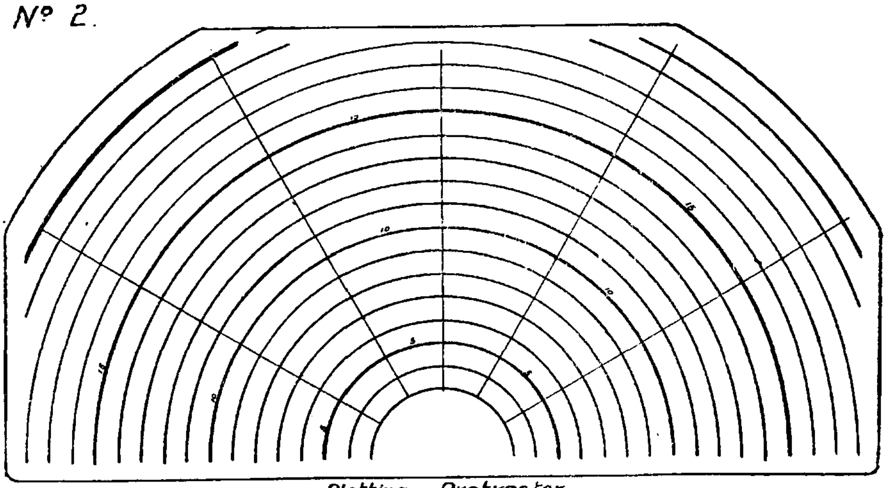
In operation the disc is set to the course being made good, and the arm to the true bearing of the second object. The correction to the second range is read off the disc against the time interval on the arm. The arm is changed for a variation of one knot in the speed of advance.

Diagram Nº 1



The Dalrymple Second Radar Range Corrector
(Actual size)

Diagram Nº 2.



Plotting Protractor.
¼ actual size.
On the protractor, the semi-circles shown above represent 1,000 yard intervals and are sub-divided by red lines of 200 yard intervals.

The Dalrymple Second Radar Range Corrector. (Diameter = 165 mm.)

Plotting Protractor. (Length = 57 cm.)

On the protractor, the semi-circles shown above represent 1,000 yard intervals and are sub-divided by red lines of 200 yard intervals

(c) In practice it was found that the radar operator can give the second range at an average interval of 20 seconds from the first and can conveniently call out the true bearing of the second object and the stop watch time interval. The correction is of course zero when the second object is abeam and the objects should be selected with this in mind. But even when this condition cannot be met it is considered that the method gives sufficient accuracy for work on a scale of 1 : 50 000 (See also para. 6 (c)).

(d) Having thus rapidly achieved a corrected range of a second object (and a third may be similarly treated as a check), the two ranges were plotted by a protractor as shown in diagram 2. Protractors were made of celluloid, range circles being drawn in ink after the surface had been roughened by sand paper. Perspex would be preferable. Suitable colours were used to emphasise 5, 10, 15 and 20 thousand yards, the sub-division being in 500 yards on the 1 : 150 000 survey and 200 yards on the 1 : 60 000 survey. Bearing lines at 30° intervals are useful. Even on the 1 : 60 000 survey the protractor, of 12" radius, was not unwieldy, especially after it was cut to the shape shown in view of the unlikelihood of more than one object being used at a greater range than 18,000 yards.

It has yet to be decided how to plot two ranges when one is of a land object at a considerable distance. It is likely that the range circles from such an object would be best drawn on the sounding board.

(e) It should here be mentioned that it was found easiest to refer to ranges in thousands of yards and then decimals, e.g. 16,320 yards is 16.32. This suits the range dial of the radar set, the second range corrector and the protractor.

3, (a) *Plotting by one angle and a simultaneous range.*

This combination was found to be of great use although of course it requires visibility. For example the 1 : 60 000 survey lay to the eastward of Malta which with Gozo island lies northwest/southeast. Shore marks gave a fix for beacon A (diagram 3) but were not suitably disposed to give a fix at C and on the day could not be seen at B. So C was fixed by sextant angle at it between a shore mark and A and a range of A. B was shot up in a similar way from fixes obtained whilst steaming from C towards A. Later when extreme visibility permitted the use of shore marks no appreciable change was observed in the plotted position of the beacons, which incidentally were moored with two anchors.

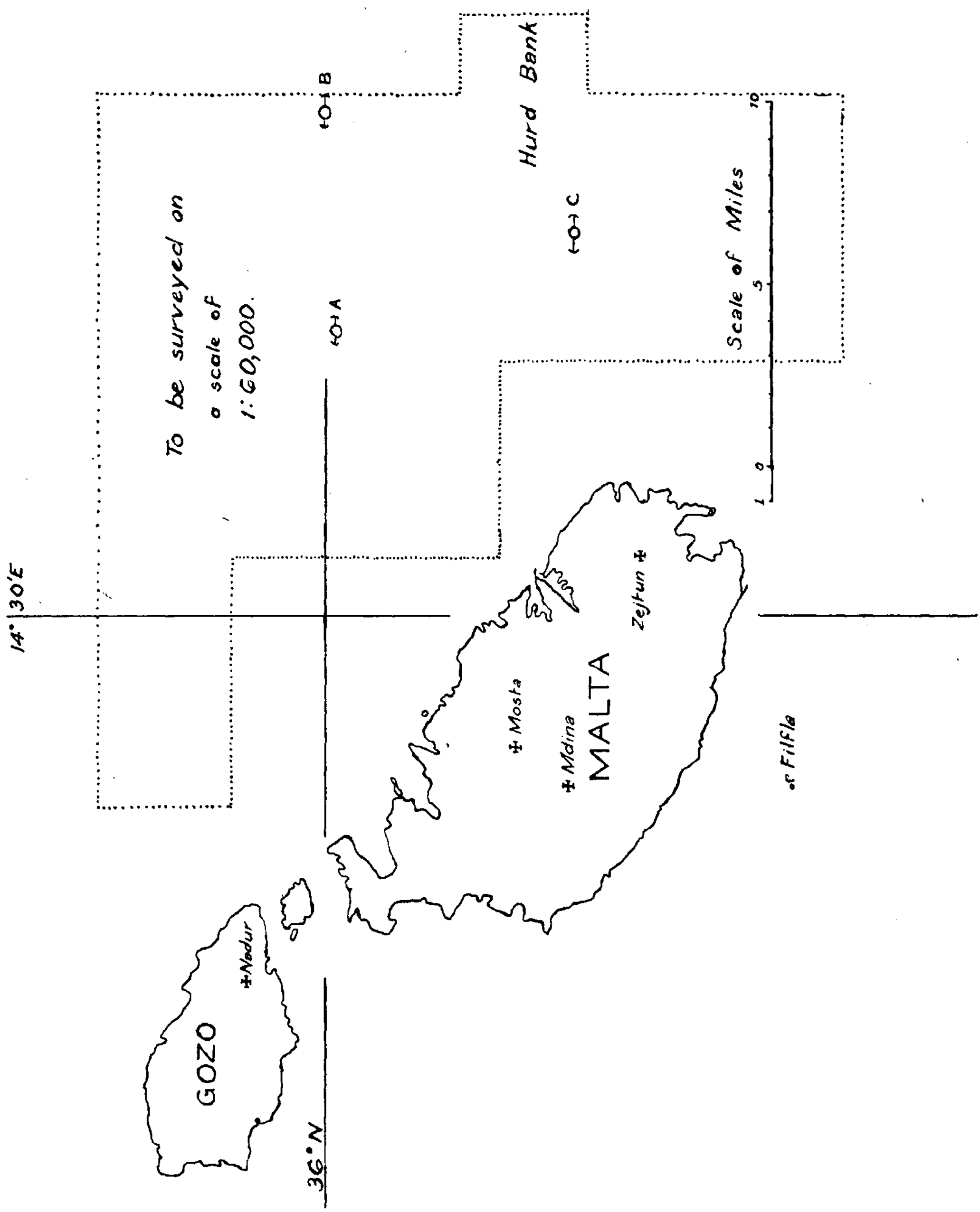
Thereafter an area of some four miles east and eight miles south of beacon C was sounded in good visibility on fixes using a range of C and an angle between it and a shore mark.

(b) In practice, one angle and a range were readily plotted by the station pointer, two legs of which had a paper range scale stuck to them. It was found necessary to roughen the bevelled edges of the legs before the paper would adhere properly.

On the smaller scale survey (1 : 150 000), the three armed transparent protractor was readily graduated in pencil along the underside of the centre « leg ».

(c) Finally, it is noted that one angle and a range may be of use when one of two beacons is a bad radar target owing, probably, to a bent reflector or to one not showing its best « face ». See para. 6 (c).

Diagram N°3


To be surveyed on
a scale of
1:60,000.
B
A
C
Hurd Bank
Scale of Miles
1
0
5
10
14° 30'E
36° N
MALTA
Zejtun
Mosta
Mdina
Filfla
GOZO
Nadur

4. (a) *Procedure and booking.*

The officer plotting and the writer-down worked on the bridge in the usual manner, with the survey broadcast switched on in the Radar Office, E/S Hut and on the bridge. They could as well work in the chart room, where there is another broadcast speaker, but an O.O.W. on the bridge would be required for the safety of the ship and to relay order to the Quartermaster at the wheel.

The officer in charge gave the customary instructions regarding the time interval between soundings, e.g. 30 secs., and the number of soundings between fixes, e.g. 5. He furthermore detailed the objects to be used as No. 1 and No. 2 (vide para. 2 (c)), advising the radar office of approximate bearings and distances when the fix was being changed.

Thereafter the procedure was :

Two ranges

(1) E/S reader off : —

« Five (soundings) gone ». « Ten seconds to go ». The sounding (at the fix).

(2) Radar Office : —

16.28 (object No. 1) 15.18 048 (Range and bearing of object No. 2) 15 secs. (time interval between ranges)

Book Entries : —

Object n° 1 Daisy (Bn.)	Object n° 2 Eva (Bn.)	Bearing. True.	Interval. Seconds.	Correction	True Range. of No. 2.
16.28.	15.18.	048.	15.	—0.16.	15.02

Angle and range

(1) As above.

(2) Radar office 17.21.

Sextant observer. 33° 29'.

Book Entries : —

Object Rinella W/T.	Angle	Object	Range
Rinella W/T.	33° 29'	Daisy (Bn.)	17.21

N.-B. — If the left hand object was being ranged upon the range was booked in the left hand column.

4. (b) If for any reason the radar operator was going to be unable to obtain ranges he called « No fix » as soon after the ten second warning as possible. The same applied to sextant observer when an angle was being used.

The E/S operator, advised as necessary by the writer-down then called another 10 seconds warning before the next sounding. The fix push to mark the E/S trace was pressed by the E/S operator as soon as the Radar office called the range, whether the two ranges or the range and angle method was in use.

5. (a) *Good and Bad Conditions of Fixing.*

When fixing by two ranges the angle subtended by the two objects at the ship (and hence the angle of cut between the two range circles) should not be less than 25° or more than 155°. Diagram 4 illustrates the areas of good and bad fixing when plotting by two ranges.

(b) When fixing by an angle and a simultaneous range the area of bad fixing is that in which at the object not being ranged on, the angle between the other object and the ship is more than 65° but less than 115°. Diagram 5, where A represents the object not being ranged on illustrates the sectors of good and bad fixing when using the range-and-angle method. It should be noted that : —

1. There is an area of good fixing between the two objects where the subtended angle at the ship is over 140°. So this area can only be used if a sextant with 90° prism is available.

2. The fix is always good if the range of B (the object being ranged on) from the observer is less than 0.9 times (cos 25° = 0.91) the distance A - B between the objects.

6. (a) *Accuracy of Radar ranges.*

It so happened that there was off the coast of Malta a radar reflector especially erected for calibration. This could be brought in transit with a distant rear object at the same time as a horizontal angle to a third object was observed by sextant. With the co-ordinates of all three objects known a table of distances in yards from the radar reflector for a given horizontal angle was readily compiled.

(b) In a number of runs across the transit at slow speed one officer and seven ratings trained as radar operators each took a rapid series of some ten ranges whilst the sextant angle to the third object was observed as the transit was crossed.

The result of these trials was that any one observer's series of ranges only exceptionally varied by more than ten yards (the interval on range dial, though interpolation to five yards may be attempted) ; the mean difference from the true range as given by the sextant angle was accepted as the index error of the radar set (in this case, 20 yards) ; and the resulting differences of the eight observers from the true range varied by from four to twelve yards.

(c) This was considered an entirely satisfactory test both of the radar and the method of determining the true range in which one minute of the horizontal angle was equivalent to some six yards. Accordingly it has been confidently assumed that, under normal operating conditions, radar ranges will have an accuracy of ± 15 yards.

It is noted in this connection, that, on a survey scale of 1 : 50 000, 35 yards represents 1/40th of an inch which approaches the smallest plottable quantity.

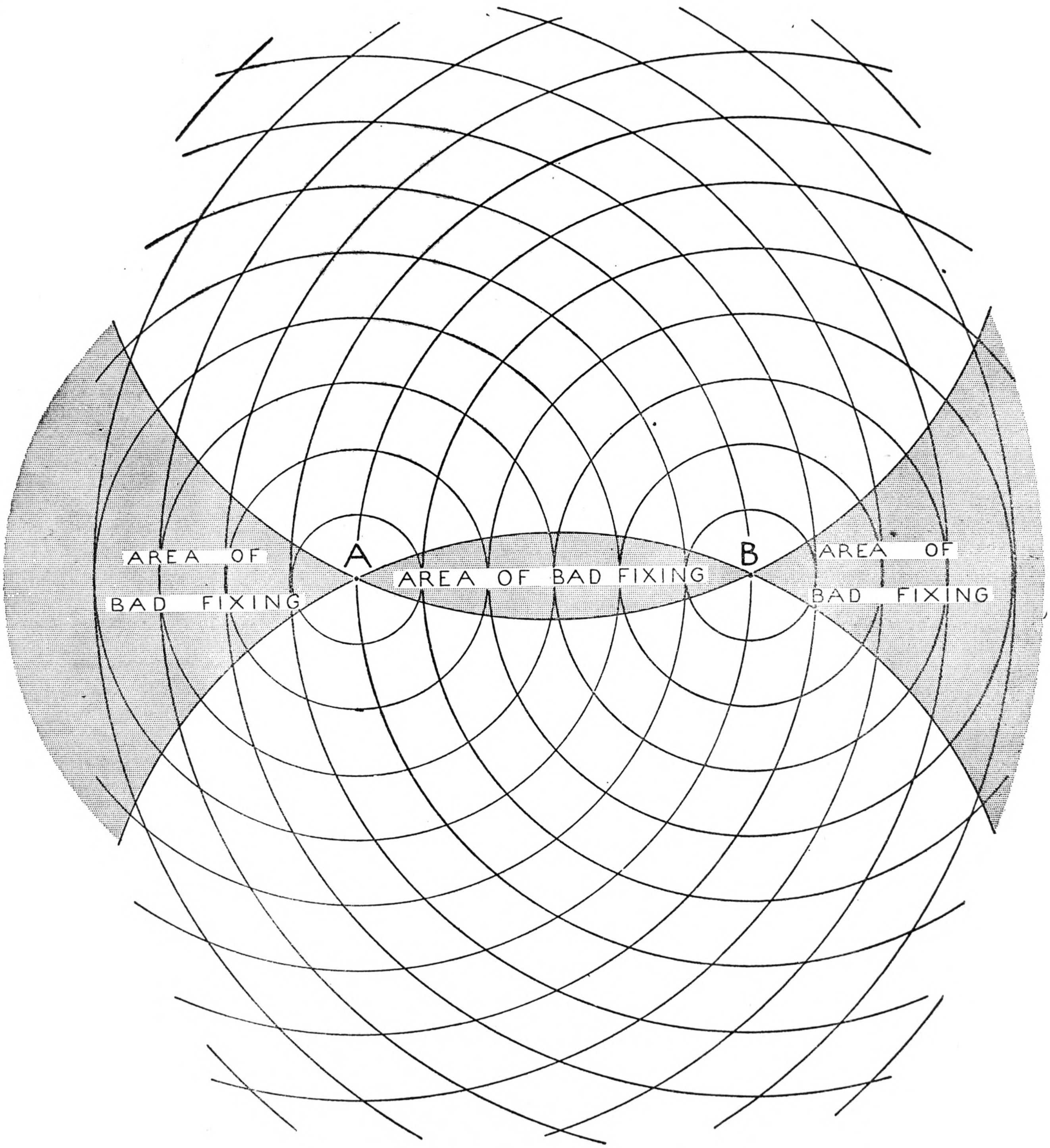
7. (a) *Performance on Beacon Reflectors.*

It has been stated that 18,000 yards is a comfortable range on a reflector made of wire mesh some 20 feet above the beacon drum. The reflectors supplied to Dalrymple were made of 1/32nd. plate but to the same size and design which can be best described as three intersecting square plates of 2'3" side, making in all « eight » corners. First experiments with these reflectors were very discouraging and larger reflectors with 2' 9" sides and of 1/16th plate were made.

Continuing experience showed that the set had been at fault and in fact the larger reflector gave little if any better results. It has since been learnt that there

Diagram No. 4

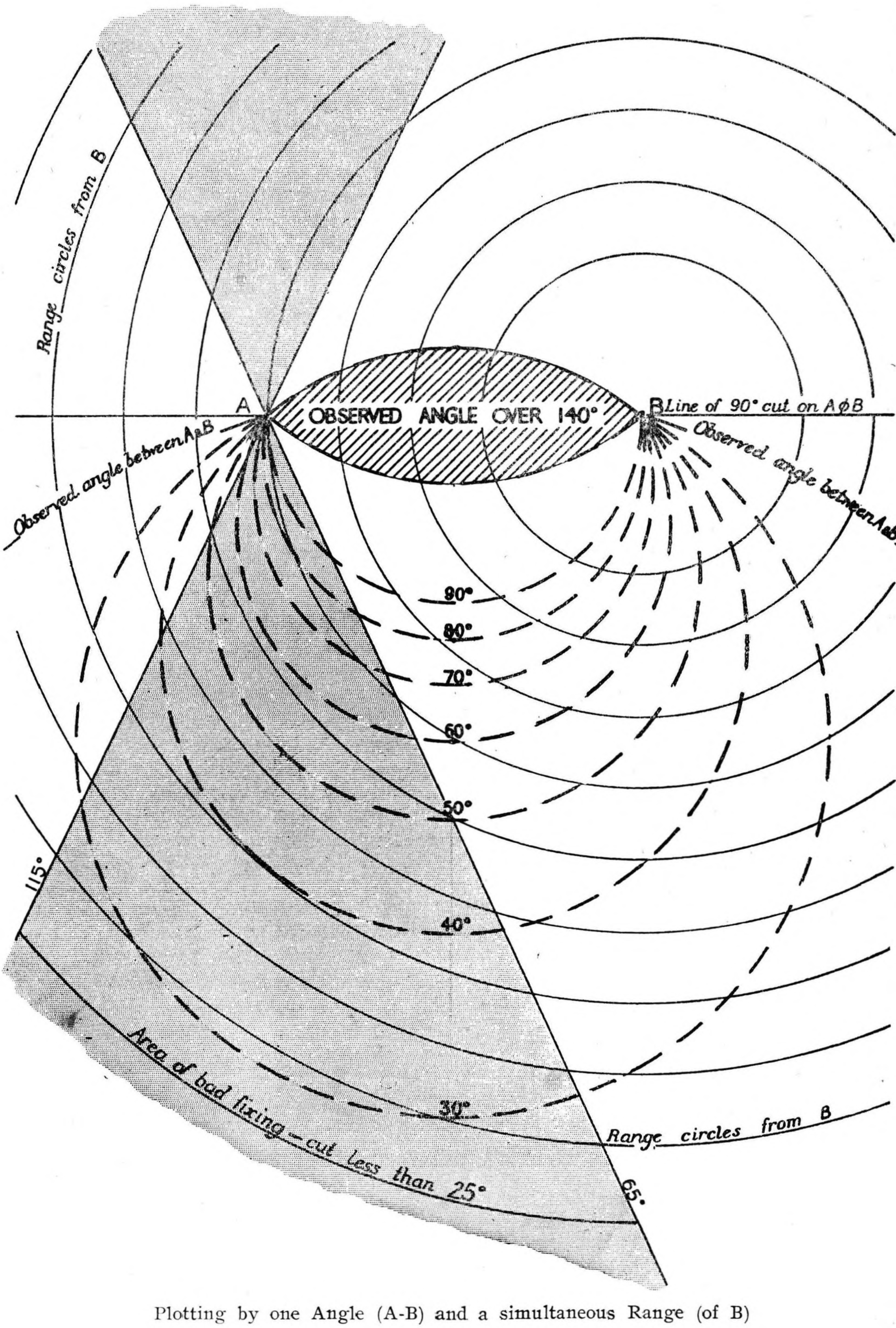
PLOTTING BY TWO RANGES



NOTE:- *Within the area shown in stipple cuts are less than 25°*

Diagram No. 5

PLOTTING BY ONE ANGLE (A-B) & A SIMULTANEOUS RANGE (OF B)



Plotting by one Angle (A-B) and a simultaneous Range (of B) is a close relation between the wave length of the set and the optimum size of the reflector.

(b) As has been shown in para. 1 (d) it is good to be able to use radar or V/S methods at will. Indeed this was forced upon Dalrymple by the early teething troubles of the set, and the radar reflector was rigged immediately below the ordinary 16 × 8 feet flag. To do this a 4" diameter hole was cut through the reflector so that the bamboo could pass through it. This it is now realised was taking considerable liberties.

Reflectors were 14 feet above the drum and the buoyancy and the stability of the beacon were sufficient even with the larger and heavier reflector.

(c) This reflector height combined with an aerial height of 67 feet gives an above horizon distance of 13.7 miles and it was hoped that ranges would in all conditions (especially with the larger reflector) be obtained to 10 miles compared with the 9 1/2 miles V/S range of beacon flag from bridge height in extreme visibility.

However it was soon learned, somewhat unexpectedly, that in rough weather the maximum range obtainable dropped considerably. It is surmised that movements of the ship and consequently of the radar aerial, despite its azimuth stabilizer, are the cause. It was also learnt that wave clutter appreciably increases the minimum range. Lastly there was some evidence of reflectors giving less good signals in certain directions and here the cutting of a hole through them may be the reason (see para. 7 (b)).

(d) In the upshot and over some months' experience results were : —

(i) In calm weather ranges from 1500 to 20,000 yards were operationally practicable with 22,000 yards exceptionally.

(ii) In moderate to rough weather the limits became 5000 to 15,000 yards with an intermediate stage of 4,000 to 18,000 yards which was frequently encountered.

(iii) Rain may cause sufficient interference to make signals indeterminable, though this is not based on much experience.

N.-B. — By operationally practicable is meant a good signal on the P.P.I. which is important if the time interval between the two ranges is to be kept within bounds.