STRUCTURES FOR MAXIMUM RADAR RETURNS

In International Hydrographic Bulletin, *No. VIII, August 1955, the Bureau reported the receipt from the Hydrographic Department, British Admiralty, of material regarding structures supplying maximum radar returns. These reports are summarized below.*

I. — AN INVESTIGATION OF THE RADAR REFLECTING PROPERTIES OF THE KING WILLIAM BANKS BUOY USING AN 18" OCTAHEDRAL REFLECTOR.

Trinity House, London.

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1. *Introduction.*

These trials were a continuation of those carried out by the British Railways ship *Duke of Lancaster* using an 18" octahedral reflector in place of the 12" pentagonal cluster as used during the other trials. Four ships were used, but only three returned a sufficient number of observations.

The method of treatment in these investigations was to make a general comparison, as far as possible, between the results obtained from all three vessels, and then to make a more detailed analysis of the returns from each individual ship. The period of time covered by these trials was February to September 1951, thus giving a wide variation in weather conditions.

The buoy involved is an unlit, third class, spherical buoy used as a turning point by British Railways vessels in the Northern Irish Sea. These ships pass it at night at a range of about 1.5 nautical miles, but since it could be detected by radar at only 1.7 miles, it was decided to increase the radar reflecting properties of the buoy.

2. *Observation Policy.*

Strict instructions were given to radar operators to fill in record sheets showing:

— Maximum range of detection;

— Maximum range at which the buoy was finally lost;

— Weather conditions, state of sea;

— Strength of echo, etc.

3. *Results and Analysis.*

Several references in the report are made to a t-significance test. This is a statistical test applied to the mean of a small sample from a given set of results. If the probability of repetition of this type of sample is less than 1 % or more than 99 % it is termed a « highly significant » variation and shows there is no relationship between the sample mean and the overall mean. If the probability is between 1 %

and 5 % or 95 % and 100 %, it is designated a « significant » variation, and shows that although there is some relationship between the sample mean and the overall mean, it is not a normal sample. If the probability lies between 5 % and 95 %, it is termed « not significant », and shows that such a sample is to be expected in practice.

The results obtained from the three ships do not give the same mean maximum radar range, since the *Slieve Bearnagh* is fitted with a Cossor Marine Radar, and the *Duke of Lancaster* and *Duke of Argyll* with a Marconi Radiolocator Mark III. The heights of the aerials are also different.

The mean maximum radar ranges obtained on this buoy for the three vessels were found to be 11,800 yards, 10,500 yards and 8,400 yards respectively. A mean range of 10,300 yards was derived, with a standard deviation of 1770 yards. It can therefore be said that, in general, the maximum ranges obtained with an average aerial height of 55 feet and any type of radar set as used in these trials lie between 6,500 and 13,750 yards on 95 % of the occasions, and between 9,150 and 11,450 yards on 50 % of the occasions.

A histogram of the maximum ranges obtained with the three ships is shown in Figure I, and a histogram of all ranges obtained appears in Figure II.

An extremely detailed analysis of the results obtained for each vessel follows. The readings are individually analysed for sea and swell states broken down into two divisions, wind force and wind direction, and weather conditions (fine and clear, cloudy, precipitation, etc.). Histograms are used for analysis purposes.

Where several operators were engaged in tests aboard the same ship, the mean maximum range for each operator was computed.

4. *Minima.*

As the range between a radar carrying vessel and the buoy is increased from zero to a maximum, it will be found that at some ranges the echo from the buoy will either be much reduced or will disappear completely for a while, to reappear at some greater range. This is due to interference between the direct path ray and the ray reflected from the surface of the sea when their relative phases differ by 180°. There are a large number of such minima, the distance between the centres of the troughs increasing as the range increases. In practice, only the outer minima are well defined since at that range the echo is due to reflection from the refllector only. The closer minima will be filled in by reflections from the buoy itself. The ranges of these minima may be estimated by means of a formula (2) given the effective height of the radar aerial and the height of the reflector above sea level. If the sea is not calm, the minima are not so well defined as the reflected ray suffers considerable scatter.

5. *Observation of minima.*

The operators were asked to record the ranges of partial or complete reduction of the echo, as well as the point at which this occurred.

In each case, the expected minimum was calculated and its mean range was compared with the results obtained.

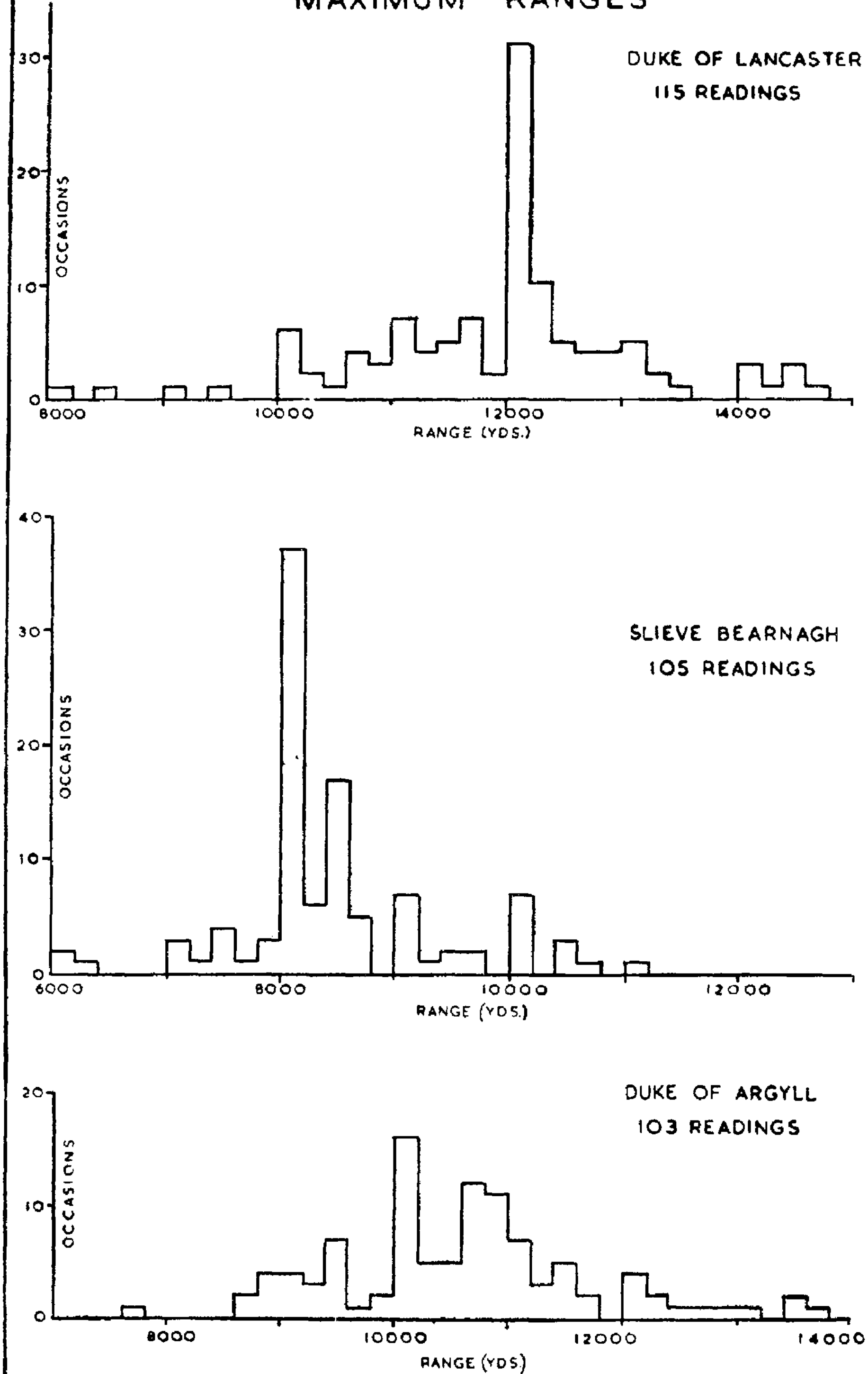
6. *Results and Analysis of Minima.*

The analyses were made separately for each vessel in view of the fact that their aerials were of different heights.

Figure III shows a histogram of the minima ranges obtained by each vessel.

MAXIMUM RANGES

FIG I



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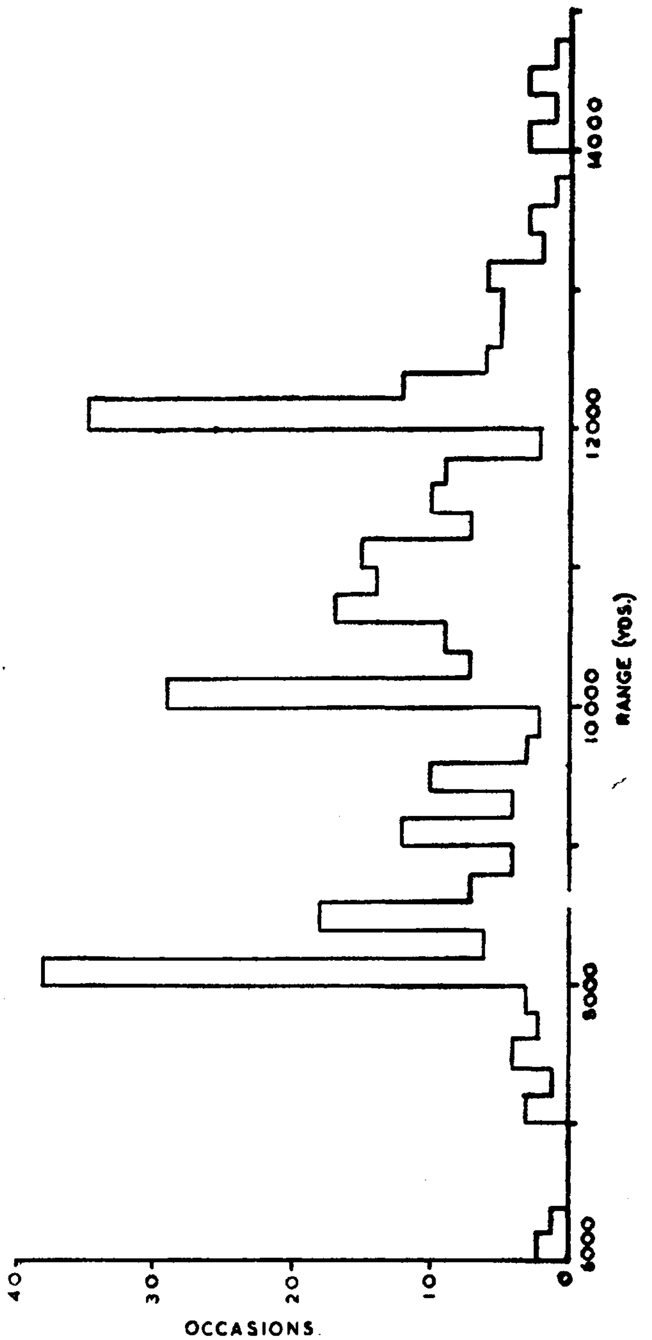
MAXIMUM RANGES FIG II

COMBINED READINGS FOR THREE VESSELS

323 READINGS



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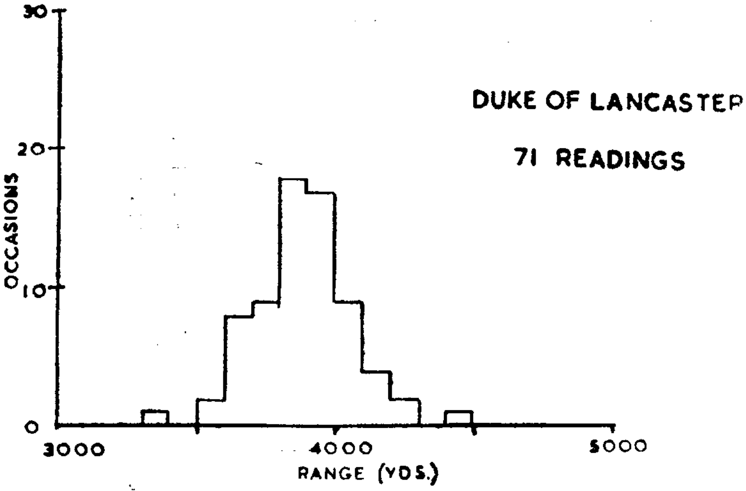
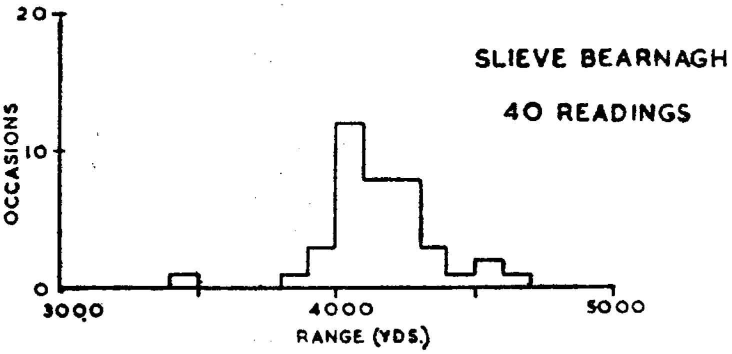
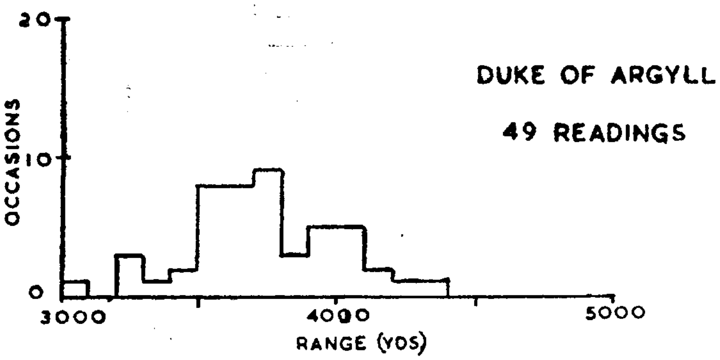
MINIMA RANGES

FIG III







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As in the case of the maxima, a study was made of the influence of the operator and of sea and swell conditions.

When sea and swell states become worse, the chances of detecting the minimum decrease.

7. *Conclusions.*

a) Maximum ranges:

For the type of fittings used, the mean maximum detection range of the buoy falls between 9,150 and 11,450 yards with a 50 % probability for any of the ships concerned.

It would appear that the range obtained by the two clusters (octahedral and pentagonal) for the same size of corner are not very different.

The mean maximum detection range is reduced as the sea becomes rougher, due to increased sea returns and the swing of the buoy.

An increase of wind force reduces the probability of detection at extreme range.

In general, it would appear that when the ship is to the leeward of the buoy (i.e. when the buoy tends to lean towards the ship), the mean detection range is decreased.

It was noticed that as the moisture content of the air increased, a slight diminution in the mean detection range occurred.

b) Minimum ranges.

Experience showed that the minima (i.e. the distances at which the echoes diminished or disappeared altogether because of interference both by the wave reflected directly by the reflector and by the wave reflected by the receiver and the surface of the sea) could be calculated, in terms of the heights of the radar aerials and radar reflector, to within a fair degree of accuracy.

When the state of the sea worsened, the chances of observing a minimum diminished. Even under relatively calm conditions, the minima were only noticed in about 45 % of the cases. A reduction of echo can occur over a distance of about 1,000 yards.

REFERENCES

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2. HOGBEN H. E., MILWRIGHT A. L. P., STEMP V. P., 1948 : *Radar Reflectors for Marine Navigation;* A. S. R. E. Monograph 833.

3. HARRIS-WARD L., 1950 : *An Investigation into the Radar Reflecting Properties of the Lightning Knoll Buoy - Morecambe Bay;* Ministry of Transport Operational Research Group Report.

II. — INVESTIGATION INTO RADAR RANGES OBTAINED FROM VARIOUS TYPES OF SEA MARKS USED FOR NAVIGATIONAL PURPOSES

by E. R. RICHARDS, Research and Development Department.
Corporation of Trinity House.

Introduction and object of study.

Efforts were made to establish experimentally the reliable detection ranges of such marks as lighthouses, lightvessels, buoys, etc.

With this end in view, detection was defined in the following three categories:

— 1/10 paint: in which an echo appeared once in every ten revolutions of the aerial;

— 5/10 paint (« average » contact): in which an echo appeared five times in every ten revolutions of the aerial;

— 9/10 paint (« close » contact): in which an echo appeared nine times in every ten revolutions of the aerial.

Observations.

These were carried out over a period of two years by Trinity House Tenders on *all* possible navigational marks.

Echoes were classified according to:

— Buoys: class and shape;

— Lighthouses: separate classification for each;

— Lightvessels: size and type of construction.

The state of the sea and the atmospheric conditions that could affect radar range were noted.

The ranges were read off from the radar set in two different ways. For ranges under ten miles, they were generally obtained from range markers operated by a calibrated control scaled off in cables and miles (10 cables = 1 mile), which would only incur a small error.

For greater distances, calibrator rings were available on the cathode ray tube. As these are generally between 3 and 5 miles apart, a human error occurred on the part of the operator who had the tendency to give ranges to the nearest mile or half-mile.

Three types of radar fittings were used in the five vessels employed in this test. They were:

— 1 Decca Type 12 on Trinity House Vessel « Vestal »;

— 1 Cossor Marine Radar on T.H.V. « Alert »; and

— 3 Kelvin Hughes Type 2 A, one on each of the T.H.Vs. « Patricia », « Ready » and « Triton ».

Results.

The histograms prepared for and contained in this report are not being reproduced here. The report gives the results obtained for each category of target by the five vessels as a group, as well as by the vessel « Alert », but only the results of the group will be reproduced herewith.

Lightvessels, Class I.

Lengths: Between 98' 6" and 103'.
Breadths: Between 24' and 24' 9".
Results: Reliable.

Mean	detection	range	:	8.0 m.	Stan.	Dev.	:	1.0 m.	for	1/10	paint
»	»	»	:	7.28 m.	»	»	:	1.12 m.	for	5/10	paint
»	»	»	:	6.62 m.	»	»	:	1.33 m.	for	9/10	paint

Lightvessels, Class II.

Construction: Iron.
Length: 104'.
Breadth: 24'.
Returns: Very few.
Results: To be treated with precaution.

Mean	detection	range	:	8.54 m.	Stan.	Dev.	:	1.25 m.	for	1/10	paint
»	»	»	:	7.71 m.	»	»	:	1.15 m.	for	5/10	paint
»	»	»	:	7.17 m.	»	»	:	1.03 m.	for	9/10	paint

Lightvessels, Class III.

Construction: steel.
Length: 85'.
Breadth: 22'.
Returns: Very few.
Results: to be treated with precaution.

Mean	detection	range	:	7.77 m.	Stan.	Dev.	:	0.76 m.	for	1/10	paint
»	»	»	:	6.91 m.	»	»	:	0.91 m.	for	5/10	paint
»	»	»	:	6.6 m.	»	»	:	0.87 m.	for	9/10	paint

Lightvessels, Class IV.

Construction: steel.
Length: 104'.
Breadth: 25'.
Returns: Numerous.
Results: Reliable.

Mean	detection	range	:	8.66 m.	Stan.	Dev.	:	1.32 m.	for	1/10	paint
»	»	»	:	7.9 m.	»	»	:	1.24 m.	for	5/10	paint
»	»	»	:	7.08 m.	»	»	:	1.22 m.	for	9/10	paint

Lightvessels, Class V.

These are the most up-to-date and the most numerous of the lightvessels.

Length: 118'.

Breadth: 25'.

Returns: Very numerous.

Results: Reliable.

Mean detection range	:	8.8 m.	Stan. Dev.	:	1.31 m.	for 1/10 paint
» » »	:	7.81 m.	» »	:	1.31 m.	for 5/10 paint
» » »	:	7.4 m.	» »	:	1.25 m.	for 9/10 paint

Lighted Pillar Buoys.

These buoys have a lattice pillar superstructure.

Returns: Few.

Mean detection range	:	2.61 m.	Stan. Dev.	:	0.36 m.	for 1/10 paint
» » »	:	2.07 m.	» »	:	0.45 m.	for 5/10 paint
» » »	:	1.77 m.	» »	:	0.43 m.	for 9/10 paint

High Focal Plane Buoys.

Returns: Few.

Mean detection ranges: Very scattered.

Lighted Buoys.

Returns: Very numerous.

Results: Reliable.

Mean detection range	:	2.98 m.	Stan. Dev.	:	0.43 m.	for 1/10 paint
» » »	:	2.56 m.	» »	:	0.40 m.	for 5/10 paint
» » »	:	2.26 m.	» »	:	0.41 m.	for 9/10 paint

The shape of the buoys has a negligible effect on the detection range.

Second Class Buoys.

Returns: Quite numerous.

Results: Reliable.

Mean detection range	:	2.73 m.	Stan. Dev.	:	0.41 m.	for 1/10 paint
» » »	:	2.3 m.	» »	:	0.42 m.	for 5/10 paint
» » »	:	1.95 m.	» »	:	0.43 m.	for 9/10 paint

Third Class Buoys.

Returns: Quite numerous.

Results: Reliable.

Mean detection range	:	2.46 m.	Stan. Dev.	:	0.49 m.	for 1/10 paint
» » »	:	2.11 m.	» »	:	0.49 m.	for 5/10 paint
» » »	:	1.85 m.	» »	:	0.45 m.	for 9/10 paint

Fourth Class Buoys.

Returns: Few.

Mean detection range	:	2.08 m.	Stan. Dev.	:	0.49 m.	for 1/10 paint
» » »	:	1.75 m.	» »	:	0.45 m.	for 5/10 paint
» » »	:	1.49 m.	» »	:	0.42 m.	for 9/10 paint

Appreciable variation in range with shape of buoy.

Automatic Whistle Buoy.

Only one buoy observed.

Mean detection range : 3.35 m.	Stan. Dev. : 0.6 m.	for 1/10 paint
» » » : 2.95 m.	» » : 0.56 m.	for 5/10 paint
» » » : 2.62 m.	» » : 0.47 m.	for 9/10 paint

Buoys with Radar Reflectors.

The fittings were octahedral with 18" corners.

The echoes from these buoys were surprisingly low. The results obtained for the third-class buoys line up quite well with the results obtained from previous work and show that « maximum » range corresponds closely with the regular 1/10 paint.

Lighthouses.

The number of returns obtained were so very few that the results must be treated with precaution.

Only four lighthouses were reported on.

Effects of Sea and Swell on Ranges.

The results show that the range diminishes with a worsening of sea or swell state.

Effect of Observer Error on Ranges.

The results show that some variation is to be expected between observers.

TABLE

MEAN RANGES FOR ALL TARGETS

	MEAN RANGE (Miles)					
	WHOLE GROUP			T.H.V. « Alert »		
	1/10	5/10	9/10	1/10	5/10	9/10
Lightvessels Class I......	8.01	7.28	6.62	8.88*	8.49*	8.07*
— Class II......	8.54*	7.71*	7.17*	7.84*	7.13*	6.51*
— Class III......	7.77*	6.91*	6.60*	8.90*	8.10*	7.70*
— Class IV......	8.66	7.90	7.08	9.20*	8.65*	7.90*
— Class V......	8.80	7.81	7.40	9.09	8.50	7.90
Lighted Pillar Buoys	2.61	2.07	1.77	3.16	2.88	2.54
Lighted Buoys	2.98	2.56	2.26	3.39	3.11	2.81
Second Class Buoys	2.73	2.30	1.95	3.42	3.07	2.77
Third Class Buoys	2.46	2.11	1.85	2.75	2.41	2.20
Fourth Class Buoys........	2.08	1.75	1.49	2.51	2.22	1.92
Automatic Whistle Buoys..	3.35	2.95	2.62	—	—	—
Third Class Reflector Buoys	4.10	3.60	3.30	—	—	—
Lighted Reflector Buoys....	5.45	5.02	4.69	—	—	—
Beachy Head L/H	8.4 *	8.0 *	7.8 *			
Eddystone L/H...........	9.7 *	9.0 *	8.5 *			
Skerries L/H.............	7.35*	6.2 *	5.1 *			
Wolf L/H	9.2 *	8.6 *	8.0 *			

* These ranges are to be treated with caution.

Conclusions.

A summary of mean ranges obtained for the various targets is shown in the foregoing Table for the group total, as representative of the majority of radar sets fitted in small vessels, and for the Cossor Marine Radar, as representative of the more powerful sets. Most of the ranges quoted may be treated with confidence, but those marked with an asterisk, although representative, must be treated with extreme caution, as the number of returns were insufficient to quote a definite range for these targets.

The standard deviations obtained show that quite a wide scatter of ranges about the mean is to be expected, though the order of standard deviation for all light vessels is similar, as is the case with buoys. In particular, the standard deviation for any class of buoy is sensibly constant for any degree of paint (1/10, 5/10, 9/10).

As was to be expected, the size of the light vessel has an effect on the range, but the type of construction only has a slight effect. In general, the light vessels have iron or steel plating on a steel frame. The Class I has a wooden plating on a steel frame. It is this class which tends to give a slightly lower range when compared with other classes of different construction but comparable size.

The states of sea and swell have some effect on the range of a target. Although the individual sea/swell classifications tend to show a general lowering of the range as the sea and swell states worsen, this is shown more clearly when the sea or swell states are considered separately. This bears out results previously obtained but the effects seem to be slightly less than was the case when « maximum range » was quoted.

A variation in range is introduced by the observer, though it is not excessive. This variation is to be expected because of the human factor arising in assessing the various types of paint, which is continuously varying since the ship is in motion, and also in the setting of the cathode ray tube brightness, which each observer uses. An interesting comparison is that in general the observer giving the lowest mean ranges with the buoys also gives the lowest mean ranges with the light vessels and vice versa.

One great advantage this investigation has over many that have been carried out by one or two ships working on a given target during a short period is that in this case a total of five ships was used, thus taking into account variations between individual sets.

This investigation covers a period of just over two years, thus taking into account all forms of weather conditions, unlike readings taken over a short period which will not give a realistic result unless the weather conditions are quoted. Again, all forms of navigational targets have been reported on, instead of just one particular target. For any one type of target, many stations have been used to produce the results quoted, thus giving a much more realistic general picture.

III. — RADAR REFLECTORS FOR LIGHTHOUSES.

by H. E. Hogben, B. Sc., & A. L. P. Milwright,
Admiralty Signal & Radar Establishment.

1. *Introduction.*

Researches carried out by the Ministry of Transport on lighthouses of various types and heights have shown that, in general, the maximum radar range of a typical lighthouse is 9 to 10 miles, compared with an optical range of 18 to 20 miles.

2. *Trials arrangements and results.*

A single dihedral reflector was constructed, with sides 3' × 1' and aperture of 4.25 sq. ft. This was mounted on the gallery rails with the aperture normal to a bearing of 178° true, at a height of about 140 ft. above sea level.

Observations of the echoing performance of the lighthouse and the reflector were carried out on 28th July, 1949, using the Kelvin-Hughes Radar Set Type 1 A in H.M.S. *Loch Fada,* the aerial height being 60 ft.

The trials consisted of a series of runs to measure the variation of signal/noise ratio with range for the lighthouse, and lighthouse plus reflector, and a run at a fixed range of 10,000 yards to determine the effective beamwidth of the reflector.

3. *Discussion of results.*

The echoing characteristics of a lighthouse not fitted with reflectors must be considered unsatisfactory (maximum range of detection 8 miles).

The effect of the reflector was to increase the maximum range of detection to 28,000 yards. The theoretical range varies from 24,500 yards in a very rough sea (no reflections) to horizon range (43,000 yards) in a calm sea. Although the sea was quite rough (8 ft. waves) minima were pronounced, and the signal/noise ratio was low at ranges beyond 16,000 yards. The positions of the observed minima agree with the theoretical positions (27,000, 18,000, 13,500, 10,800, and 9,000 yards) except in the case of one observed at 22,000 yards.

The angular range of the reflector was approximately 40°, as expected.

4. *Conclusions and recommendations.*

The echoing area of the experimental reflector was not adequate to compensate for the effects of interference due to reflections from the sea. One possible method of reducing the extent of minima due to sea reflections would be to mount additional reflectors at a height of 70 ft. above sea level. This, however, is not considered to be an appropriate general solution to the problem, as in many cases reflectors mounted at this height would be liable to be swept away in rough weather.

It is therefore proposed to increase the dimensions of the reflector to 3 ft by 2 ft, or 4 ft by 18 inches.

This increase of the reflector size should increase signal/noise ratio by 6 db; it is expected that this increase will be enough to ensure a reliable detection range of 24,000 yards in all weather conditions, with a significant reduction in the extent of the minima.

It is considered that a symmetrical arrangment of 8 reflectors, equally spaced around the gallery rail, should ensure satisfactory performance over 360 degrees of azimuth.

IV. — RADAR REFLECTORS FOR LIGHTHOUSES (Second Report)

by A. L. P. MILWRIGHT.

1. *Introduction.*

Following trials described in the preceding report, Skerryvore Lighthouse was fitted with two of the larger reflectors.

2. *Trial arrangements and results.*

The reflectors were large dihedral reflectors and were made of two plates each 4 ft high × 1 ft 6 in. wide. These reflectors were mounted on the gallery rails with their apertures normal to true bearings of 135° and 225°, at a height of 140 ft above sea level. In addition the reflector referred to in the preceding report was left in position on a bearing of 178° true.

Observations of the echoing characteristics of the lighthouse and reflectors were made on 14th July, 1950, using the Cossor Radar fitted in the S.S. *Pole Star*.

The trials consisted of measurements of amplitude of the echo from the lighthouse at various ranges and bearings. The ship first closed the lighthouse on a bearing 055° which was free of reflectors, and the measurements made during this run are shown in graphical form in Fig. IV (Curve 1).

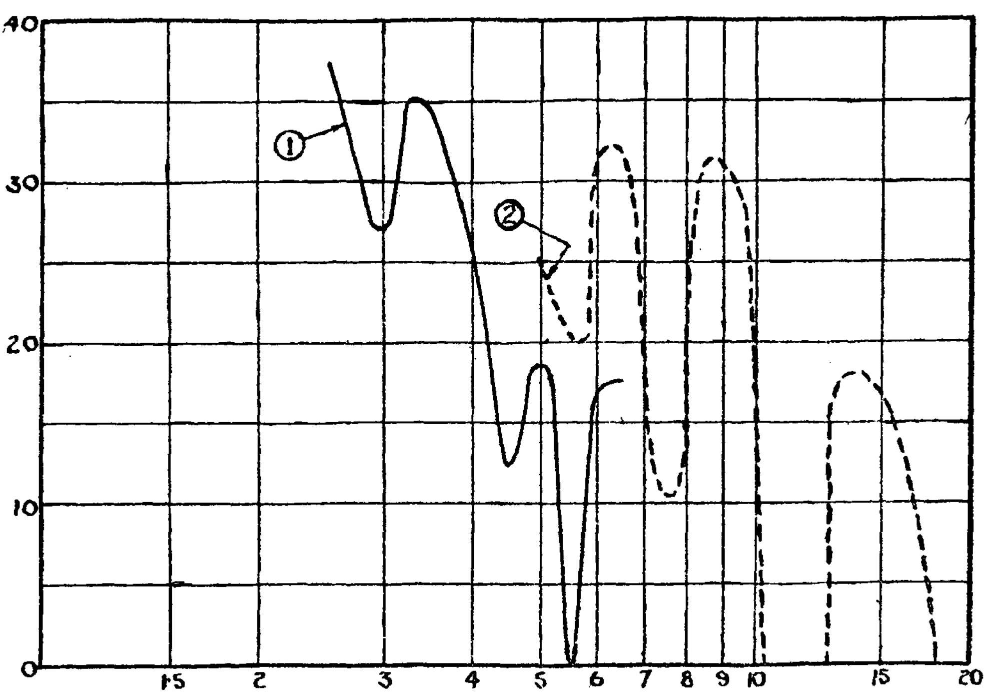

Fig. IV.

Curve 1 : Range/amplitude curve on bearing 053° i.e. without reflectors.
Curve 2 : Range/amplitude curve on bearings 120° to 146° i.e. with large reflectors.
Ordinates : Echo amplitude (dbs above noise).
Abcissae : Range nautical miles.

Unfortunately the maximum range of detection was not obtained as the installation was such that a blind arc existed dead ahead of the ship due to the foremast. No echo, however, was visible at eight miles, when the lighthouse should have been clear of the blind arc.

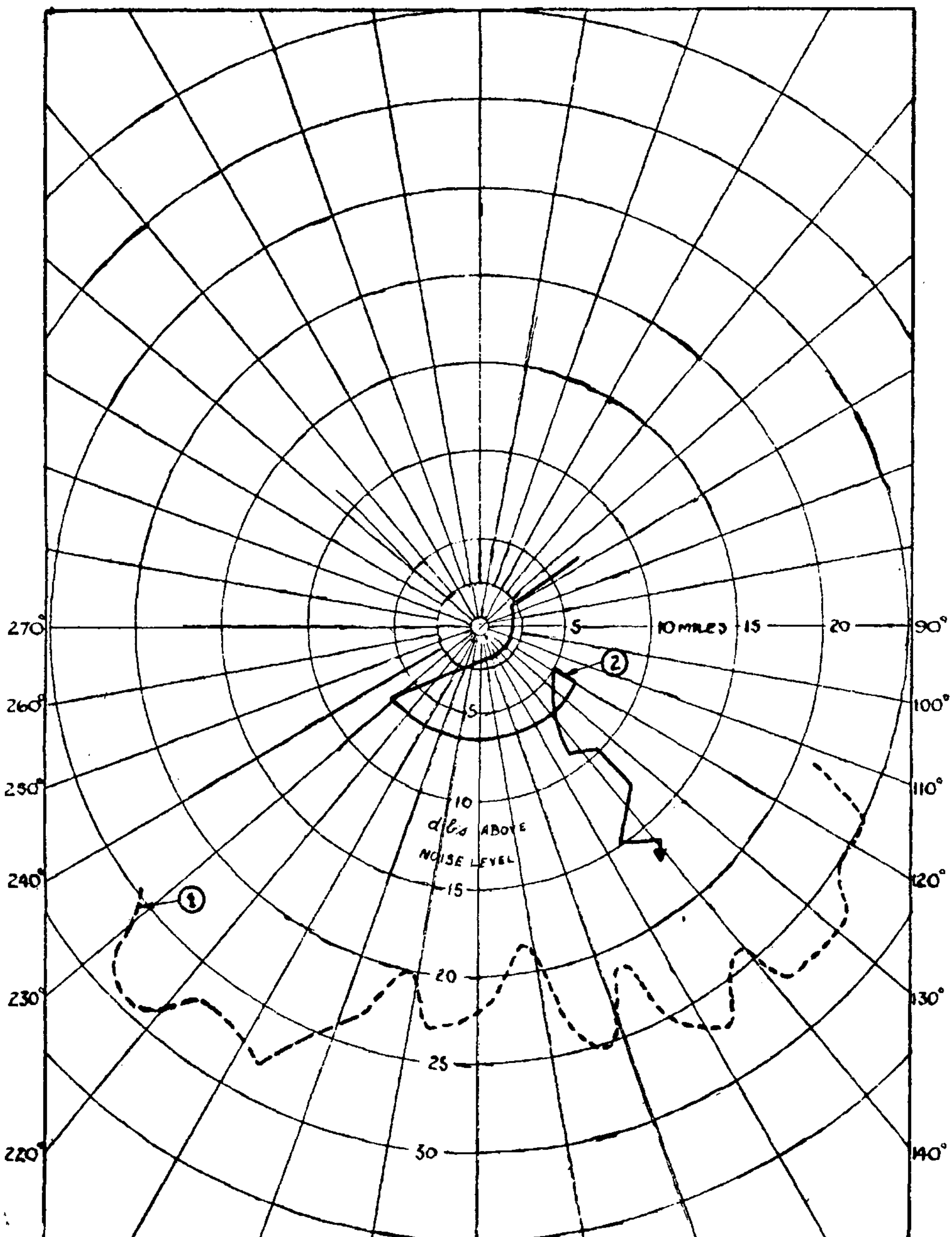

Fig. V.

Curve 1 : Radar echoing diagram (Use db. Scale).

Curve 2 : Track chart of S.S. Pole Star (Use Miles Scale).

The ship then steamed over an arc of 120° at a distance of 6 1/2 miles from the lighthouse, and the echo amplitude in decibels above noise level over this arc was measured every 5 degrees. The results are shown in Fig. V (Curve 1).

Finally the ship opened range on the lighthouse, zig-zagging about a mean bearing of 140° as shown in Fig. V (Curve 1) and the results of measurements of echo amplitude are shown in Fig. V (Curve 2).

3. *Discussion of results.*

Fluctuations in the echo amplitude from the lighthouse alone are similar to those observed during the trials in 1949 and confirm the conclusion that the main echoing area is confined to the lantern and gallery platform.

The maximum range of detection of the lighthouse when fitted with the larger reflector seems to be satisfactory at 17 miles, but an objectionable minimum at 11 miles is still present. The width of the minimum however is not necessarily as great as is indicated on Curve 2 of Fig. IV, since at that range the ship was stern on to the lighthouse (see the track chart, Fig. V, Curve 2) and the radar has a blind sector dead astern due to the shielding effect of the main mast. It should be noted from the track chart that the run was not carried out at the point of maximum amplitude but at a point 3 db below maximum. The azimuth coverage of the reflectors would appear to be satisfactory over arcs of 35° to 40°.

4. *Conclusions and recommendations.*

It is considered that the range of detection of the lighthouse when fitted with the 4 ft × 1 ft 6 in. reflectors is adequate and that the presence of the minimum at 10 to 13 miles is not too serious in view of the high level of signal between the 13 and 18 miles.

To provide effective cover in azimuth, eight of the larger type of reflectors would be required, spaced at 45-degree intervals around the gallery platform.

V. — RADAR BUOYS IN RIVER MERSEY

by A. L. P. MILWRIGHT.

1. *Introduction.*

The Mersey Docks and Harbour Board have for some time past been experimenting with various types of radar buoys and reflectors.

The Admiralty Signal and Radar Establishment took part in the design of a suitable buoy and carried out the measurements described in this report.

2. *Trials arrangements and results.*

The trials consisted of four runs on three types of radar buoys which were laid together at the end of the buoyed channel and in the vicinity of the Bar Light Vessel. These buoys are shown in Figs. VI, VII and VIII. The runs were carried out in two directions which differed by 40°.

Fig. 7 represents a pentagonal cluster of corner reflectors mounted on a conical buoy. Fig. VI illustrates the radar buoy developed by the Mersey Docks and Harbour Board and is known as a Cruciform Buoy. At the suggestion of A.S.R.E. a pentagonal cluster of corner reflectors was mounted on a cruciform buoy as shown in Fig. VIII.

The results of the runs are shown in Fig. IX and represent the mean of all four runs on each buoy, together with the results of one run each on a standard boat buoy and a standard conical buoy.

Unfortunately the signal strength of the echo from the boat buoy could not be plotted out to the maximum range of detection owing to the difficulty in identifying the target at ranges greater than 6,000 yd.

The measurements were carried out using the Cossor CMR 1 equipment fitted in the S.S. *Salvor,* which was not operating at maximum efficiency. The results, therefore, can be considered only as a guide to the comparative efficiency of the various types of buoys as radar targets.

3. *Conclusions and recommendations.*

The results confirm that the combination of the cruciform with a cluster of corner reflectors is the best of the three types. This buoy gives a good steady echo out to maximum range and is comparable to the echo from a boat buoy.

An interesting point about the results is the fact that a pronounced minimum is apparent at the longer ranges on the cruciform fitted with corner reflectors. It had been hoped that the furthest minimum caused by the corner reflector would be filled by the maximum from the cruciform, but the minima from the two types occur at ranges which are not greatly different from each other. This would indicate that the part of the cruciform buoy which contributes most to the radar echo at the longer ranges is the top of the cruciform.

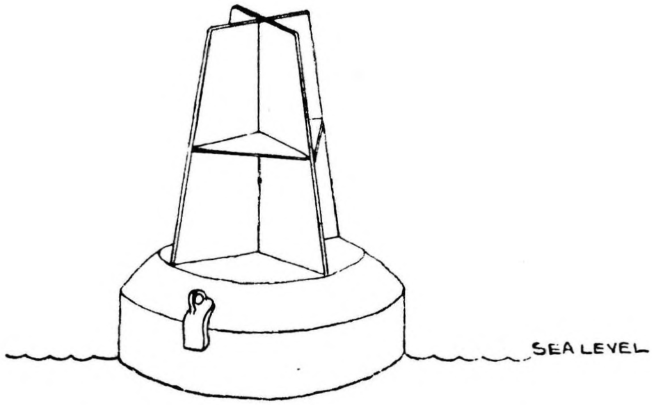

Fig. VI.

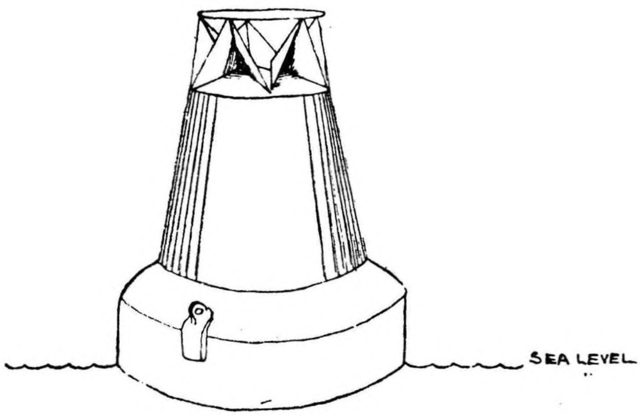

Fig. VII.

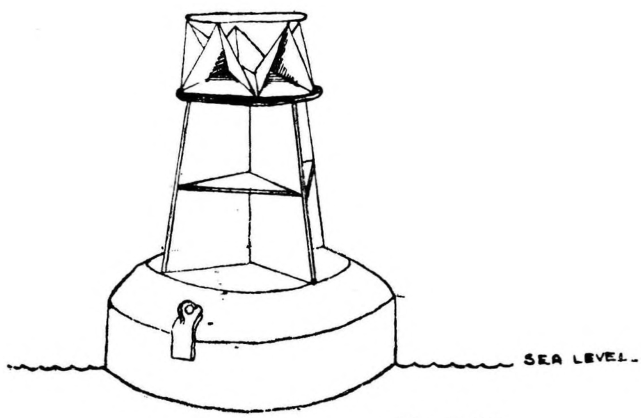

Fig. VIII.

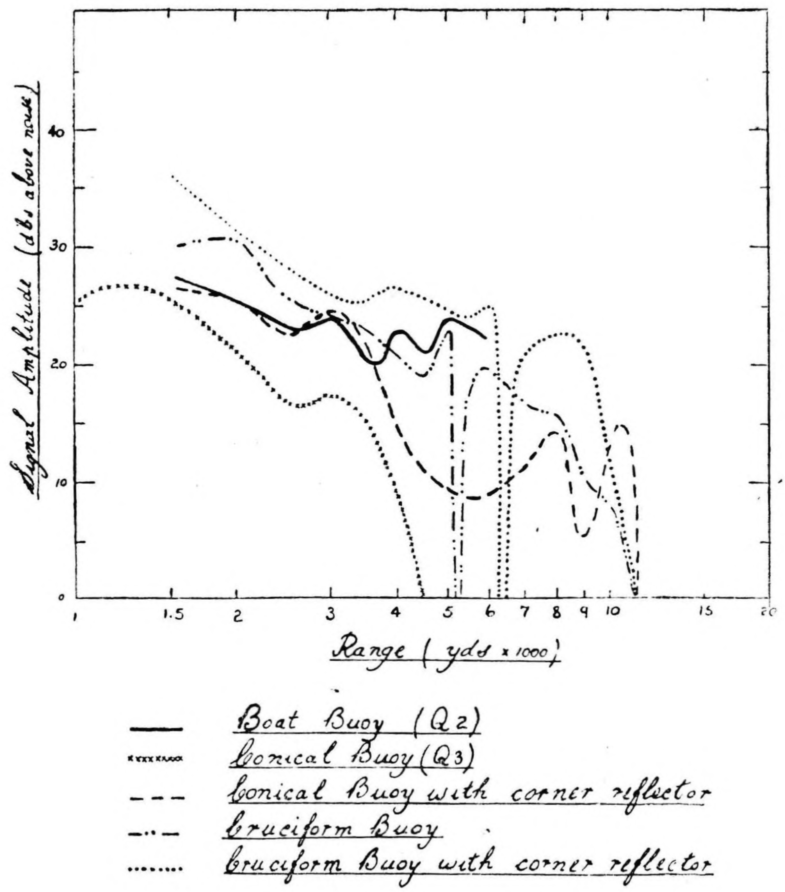

Fig. IX.

Abcissae : Range (Yards × 1000).

Ordinates : Signal Amplitude (dbs above noise).